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New Developments in International Trade: Theoretical and Empirical Investigations

Edited by
Seiichi Katayama and
Kaz Miyagiwa

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Kaz Miyagiwa

The Research Institute for Economics and Business Administration

Kobe University

Contents

Preface

This volume contains the papers presented at the RIEB (The Research Institute for Economics and Business Administration) International Conference held at Kobe University, on March 22-24, 1998. The papers were invited for presentation at the conference under the heading of international trade theory and empirical research. All the papers have been revised since the conference, and many of them have been published in a variety of journals. This book includes all the published papers as well as previously unpublished contributions.

Although it has been nearly five years since the conference, these papers offer insights that are still of considerable interest to researchers in economics, especially to those who study international trade. The editors believe that this volume brings together important contributions to economics at the dawn of the new millennium.

We are grateful to all the authors and the conference participants, especially those who cheerfully served as discussants and chairpersons. Our thanks also go to colleagues at the Research Institute for their encouragement, and especially to the Directors, Professors Ken-ichi Ishigaki and Shoji Nishijima, for their support of the project. In the editorial process we were fortunate to have an excellent and able team of Shoko Iwaki, Manami Sumino, Minako Okuno, Junko Doi, Masakazu Fukuzumi, Junpei Tanaka, Atsushi Miyake and Tetsuya Saitoh. We are also grateful to Professor Stephen J. Davies at the RIEB who kindly read parts of the manuscript and supplied useful comments and suggestions.

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Introduction

Seiichi Katayama and Kaz Miyagiwa

The last few decades have been a remarkable period for international trade economists. During that time world trade has expanded at a spectacular pace. Traditional tariffs and quotas have virtually disappeared in industrial nations under GATT-WTO initiatives, and developing countries hitherto averse to free trade have come to embrace it as a way to prosperity. Improved communications around the world have also contributed to the expansion in trade and facilitated international capital mobility.

Freer and expanding world trade however has given rise to a host of new challenges confronting many governments today. Disappearing trade barriers have induced relocation of production from high-cost to low-cost countries. Changing production and trade patterns have raised income distributional concerns. What is more, to cope with the adverse impacts of trade liberalization, many governments have instituted new protectionist measures such as antidumping levies and safeguards. At the same time trading blocs have been formed or expanded, challenging the multilateral approach to free trade.

This volume collects 14 articles that address important issues concerning or arising from trade liberalization. The articles are divided into three groups. Section I gathers articles that examine various consequences of freer trade. The articles in Section II investigate trade policy and trade policy formation from national and international perspectives. Section III contains three empirical examinations of the consequences of international trade.

I. Freer Trade and Its Consequences

As we noted above, falling trade barriers have allowed firms to split a production process into two or more stages and deploy them in different countries of the world. This phenomenon, which has come to be known as *fragmentation*, is the subject of the first two chapters. Deardorff (chapter 1) applies simple trade models of small open economies and of a two-country world to examine the effect of fragmentation on trade patterns, welfare and income distribution. His elegant analysis indicates that fragmentation benefits the country where it occurs if it induces no price change, but can hurt a country if it worsens the terms of trade. Even if there is a favorable terms of trade effect, some factors can still be hurt by fragmentation. If there is no factor price equalization in absence of fragmentation, however, fragmentation can contribute to factor price equalization.

While Deardorff works with the standard Ricardian and the Heckscher-Ohlin model, Jones (chapter 2) chooses a multi-sector Heckscher-Ohlin model. His analysis yields some surprising results not predicted by the 2×2 version. For example, a country losing out in a labor-intensive stage of production to foreign competition may nonetheless experience increases in real wages. Motivated by the recent debates in the U.S. about the effects of international trade on the skilled-unskilled wage gap, Jones also examines income-distributional implications of price changes and technical progress. Again, the model yields results unexpected in the standard model. For example, a change in a commodity price can produce diametrically opposite changes in factor incomes in two countries without factor intensity reversals.

The concern over income distributions is further explored in chapter 3. Whereas conventional research has focused on factor incomes, Das investigates the effect of trade on personal income and wealth distribution. His dynamic model of North-South trade preserves the two-sector Heckscher-Ohlin feature on the production side but departs on the demand side in that consumers derive utility from both consumption and bequest of land to the next generation. Thus, land plays a dual role as a commodity and as an asset. Diverse preferences over land lead to the endogenous formation of three classes of households: lower (landless workers), middle (workers with land) and upper class (landlords). Das shows that moving from autarky to free trade leads to more wealth and income inequality in the North and less in the South.

The multilateral approach to free trade under GATT-WTO initiatives has been based on the principle of reciprocity and nondiscrimination. However, member nations are also allowed to impose temporary protective measures such as voluntary export restraints and antidumping and countervailing tariffs, which are by nature unilateral and discriminatory. What role these unilateral policies play within the multilateral framework has attracted attention from researchers. Ethier (chapter 4) addresses this issue by presenting a multi-country multi-period model of the world economy. Letting the governments negotiate tariff reductions multilaterally, starting from high initial tariffs, he finds that the rate of multinational tariff reduction is limited to the lowest reduction any country would prefer but that the rate can be accelerated by the introduction of unilateral protectionism, which mitigates the losses nations will suffer should they happen to be technological laggards in an uncertain world. Thus Ethier concludes that contemporary unilateralism is necessary for the sustenance and success of multilateralism.

In Ethier's model unilateral protection serves as insurance in the presence of uncertainty to facilitate multilateralism [Bagwell and Staiger (1990, 1998) examine similar issues in different contexts]. Direct compensation from winners to losers from tariff changes will also induce governments to participate more readily in free trade agreements. This insight leads Kowalczk and Sjostrom (chapter 5) to consider the role of the direct income transfers in a multi-country model. In this chapter, the authors extend their earlier work (Kowalczk and Sjöström 1994), focusing on a particular income transfer scheme proposed by Grinols (1981), which in turn generalizes the Kemp-Wan (1976) theorem on formation of customs unions. The main results of the chapter are that the Grinols' transfers can be expressed as side payments from nations who lose little to those who lose much and that such transfers support the grand coalition or global free trade as a core allocation.

II. Policy Towards International Trade

Traditional trade theory ascribed protectionist policies to rational welfare -maximizing governments manipulating the terms of trade or administering corrective measures in the presence of domestic distortions. In contrast, recent research has emphasized the role of voters, pressure groups and lobbyists in influencing policy outcomes; see, for example, Mayer (1984), Young and Magee (1986), Grossman and Helpman (1994). The first two chapters of this section contribute to this strand of research.

Mayer (chapter 6) presents a dynamic two-sector model with heterogeneous agents to study the policy response when policy choices are determined by majority voting and are adjusted periodically by referendum. If labor allocation is costly and time-consuming, a one-time shock leads to a gradual adjustment of resources, which in turn affects the preferences of individuals with respect to the adoption of economic policies. Focusing on production subsidies, Mayer shows that individuals in the subsidized industry initially gain but that these gains are gradually eroded as resources move from the losing to the winning industry. The politically chosen subsidy rate may rise or fall to slow down the erosion but national income falls as the reallocation of resources deepens the distortion introduced by the initial subsidy.

The pressure group theory of policy formation [for example, see Olson (1965)] implies that smaller groups are more successful in obtaining favorable policies. However, empirical support for this presumption has been mixed. To account for lukewarm empirical support Hillman (1991) has presented a model in which competitive firms allocate resources between lobbying and cost-reducing activities. Hillman, Long and Soubeyran (2001) have extended this model to the case of an oligopolistic industry protected by import quotas. Hillman, Long and Soubeyran (chapter 7) further extend the model to tariff protection under oligopoly. The analysis with tariff protection reinforces the conclusion that the presumption holds only in limited cases, depending on various measures of comparative advantage in lobbying and on the industry demand curve.

The present WTO system allows the use of trade policy only in very limited cases. At present, however, no comparable international agreement exists that aims to align competition policies among individual countries. Since competition policies are nationally chosen, there is the concern that the restriction of trade policy induces individual countries to use competition policies to promote national interests at the expenses of others. Levinsohn (chapter 8) investigates this issue in a Counrnot oligopoly model with multiple home and foreign firms. He allows the governments to choose the merger policy nationally with or without GATT restrictions on the use of export subsidies, and finds no theoretical support for the presumption that the restriction on use of trade policy induces individual countries to pursue slack merger policies as a form of a beggar-thy-neighbor policy.

Chapter 9 takes a look at the World Bank, where there have been ongoing debates over the appropriate tariff structure to raise given revenue in developing countries. Economists at the Bank's operation divisions recommend uniform tariff rates because they fear divergent tariff rates cause price distortions, while those in its research divisions advocate non-uniform tariff rates from the efficiency point of view. Hatta reconciles these two views within the framework of optimum tax theory and shows that the uniform tariff structure is a good approximation of the revenue-constrained optimum tariff structure as long as substitutability among commodities is dominant.

The next two chapters examine issues concerning increases in international investments. Host country governments often grant foreign investors tax holidays and other investment inducements [see, for example, Miyagiwa and Ohno (2002)], while at the same time trying to regulate them with various performance requirements such as local content requirements for exports. The previous literature on performance requirements [e.g., Davidson et al. (1985), Lahiri and Ono (1991)] has assumed that there is only one foreign firm and/or one host country, neglecting the strategic aspects of performance requirements among multiple host governments. To study such strategic interactions Kayalica and Lahiri (chapter 10) present a model with two host countries with many foreign firms. There are two versions; in one the number of foreign firms is given and in the other there is free entry and exit. In either case, the non-cooperative levels of local contents are higher than the cooperative levels for both host countries. Comparing the optimal levels of content requirements across countries and between the two cases, the authors show that allowing for free entry in one host country reduces the levels in both countries.

Increased capital mobility also raises the macroeconomic concern about the long-run adjustment of current account imbalances under flexible exchange rates. Assuming perfect international capital mobility and unequal time preferences across two nations, Ohyama (chapter 11) considers two adjustment mechanisms: interest rates and money supply (or exchange rates). The adjustment process by interest rates is stable but leaves the country having a greater time preference in persistent and impoverishing indebtedness. In contrast, adjustment by money supply to peg interest rates is potentially unstable but may succeed in dissolving international indebtedness under certain conditions.

III. Empirical Studies on International Trade

Although theoretical models help us understand the basic structure of economic environments that interest us, often everything hangs on empirical results. This section collects three articles that go towards settling important theoretical issues using up-to-date data and estimation techniques.

Today there exists a large literature testing trade theories, especially the Heckscher-Ohlin model [see reviews by Deardorff (1984) and Leamer and Levinsohn (1995)]. However, empirical support for the theory has been mixed at best. Deardorff (1984, p. 512), for example, observes that “[the factor proportions model] does reasonably well at explaining the commodity composition of trade, but beyond that it is fairly helpless.” Eaton and Kortum (chapter 12) argue that the factor proportions theories have not come to grips with these basic facts: (1) trade diminishes with distance, (2) prices vary across locations (3) factor prices are not equal (4) countries’ relative productivities vary across industries. To incorporate these facts Eaton and Kortum focus on a Ricardian model, which yields two key structural equations for bilateral trade with parameters relating to absolute and comparative advantages and to geographical barriers. The authors estimate these parameters using manufacturing data from 19 OECD countries and solve for the world equilibrium. They then quantify the gains from trade, the effect of technology and geography on patterns of specialization, the role of trade in spreading the benefits of new technology, and the consequences of tariff reductions. In particular, it is found that a unilateral removal of U.S. tariffs makes every other country better off except Americans. The fact that the total benefits exceed the American loss indicates the importance of pursuing freer trade multilaterally.

Trade theory indicates that the net benefit of preferential trade agreements (PTAs) depends on the relative strength of trade creation and diversion effects, which in turn are functions of the pre-liberalization volumes of trade with the partner. Whether the net benefit is positive is however an empirical matter. Konan and Maskus (chapter 13) apply a computational general equilibrium model to estimate the potential gain for Egypt from its preferential trade agreement with the EU. The simulation results indicate that aggregate welfare gains increase with the initial partner trade share, implying that the greater the initial trade share with Europe the more Egypt gains from a PTA. However, the simulation also shows that its potential gains are modest.

The last chapter deals with one of the most contentious trade issues today: the link between free trade and environmental damage. At the core of recent debates lies the pollution haven hypothesis, which suggests that low-income developing countries will be polluted by openness to trade. Previous empirical studies however have failed to discover a convincing link between trade and pollution due to the lack of firm theoretical underpinnings. To correct this shortcoming Antweiler, Copeland and Taylor (chapter 14) first present a theoretical model based on the Heckscher-Ohlin framework to divide trade's impact on pollution into scale, technique, and composition effects. They then use data on sulfur dioxide concentration to estimate these effects. Their results show that international trade creates relatively small changes in sulfur dioxide concentrations by altering the composition of national output. Combining this result with estimates of scale and technique effects yields a surprising result: if trade liberalization raises GDP per person by 1 percent, pollution concentrations fall by about 1 percent. Free trade is good for the environment.

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1 Fragmentation in Simple Trade Models

Alan Deardorff

1. Introduction

The subject is fragmentation: the splitting of a production process into two or more steps that can be undertaken in different locations but that lead to the same final product. Also called “intra-product specialization” by Arndt (1996) and by the more loaded term “outsourcing” in some economic literature as well as in the popular press, fragmentation occurs both within countries and across countries.[1] Within countries, if domestic factor markets are well integrated and markets are competitive, then fragmentation would be expected to occur only if the combined resources used by the fragmented steps were less than those used by the original process, in which case fragmentation would also represent a technological improvement. In this paper I will assume instead that fragmentation does not economize on resources, and therefore I will focus on fragmentation that occurs across countries.[2]

Internationally, fragmentation has become increasingly common in recent years as barriers to international trade and investment have fallen and

1. The term “fragmentation” comes from Jones and Kierzkowski (2001). Several other terms for this phenomenon were also suggested at the NAEFA session, none seeming to generate a consensus.

2. Even without any saving in resources, fragmentation could occur within a country for a variety of reasons. Perhaps the most obvious is if labor markets are not competitive, so that wages are bid up in some sectors by the bargaining power of unions. Fragmentation in order to divert some parts of a production process outside the purview of the union then makes obvious economic sense. Even with perfect competition, if a country is “lumpy”—that is, if different equilibrium wages are paid in different regions within the country as in Courant and Deardorff (1992)—then fragmentation may occur across regions for much the same reasons as the international fragmentation I will examine here.

as an increasingly competitive world environment has forced producers to look outside their own borders for ways to reduce costs. In the debate over the causes of increased wage inequality in the United States in the 1980s and 90s, "globalization" and technology have both been suggested as important causes of the increased wage differential paid to skilled labor, globalization being represented variously by international trade, foreign direct investment, factor mobility, and outsourcing.[3] In fact, fragmentation may be thought of as a manifestation of globalization and technology combined, since in many industries it is only advances in technology that have made the splitting of production processes and the coordination of the resulting parts possible.

In any case, with the exception of Arndt (1997) and Jones and Kierzkowski (2001), the economic effects of fragmentation do not seem to have been given the theoretical treatment they deserve, and in this paper I will attempt to correct that.[4] Using several familiar and simple models of international trade, I will examine the implications of fragmentation on trade, patterns of specialization, and factor markets, looking especially at its effects on factor prices and on the overall welfare of the countries involved.

I will examine the effects of fragmentation first in a Ricardian model in section 2, then in a Heckscher-Ohlin model in section 3. Section 4 concludes.

2. Fragmentation in Ricardo

I will look first at the effects of fragmentation on a small open economy, then at a large country in a two-country world.

2.1. A Small Open Ricardian Economy

Consider first the textbook case of only two goods. The country is endowed with a fixed amount of labor, L, and it can use this labor to produce either of two (final) goods, X and Y. The unit labor requirements of each are fixed at a_X and a_Y respectively. As a small open economy, the country faces fixed prices of the two goods on a world market, p_X and p_Y, at which it can buy or sell unlimited quantities. As usual, if the wage in

3. There have been many surveys of this voluminous "trade and wages" literature, most recently by Johnson and Stafford (1997). One pair of papers that has focused attention on outsourcing is Feenstra and Hanson (1996, 1999).

4. The literature now also includes two of the other papers prepared for the NAEFA session for which this was written. Not coincidentally, they are by the same authors: Arndt (1998) and another paper by Jones and Kierzkowski for which I do not have the exact citation. The empirical literature on fragmentation has also been expanded with a new paper by Slaughter that I also don t have.

the country were w, then the supply prices of the two goods would be wa_X and wa_Y respectively, and profits would be made if either of these were below the corresponding world price. Therefore the market equilibrium wage is instead

$$w_0 = max\left(\frac{p_X}{a_X}, \frac{p_Y}{a_Y}\right). \tag{1}$$

The country specializes in whichever good yields this highest wage, exporting X if $p_X/a_X > p_Y/a_Y$ and vice versa. Equivalently, if

$$\frac{a_X}{a_Y} < \frac{p_X}{p_Y}, \tag{2}$$

then the country has a comparative advantage in X and will export it. I will assume this to be the case.

Now suppose that fragmentation becomes possible in the X industry. In general, this means that the process for producing one unit of good X can be split into multiple parts, $i=1,...,n_X$, each requiring an amount of labor a_{Xi}, and since I do not want to conflate fragmentation with technological progress, I assume that $\sum_{i=1}^{n_X} a_{Xi} \geq a_X$. Coordination of these fragmented parts might in general require oversight by a single entity such as a multinational enterprise (whose function could itself be represented by one of the parts), but to consider explicitly how the parts are organized would take me too far afield.[5] Instead I will define each part as producing one unit of an intermediate good, Z_{Xi}, that is also an intermediate input to the next part that produces one unit of Z_{Xi+1}, the final step producing a unit of good X itself: $Z_{Xn_X} = X$. Thus production of a unit of each intermediate input except the first requires, in addition to the labor a_{Xi}, one unit of the preceding intermediate good, Z_{Xi-1}.

In general not all of these intermediate goods need be regarded as tradable; their tradability indicates whether two adjacent parts of the fragmented production process can take place in different countries. However, if they are not tradable, then their separate identities will play no role in the model here with an integrated competitive domestic labor market, and they could be combined into one. Therefore, I will assume that all of these

5. The analysis here is general enough, both in this section and the next, to include the sorts of disembodied contributions to a firm's operations that Helpman (1984) took to be the hallmark of a multinational corporation. Although I will define each fragmented part of the production process as producing an intermediate input that is then used in the next stage of production, this intermediate input can be a fiction, at least until one attempts to apply this approach to the data.

intermediate goods are internationally tradable.

What I have described is a fairly general formulation of fragmentation, but in the spirit of my initial 2-good model, let me start with the simple case of n_X=2. That is, let production of X be fragmented into just two parts, requiring amounts of labor a_{X1} and a_{X2}, the first of which produces an intermediate good Z, that is required one-for-one with production of good X in the second part. The result is simply a 3-good Ricardian model, where the three goods are X, Y, and Z, and where the demand for Z is the quantity of X that is produced using the fragmented technology. Since Z is tradable, introduction of fragmentation also requires that the world market provide an additional price for it, p_Z. The question is, what does all of this do to the small open economy facing this and the other prices?

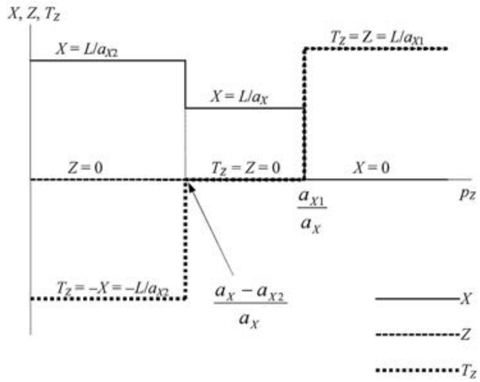


Figure 1

The answer depends in part on whether those other prices—p_X and p_Y—also change as a consequence of fragmentation. This is an issue that will come up more clearly in the 2-country model below, so for now I simply assume that they do not. This will in fact be the case if the large rest-of-world with which our small country trades is itself a fully integrated economy. In that case, there is a single wage of labor prevailing throughout the rest-of-world, and fragmentation that does not lower total labor requirements cannot lower the price of X. Its price cannot rise, either, since the original unfragmented technology is still available.

What matters for the small country, then, is the price of Z, which will depend on the parameters of the fragmented technology in the rest-of-world. Since this is a Ricardian model, these are not necessarily the same as in the small country, and I will therefore just examine how behavior in the small country depends on p_Z.

The answer is simple. Labor now has two additional options for employment, in addition to producing X from scratch and producing Y. It can produce Z, earning a wage p_Z/a_{X1}, or it can produce X from Z, earning a wage $(p_X - p_Z)/a_{X2}$. Labor will therefore engage in whichever of the four activities earns it the most, and it will do more than one thing only if two or more of the activities yield the same wage. Thus the equilibrium wage in the fragmented small open economy, w_F, is

(3) $$w_F = max\left(\frac{p_X}{a_X}, \frac{p_Y}{a_Y}, \frac{p_Z}{a_{X1}}, \frac{(p_X - p_Z)}{a_{X2}}\right).$$

The country will engage in whichever activity or activities yields this maximum wage.

The country's production and trade are summarized in Figure 1. By assumption (2) that it has a comparative advantage in good X, it will never produce good Y. Whether and how it produces good X, however, depends on the price of the intermediate input. Taking good X as numeraire, comparison of the arguments in (3) shows that if p_Z is sufficiently low—below $(a_X - a_{X2})/a_X$—then the country will employ only the second fragmented part of the new technology for producing X, importing all it needs of good Z from the rest-of-world. For a somewhat higher price of the intermediate input, however—above $(a_X - a_{X2})/a_X$ but below a_{X1}/a_X—it will continue to produce X from scratch with the old technology. Finally, if the price of the intermediate is high enough—above a_{X1}/a_X—then it will produce only Z. In the latter case, since it does not produce X and therefore does not need Z, it exports all of its output of Z. The figure shows these responses of output to price as the heavy solid line for X and the heavy dashed line for Z. In addition, it shows net trade in Z (exports if positive, imports if negative) as the heavy dotted line.[6]

For some prices, then, Figure 1 shows the fragmented technology not being used at all. This occurs only if a_{X1}/a_X is in fact greater than $a_X - a_{X2}/a_X$, which it may not be. This requires that

(4) $$a_{X1} + a_{X2} > a_X,$$

6. Trade in X and Y are not shown, since they depend on preferences and income. Good Y, which is not produced, must be imported for all p_Z, although the quantity imported will be somewhat larger when the fragmented technology is being used, due to the country's higher income, and it will fall with p_Z for low p_Z and rise with p_Z for high p_Z due to changes in the terms of trade in Z. When only good X is produced, then part of it must be exported in exchange for Y, while it must be imported when it is not produced. Again, the quantities kept or imported depend on real income, which is larger when the fragmented technology is being employed and depends then on the p_Z.

or in other words that the fragmented technology use more resources than the original, or that fragmentation is, in this sense, "costly." I will take this to be the normal case in this section, although the justification for doing so most easily relies on transportation costs, which I am assuming away in the rest of the model.

In any case, the model says that if fragmentation is costly, then for some parameters and prices it will not be used, but for other parameters it will. Also, if fragmentation is not costly, then the middle range of behavior in Figure 1 collapses to a single price, and fragmentation is used at all prices but one, a_{X1}/a_X, where all are indifferent between producing Z, producing X from scratch, and producing X from Z.

It might seem in the case of costly fragmentation that welfare might fall, since the country is using part of what seems to be an inefficient technology. In fact, however, we see immediately from (3) that welfare cannot fall with the introduction of fragmentation in this Ricardian Model. The entire population is labor, and everyone earns a common wage that is at least as great as it was before, in real terms since prices of consumer goods are fixed. The reason, of course, is that while using both parts of the fragmented technology would indeed be inefficient, the country does not do that. On the contrary, it uses only one part of it, and the other part is not used anywhere. It is the latter part that is really inefficient at prevailing prices.

So far I have assumed that fragmentation occurs only in the export industry. That, of course, need not be the case. If fragmentation were to become possible in producing good Y instead, then the above analysis would be modified but only slightly. Parameters a_{Y1} and a_{Y2} would replace their X counterparts, and Y would replace X in the third and fourth arguments of (3). The result is again a range of prices of the intermediate good Z for which fragmentation is not observed, although in this case it will continue to be good X, not the potentially fragmented good Y, that is produced in the mid-range.[7] If the price of the intermediate is outside this range, however, good X, will not be produced at all, and the country will either produce and export the intermediate or produce and export Y. Thus fragmentation may give a country a comparative advantage in a good where it had no comparative advantage before.

This is about all that the simple Ricardian model of a small economy can tell us, but the results are pretty clearly robust to expansion of the model to include, say, more goods or more degrees of fragmentation. With both of these arbitrarily large, the wage is set as

7. This mid-range will exist even if fragmentation in the import-competing good is costless, since fragmented production must now overcome the comparative disadvantage in (2).

(5) $$w_F = \max_{\substack{j=1,\dots,n \\ i_j=1,\dots n_j}} \left(\frac{p_j}{a_j}, \frac{\left(p_{ji_j} - p_{ji_j-1}\right)}{a_{ji_j}} \right),$$

where the technology for producing each of n goods j is potentially fragmented into n_j parts, the last of which produces the final good itself. p_j, a_j are the prices and unit labor requirements for producing the jth good, j=1,...,n, using the original Ricardian technology. p_{ji_j}, a_{ji_j} are the prices and unit labor requirements for the i_j th intermediate input to good j, i_j =1,...,n_j, with p_{j0} = 0 and $p_{jn_j} = p_j$.

From this, it follows that the country will tend to specialize in using only one fragment of one technology, unless parameters and prices coincidentally align so that more than one process yields the same wage. Comparative advantage now refers most appropriately to processes, not goods, although we may identify them with the intermediate goods that they produce. As in the 2-good model, as long as prices of final goods in the rest-of-world are given and unchanged by the introduction of fragmentation, the small country cannot lose from it. Patterns of production and trade will not be determined quite as simply as in the 2-good model, but one of the patterns suggested in Figure 1 will continue to hold: given the prices of all other goods and fragments, a particular fragment will be employed and its intermediate product exported if its price is high enough. A low price, on the other hand, will not necessarily assure that it will be imported, since that also requires a high price in the next stage of production.

2.2. A Two Country Ricardian World

A small country in the Ricardian model, then, cannot lose from fragmentation so long as prices of final goods remain fixed. And fixity of prices has a certain plausibility if the rest-of-world is integrated, as noted above. However a large country can surely not take prices as given, and the problems that arise for a large country are also those that arise for a non-integrated rest-of-world. We therefore need to look at a two-country world in order to explore these problems. In that context, I will focus only on one issue: whether a country can lose from fragmentation. Along the way we will incidentally see a bit more about how fragmentation affects specialization and trade.

For a country to lose from fragmentation, prices must turn against it, and this requires that it be trading initially so that there is scope for its terms of trade to worsen. I will consider, therefore, a country that specializes initially in good X, and try to see whether fragmentation can lower the relative price of good X sufficiently for it to lose. I will consider the same simple form of fragmentation that I looked at before, splitting production of good X into two parts. For simplicity and to avoid the costs of fragmentation itself being the source of any loss, I will now assume that fragmentation is costless. Analogous other cases should not be hard to find.

Figure 2 tells us most of what we need to know, although some explanation is required. In the upper left corner is drawn the production possibility frontier (PPF) for the country of interest, Country A, which is assumed again to have a comparative advantage in good X. Its customary Ricardian transformation curve is T_AT_A' in the X-Y plane, showing the maximum amounts of goods X and Y that it can produce without fragmentation. Fragmentation expands its production possibilities into a third dimension, with the Z axis measuring its net output of intermediate good Z, positive if it produces it, negative if it is a net user of Z in production of X. Point Z_A shows the maximum amount that can be produced if all labor is devoted to production of good Z. Production possibilities include the triangular plane through Z_A, T_A, and T_A'. It is also possible to be a net user of Z in producing X, and the maximum amount of X that can be produced that way is graphed together with the equal negative input of Z at point Z_A' (which is on the dotted 45° line in the horizontal $(X,-Z)$ plane). Again, linear technologies also permit production anywhere on the triangular plane through Z_A', T_A, and T_A' If fragmentation were costly, the surface combining these two triangles would be kinked along T_AT_A' (i.e., the straight line connecting Z_A and Z_A' would pass to the left of T_A'). But with costless fragmentation as I assume here, the two triangles are part of the same plane, and the full PPF of country A with fragmentation consists of the larger triangle $T_AZ_AZ_A'$. To assure that Country A will have a comparative advantage in X both with and without fragmentation, I have drawn these production possibilities as skewed in the X direction.

The top right portion of Figure 2 shows the PPF for Country B, with its greatest productivity being in the directions of final good Y and intermediate good Z. Otherwise the graph for Country B has exactly the same interpretation as for Country A.

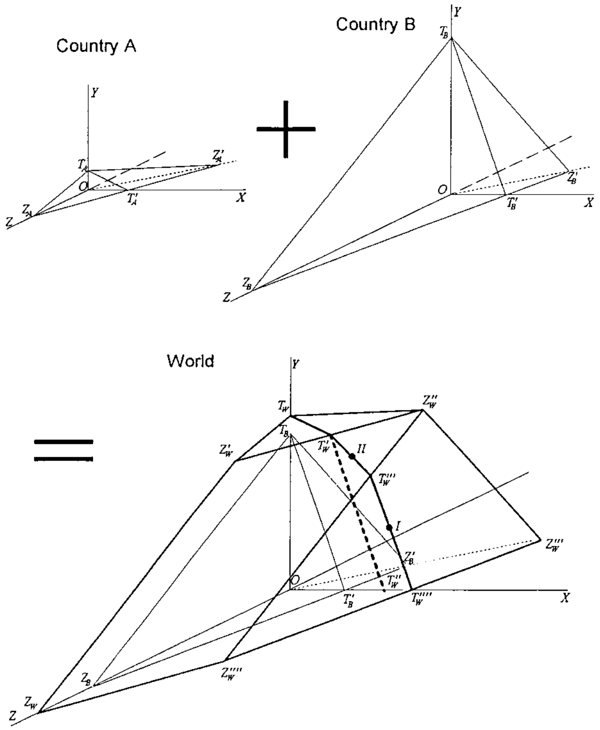


Figure 2

Now combine these two PPFs, to get the PPF of the world in the bottom part of the figure. The construction is a little messy but actually not all that difficult if you draw it carefully. As is familiar in the 2-good Ricardian model, one simply places the origin for one PPF on the surface of the other, then slides it around in all possible ways to generate the largest outputs possible. In two dimensions only, this process of adding together $T_A T_A'$ and $T_B T_B'$ would yield the world frontier $T_W T_W' T_W''$ that appears in the X-Y plane in the bottom graph. It is linear with just one kink (at T_W'), and the two linear segments are exact replicas of the transformation curves of the two individual countries.

To construct the PPF in three dimensions, I place the origin of Country A's PPF on the surface of Country B's PPF, $T_B Z_B Z_B'$. As a result of the shapes to the two PPFs, point Z_A' of A's PPF traces out a duplicate of B's PPF: the triangle $Z_W'' Z_W''' Z_W''''$. The bottom edge of A's PPF, $Z_A Z_A'$ traces out the parallelogram $Z_W Z_W' Z_W'' Z_W''''$ as its origin traverses $T_B Z_B$. And A's PPF itself becomes the topmost facet of the world PPF, the triangle $T_W Z_W' Z_W''$. Note that the parameters underlying these figures are such that only three patterns of specialization are possible: County B produces only good Y (the top triangle); Country A produces only good X using the fragmented technology and imported inputs of good Z (the lower triangle); and Country B produces a mix of Y and Z while Country A produces only X, mixing the original and the fragmented technology (the parallelogram).

However, the world cannot be in equilibrium just anywhere on the three-dimensional surface. By assumption, good Z has no use except in producing X, so the world's net output of Z must be zero. Therefore the only relevant part of the world PPF is the solid heavy kinked line, $T_W T_W' T_W''' T_W''''$. Just where on this curve the equilibrium will be found depends on preferences of consumers in both countries for consuming goods X and Y.

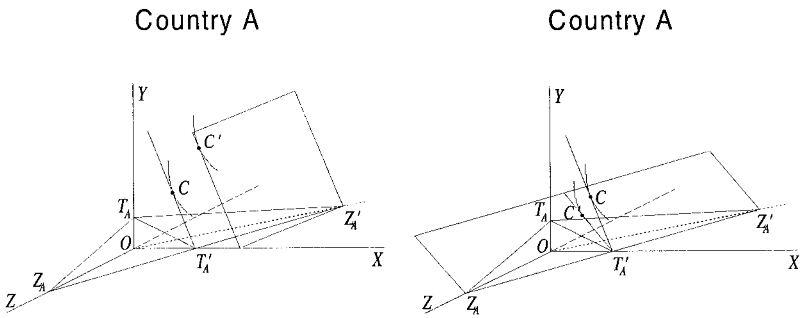
The potential gains for the world from fragmentation are now evident. Without fragmentation, the world was confined to the output combinations on $T_W T_W' T_W''$, and if preferences put the equilibrium on the steeper segment, $T_W' T_W''$, then fragmentation permits an increase in the world consumption of both goods. These gains should not be surprising: they are simply the result of comparative advantage being followed within the fragmented technology for producing good X.

What are prices in the world equilibrium? They are given by the slopes of a plane tangent to the world PPF wherever the equilibrium is located. As usual in a Ricardian model, these may be determined mostly by preferences if the equilibrium is at one of the kinks, T_W' or T_W''', or they may be determined entirely by parameters of production if the equilibrium is in one of the straight segments. Note that if demand for X is sufficiently high so that the equilibrium is in the steeper of these segments, $T_W''' T_W''''$, then prices are those of Country B in autarky and do not change with fragmentation. That is the situation addressed in our analysis of the small country above, thus indicating that the assumptions made there were appropriate. Of course in this case, represented for example at point I in Figure 2, Country A does not lose from fragmentation, as already noted.

The possibility of loss arises in the other segment, $T_W' T_W''''$, at points like the one marked II. Here the relative price of good X falls as a result of fragmentation, and since Country A initially exported X, this constitutes a fall in its terms of trade. This is not enough to show that it loses, however, since it would have gained a positive amount from the fragmentation itself had prices not fallen. It turns out, though, that Country A *must* lose from fragmentation in this case. Segment $T_W' T_W''''$ is part of the parallelogram traced out by the lower edge of Country A's PPF as its origin traverses the upper left edge of B's PPF. Therefore the price plane tangent to the world PPF in this segment includes the entire bottom edge of A's PPF. This is enough to assure that there are no gains to it from shifting resources toward fragmented production, and the reduced terms of trade therefore causes an unambiguous loss.

Both results are illustrated in Figure 3. In the left panel, prices remain fixed with fragmentation and country A gains unambiguously. Initially trading only X and Y, it consumed at point C along the two-dimensional price line given it by Country B. With fragmentation prices do not change, but Country A shifts all of its labor to producing good X with inputs of Z and the fragmented technology. Production moves to point Z_A' and it trades from there to point C' along the price plane, also given it by Country B. The nature of the trade, incidentally, is that it imports both Y and Z, since it produces neither.

The other case is shown in the right-hand part of the figure. Here again Country A starts at point C, but now with fragmentation it trades along a price plane that is both flatter (lower p_X/p_Y) and rotated clockwise from above (lower p_X/p_Z), as shown. The loss in welfare is unambiguous. Production, incidentally, is somewhere on the bottom edge between points T_A' and Z_A', and the country imports Y and Z. The main difference between this and the case on the left is that the country also produces some of good X from scratch, and indeed it is this that requires prices that make the two processes for producing X equivalent and prevents any gain to Country A from using the fragmented technology. Country B, of course, now does gain.



3-1: Equilibrium at I in Figure 2 3-2: Equilibrium at II in Figure 2

Figure 3

3. Fragmentation in Heckscher-Ohlin

The simplicity of the Ricardian model is valuable for the insights that it can yield into the behavior of more complicated models. For example, a Heckscher-Ohlin (H-O) model can approximate arbitrarily closely to the Ricardian model of Section 2, and therefore we can conclude immediately that a large country can lose from fragmentation, even in a H-O world. However, there are other details that are assumed away in a Ricardian model that it therefore cannot address. The most obvious and important is the existence of separate factors of production and the possibility that some factors may gain while others may lose from a change such as fragmentation. I will explore that possibility here.

The first thing to note about a H-O model, however, is that fragmentation as defined here will not occur in the kinds of equilibria most often considered in the H-O literature. That is, if prior to fragmentation there is factor price equalization (FPE), and if fragmentation is costly, then there will be no incentive to fragment production. Therefore, in order for the issue of fragmentation to be interesting, we must start with a world economy in which factor prices are different. That is, I will assume that factor endowments differ sufficiently across countries that they are unable, in free trade, to produce enough goods in common to cause FPE. I will also assume, for simplicity, that fragmentation is costless, although one could easily think of there existing an infinitesimal fragmentation cost, ε, that is too small to show up in the diagrams. Again, I will start with a small country and then move to a 2-country model.

3.1. A Small Open H-O Economy

Figure 4 shows what can happen in a 2-good model. The solid lines show the initial situation before fragmentation. It is a familiar Lerner diagram with good X chosen as numeraire so that the unit value isoquant for X is also its unit isoquant.

A small country trades with a large rest-of-world in which prices of the two goods, X and Y, are given and imply the unit value isoquants shown. The diversification cone is given by the rays k_X and k_Y, with corresponding factor prices $\tilde{w}$ and $\tilde{r}$. The small country, however, is not inside the cone. Its endowment point is E, and it therefore specializes in good X with factor prices w_0 and r_0.

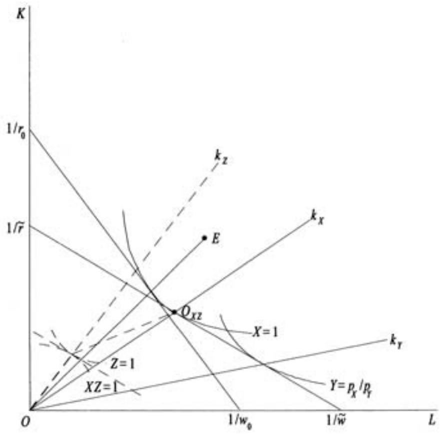


Figure 4

Now fragmentation becomes possible everywhere. The technology for producing good X now includes the possibility of producing an intermediate input, Z, one unit of which requires the factors shown by the new isoquant labeled $Z=1$.[8] A unit of good Z can be used together with additional inputs of capital and labor to produce a unit of X. Since I am now assuming that fragmentation is costless, the isoquant for producing a unit of X from Z is simply the factors that are left over out of the original $X=1$ isoquant. That is, the isoquant for producing X from Z can be drawn upside down relative to, say, point O_{XZ} as an origin, and it will then be just tangent to the $Z=1$ isoquant.[9]

Note that I have drawn the technology for producing Z as more capital intensive than for producing X. With that assumption, the activities available to the world now include one whose factor requirements (at the rest-of-world's factor prices) are given by the ray k_Z. The diversification cone is therefore enlarged by fragmentation. In the case shown, the small country is now inside it, and it will therefore now be able to fully employ its factors at the world's factor prices. This is now a 3-good, 2-factor H-O model, so exact outputs and the pattern of trade are indeterminate *à la* Melvin (1968). But we can be sure in this case that the small country will produce some of intermediate good Z together with some of either X and/or Y.

More important here, however, is what happens to factor prices. Evidently from the figure, the wage has fallen from w_0 to $\tilde{w}$, while the rental on capital has risen from r_0 to $\tilde{r}$. Since prices are fixed, these changes are real as well as nominal.

Thus we have a case here where a country gains from fragmentation,[10] but not all factor owners within that country share in the gain. On the contrary, workers here are made worse off as the production process for their product fragments into a capital-intensive and a labor-intensive part, only the former of which necessarily remains viable within their country.

8. Again, this intermediate input need not be a physical entity, and therefore could represent, say, the "headquarter services" that Helpman (1984) and others have used to model multinational corporations. For my purposes, it is immaterial (literally) whether the different fragments of production are performed within a single firm or between firms. This generality is desirable, of course, but it also means that none of the results of this section are really new. They are merely extensions of what was shown by Helpman (1984) and Helpman and Krugman (1985). I am grateful to Steve Matusz for pointing this out.

9. If these were drawn correctly, then the $X=1$ isoquant could be traced out by the origin for the $XZ=1$ isoquant as it slides around the $Z=1$ isoquant. The construction is much the same as we used to use to construct Scitovsky indifference curves. Remember them?

10. I have not shown that gain, but I hope it is clear. Fragmentation has expanded the small country's production possibilities, and at fixed prices this can only help.

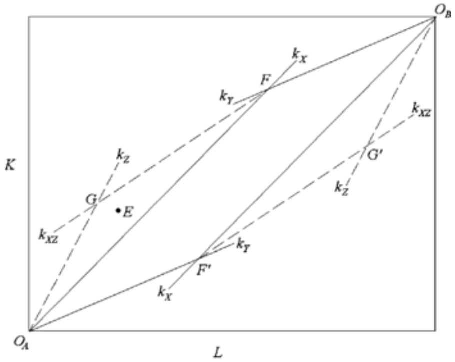


Figure 5

3.2. A Two-Country H-O World

What happened in Figure 4 did not really require that the country in question be small. To see this, consider a two-country world of the same sort. Figure 5 shows the Travis-Dixit-Norman[11] integrated world economy (IWE) diagram that Helpman and Krugman (1985) exploited so successfully for a variety of purposes. Without fragmentation, the FPE region is the parallelogram O_AFO_BF'. Fragmentation, which makes it possible to duplicate the X output of factor vector O_AF with the two fragmented vectors O_AG and GF, expands the FPE region to $O_AGFO_BG'F'$. Thus, for some allocations of the world's factors for which FPE would not have been possible, fragmentation leads to FPE.

For example, if the allocation were at point E, then there could not have been FPE without fragmentation. What exactly would have happened instead we don't know, since prices would not have been those prevailing in the IWE, but it seems plausible that Country A would have produced only

11. Years ago, I incorrectly attributed this diagram to Helpman and Krugman in the presence of both Elhanan Helpman and Avinash Dixit and had my attention gently directed toward Dixit and Norman (1980). More recently, Bob Baldwin has sent me further back, to Travis (1964). While Travis did not speak by that name of an "integrated world economy," he certainly used the concept and drew the diagram (on p. 16) for exactly the purpose of identifying a factor price equalization region. Travis in turn called it an Edgeworth box, although I am not aware (never having read Edgeworth) that Edgeworth ever used his boxes quite this way, with factor endowments measured from the corners. All of this is surely known to scholars, but the rest of us have to pick it up wherever we can.

good X and Country B would have produced a mix of X and Y.[12] Fragmentation again permits Country A to shift resources into the most capital-intensive fragment of producing Z, and again it is likely to raise the return to capital and lower the wage. There may also be small effects on factor prices in Country B, as market clearing prices of X and Y change, but these are difficult to determine.

This result illustrates the more general phenomenon that fragmentation enhances the possibility of factor price equalization. With arbitrary numbers of goods, factors, and countries, I showed in Deardorff (1994) that FPE requires that factor endowments be more similar than factor intensities in a certain well-defined sense: the set of vectors that can be constructed from parts (or all) of the factor endowment vectors—called the "factor endowment lens"—must lie inside the analogous set of vectors defined by the factors used in the IWE—the "factor use lens." Costless fragmentation unambiguously enlarges the factor use lens and thus makes FPE possible for factor allocations for which it was not possible before.

To see this, note that a factor use lens is defined as

$$L(v) = \left\{ x \in \mathbb{R}^f \middle| x = bv \quad \text{for some} \quad g\text{-vector} \quad b \in I^g \right\}, \tag{6}$$

where there are f factors and g goods, I^g is a set of g-vectors whose elements are in the unit interval, [0,1], and v is a $g \times f$ matrix of factor-use row vectors. Then let v^0 be the matrix of factor uses without fragmentation, v_j^0, j=1,...,g, and let v^1 be the matrix of factor uses in which some or all goods have been fragmented into 2 or more parts. Numbering the rows of v_{ji}^1, i=1,...,n_j, the cost of fragmentation will be zero if $v_j^0 = \sum_{i=1}^{n_j} v_{ji}^1$. It is then easily shown that[13,14]

$$L(v^1) \subseteq L(v^0). \tag{7}$$

This tells us that the possibility of FPE is increased by fragmentation. That is, there may be allocations of the word's factor endowments for which FPE is not possible without fragmentation and for which FPE becomes possible with fragmentation. It also says that if FPE is possible

12. If we assume fixed-coefficient technologies, then this is necessarily the case, since good and factor prices will leave the factor use vectors unchanged. Of course in that case, part of the capital in Country A of Figure 5 would be unemployed and the rental on capital would be zero. However the changes in factor prices identified in Figure 4 would still occur, in amplified form.

13. Suppose $x \in L(v^0)$. Then from (6) $\exists b \ni x = bv^0 = b\Sigma v_i^1$ which implies $x \in L(v^1)$.

14. See Debaere and Demiroglu (1997), who note the same thing in a different context. Their result is that the measured factor use lens will lie within the true one if measured industries are aggregated.

without fragmentation, then it must remain possible if fragmentation is introduced. If one were comfortable thinking of the world's allocations of factors as being somehow randomly determined given its total endowments and the parameters of technology and tastes, then it would say that the likelihood of FPE either rises or stays the same with fragmentation; it cannot fall.

Thus fragmentation may well cause factor prices to become equalized across countries. The analysis here does *not* say, however, that, failing that, factor prices will be drawn closer together by fragmentation. Figure 4 certainly suggests that result in a special case. There, if the endowment point were above the k_Z ray rather than below it as drawn, then indeed factor prices in the country would remain different from those in the world after fragmentation but would be drawn closer to them.[15] As far as I know, however, that is not a general result. In fact, we are surprisingly ignorant (or at least I am) of how the higher-dimensional H-O model behaves outside of the FPE region, or when the lens condition of Deardorff (1994) is not satisfied.

4. Conclusion

The underlying question addressed in this paper is, "Does fragmentation matter?" Or, since this is a theoretical piece, not empirical, "Can it matter?" The answer seems to be a relatively strong "Yes."

Of course, fragmentation will *not* matter if factor prices are equal everywhere, for then the fragmented technologies will at best duplicate what was done without them and there will be no reason to use them. But if factor prices are not equal across countries, either because technologies differ as in the Ricardian model or because factor endowments are less similar than factor intensities in the H-O model, then fragmentation can certainly make a difference. The main effects of fragmentation, at least as I have been able to identify them from these simple models, are as follows (all assuming that fragmented technologies are used at all):

1. If fragmentation does not change the prices of goods, then it must increase the value of output of any country where it occurs and that of the world.
2. If fragmentation does change prices, then fragmentation can lower the welfare of a country by turning its terms of trade against it.
3. Even in a country that gains from fragmentation, it is possible (but not necessary) that some factor owners within that country will lose.

15. Such a result may exist, but I am pessimistic. After wasting several years trying to show that free trade must draw factor prices closer together, only to find the counter-example presented in Deardorff (1986), I will not be surprised if fragmentation admits of equally poorly behaved possibilities in a general model.

4. To the extent that factor prices are not equalized internationally without fragmentation, fragmentation may be a force toward factor price equalization.

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2 Trade, Technology, and Income Distribution

Ronald Jones

1. Introduction

Recent debates, primarily in the United States, about the effects of international trade on unskilled wage rates, have involved trade economists and labor economists in empirical and theoretical investigations as to the reasons why and how inequalities in the distribution of income have been brought about.[1] American experience does not support the view that unskilled labor must continuously lose to skilled labor in a wage comparison, since in the postwar period up to the 1970's, unskilled labor's relative wage was rising. My purpose here is not to examine the causes of changes in income distribution in any one country or any particular time period. Instead, I wish to appraise several simple strands of reasoning in the international trade literature which serve to link income distribution to changes in relative prices of internationally traded products, to changes in technology which may be biased by sector or by factor-saving, and by recent tendencies to split vertically integrated production processes into separate components which may be produced in different regions of the world. I shall argue that excessive reliance on the standard two-commodity, two-factor Heckscher-Ohlin model yields predictions about income distribution which are significantly at odds with theoretical frameworks that allow a richer and wider variety of commodities to be produced and traded, or permit some factors to be limited in their mobility from sector to sector.

1. See the contributions in S. Collins (1997), as well as R. Freeman (1995), J. D. Richardson (1995), A. Wood (1995), and R. Jones and S. Engerman (1996).

2. A Price Change in the World Market

Probably the easiest place to start is with the Stolper-Samuelson theorem, since this seems to provide most of the rationale behind popular and media coverage in the United States. This theorem, more than 50 years old in the professional literature (1941), is referred to by name in the *Economist* and other current sources.[2] It states that if a country produces a pair of commodities with two factors, say unskilled labor and capital (a composite of physical and human capital), and if the import-competing product is intensive in its use of unskilled labor, a fall in the world price of such a commodity would (unless protective measures are taken) eventuate in a decline in the real return to unskilled labor. That is the bottom line; no caveats are made about technological parity between this country and the rest of the world. This theorem, seemingly so applicable to describing the fate of unskilled workers in the United States or (in terms of high unemployment rather than decreased wages) in Western Europe, is often confused with the Factor-Price Equalization Theorem, which points to the effect of free trade in equalizing wage rates among trading regions. Thus opponents of the NAFTA accord in North America, or to its extension to Chile and other countries of the Western Hemisphere, point to the drastic consequences for American wages should freer trade result in binging wage levels down to the levels in their partner areas. Most international trade economists would hesitate to suggest that this latter proposition is relevant to today's trading world, since unlike the Stolper-Samuelson theorem the Factor-Price-Equalization dictum presumes that countries not only share the same technology (including the requirement of comparable labor skills) but that their capital/labor endowment proportions are sufficiently close together that the countries will produce the same pair of commodities.

One of the fundamental results in international trade theory is that countries which are linked together by trade rid themselves of the necessity to produce as many commodities as their populace demands. Specialization in production can be severe, and it takes a model with many commodities effectively to underscore the consequences for income distribution of the possibilities of widespread concentration of productive activity with trade. Consider, therefore, a country facing an initial set of world prices for commodities 1-5. Suppose, furthermore, that this country's factors are not well suited to producing commodity 5, either because technology is inferior to that found elsewhere, or the skills of its labor and capital are deficient, but that there are techniques available for producing the other four commodities which would allow this country to compete effectively with the rest of the world at prevailing prices in a competitive setting. Stated more for-

2. For an appraisal of this theorem after 50 years, see A. Deardorff and R. Stern (1994).

mally, the home country's technology and the given set of world prices determine a set of *unit value isoquants* for these commodities, and the *convex hull* of these isoquants is illustrated by the heavy curve in Figure 1. This is made up of curved sections, along which only a single commodity is produced with trade, and of linear segments along which two commodities are produced; for points along any such segment the standard 2 × 2 results of Heckscher-Ohlin theory are relevant for small changes. Suppose the world price of commodity 2 is reduced, say as a consequence of increased world market participation by countries whose output is primarily in industry 2's sector. This has the effect of shifting the unit value isoquant for commodity 2 radially away from the origin, since now a greater input bundle must be employed to produce enough of commodity 2 to earn $1 on world markets. The new Hicksian composite unit value isoquant is illustrated by curve 2′ in Figure 2.

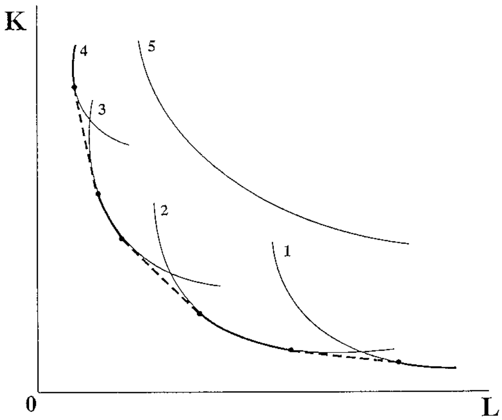

Figure 1. Composite Unit Value Isoquant

The same set of information is illustrated in Figure 3. The lightly sketched upward sloping curves reveal the home country's technological link between the factor price ratio, w/r, and the capital/labor ratios that would be adopted. Prevailing world prices determine which techniques could be used. As Figures 1 or 2 reveal, at very low relative wage rates, only commodity 1 is produced. At a slightly higher relative wage it becomes possible to produce commodity 2 as well as 1, and such a factor price ratio is consistent with many combinations of outputs of these two commodities. For higher wage/rental ratios the composition of production changes yet again alternating between patterns of complete and incomplete specialization. The dashed lines in Figure 3 correspond to the situation illustrated in Figure 2, in which commodity 2's world price has fallen. Thus there is now a more narrow range in which commodity 2 would be produced.

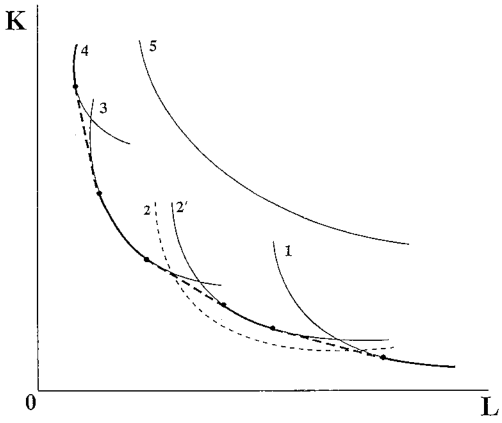

Figure 2. A Fall in 2's Price

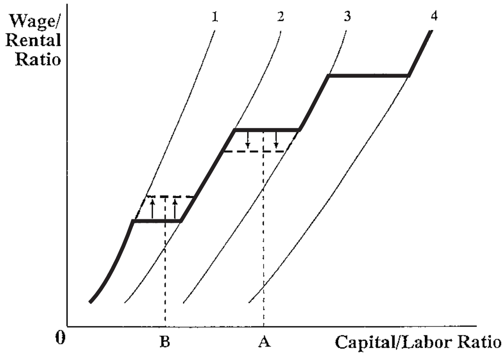

Figure 3. Factor Prices and Endowments

Figure 3 is useful in illustrating how such a fall in commodity 2's price would affect real and relative wage rates for unskilled labor. This effect clearly depends upon the pattern of production in the home country, which in turn is based upon its endowment proportions. Consider, first, the position of a very labor-abundant country producing only the first commodity. Its relative wage rate is unaffected, and the *real wage* for unskilled workers would rise since the price of one of the consumption goods has fallen with no change in the nominal wage. A similar promising result holds for unskilled labor in very capital abundant countries producing no commodity 2. The fate of countries producing commodity 2 is different. A welfare loss is shared by both types of income recipients if the country's endowment proportions have it producing only commodity 2 before and after the price rise. But if another commodity is produced as well, the effect of the price change on unskilled labor is even more damaging for relatively capital abundant countries producing commodities 2 and 3 (such as a country with endowment proportions shown by point A), since commodity 2 is relatively labor-intensive. This is the *magnification effect* familiar in 2 × 2 models. For a more labor abundant country (such as shown by point B's endowment ratio) the price drop serves unambiguously to *raise* the real wage of unskilled labor, since commodity 2 is the more capital-intensive commodity produced there. These results on the *change* in the *real wage* are summarized in Figure 4.

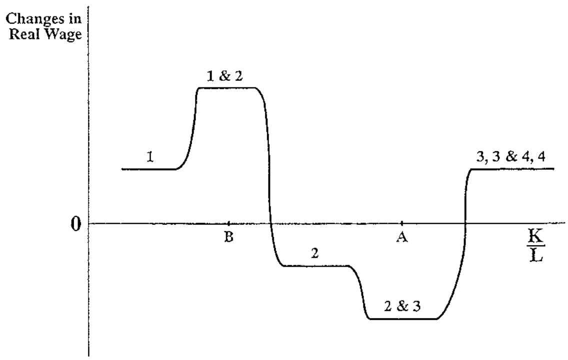

Figure 4. Changes in Real Wage as P_2 Falls

The fact that the same world price change can be unambiguously favorable to unskilled workers in some countries but damaging to the same kind of workers in another, even if it is assumed they have access to the same technology, is a property of simple trade models exhibiting *factor-intensity reversals*. In the literature stimulated by the Leontief Paradox in the 1950's and 1960's such a phenomenon could reflect a comparison of technologies of producing the *same* pair of commodities in two countries, wherein the commodity using capital-intensive techniques in one country uses labor-intensive techniques in another, so that a price change for that commodity results in factor prices moving in opposite directions in the two countries. Here something different is at work—there are not assumed to be any intensity reversals of this kind. Instead, it *must* be the case that for two countries having sufficiently close endowment proportions (and sharing the same technology) such that they produce some commodity in common but are each incompletely specialized to a different other commodity, a price change for the commonly-produced commodity will cause real wages of unskilled workers to rise in one country and fall in another. Thus compare the situation of countries with endowment proportions shown by A and B in Figures 3 and 4. Note that it is the unskilled workers in the more capital-abundant country which are the losers. (Nonetheless, for such workers in even more capital-abundant countries no longer producing commodity 2, its price fall in world markets serves to raise real wages.)

3. Technical Progress

Many economists point to the nature of technical progress as a better explanation of why in some countries the wage rate of unskilled workers has fallen, especially relative to the return on human capital. If technical progress, e.g. developments in computer software, is biased in saving on the use of unskilled labor, what does standard 2 × 2 international trade theory tell us about the effect on the distribution of income? Nothing. We need to know more—in particular, in which sector has technical progress taken place? (And we assume here commodity prices remain unchanged). If, say, Hicksian labor-saving technical progress takes place only in the labor-intensive sector, real wages will unambiguously *rise*, whereas if such progress, with whatever factor bias one assumes, takes place in the other sector, the real wage rate will fall. This is standard fare in this kind of trade model *if* the degree of technical progress is very small. In such a case, the sector in which technical progress takes place causes the distribution of income to change precisely as would a (small) price rise—the Stolper-Samuelson result once again. But with finite changes in a world in which many commodities can be produced, technical progress may have the effect of shifting the pattern of production and thus resulting in a different response of wage rates and returns to human or physical capital. And, if the change is finite, the factor bias of technical progress may influence the production pattern.

This issue is illustrated in Figure 5 for the two-commodity case. Commodity 2 is capital-intensive, and in the initial equilibrium it uses technique A along its unit-value isoquant, while labor-intensive commodity 1 adopts technique B. The initial wage/rental ratio is shown by the slope of the line tangent at A and B. Factor endowment proportions are shown by ray 0R. Now suppose technical progress takes place only in capital-

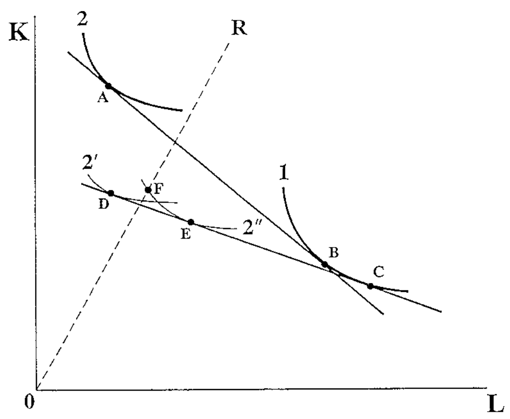

Figure 5. Technical Progress in Capital-Intensive Sector (2)

intensive sector 2. Two possibilities are shown, with different factor biases: $2'$ and $2''$, either of which would lead to the same new lower wage/rental ratio shown by the slope of DEC *if* both goods should be produced after the technical change. But this is a big “if”, one not satisfied for this economy with indicated endowment ray OR if technical progress leads to the new isoquant $2''$ instead of $2'$. Such an economy would drop its production of commodity 1 and produce only the second commodity with a wage/rental ratio shown by the slope at F. That is, if the bias in technical progress leads this country to shift its production pattern (to specialize in the capital-intensive product), a rise in the real wage could result from technical progress in the capital-intensive sector.

There is no doubt that the frequent reliance trade theorists place on the 2×2 Heckscher-Ohlin model to trace out the effects of price changes or technical progress on income distribution leads to results at odds with the intuition which many labor economists place on partial equilibrium techniques. The specific-factors model helps to bridge the gap. It is a legitimate form of production structure for use in general equilibrium analysis, but leads to more common sense results for some questions. For example, in the 2×2 setting with given commodity prices, a nation would respond to an influx of immigration of unskilled labor by altering the production mix without any change in factor prices. By contrast, suppose in each of two sectors a type of capital (human and physical) is used that is specific to that sector and not used in the other. As well, suppose each sector dips into a common pool of unskilled labor. Increased supplies of such labor would unambiguously lead to wage declines. As for technical progress, in the specific-factors model the factor bias does matter, along with the rate at which each individual sector is affected. (See Jones, 1996 for details). If technical progress were Hicksian neutral (so that at an unchanged factor-price ratio the same capital/labor proportions would be utilized as in the initial state), the wages of unskilled labor would rise regardless of the sectoral distribution of technical progress. If progress were biased in the labor -saving direction, which most commentators fear has been the case for recent advances in technology, downward pressure on wages would indeed exist, much as in the case of increases in labor supply. However, a mobile factor such as labor would tend to gain from the existence of technical progress, as would all income earners in the neutral case. What can be said of the balance in these opposing forces? As proved in Jones (1996), even in the case of pure Hicksian labor-saving progress at the same rate in each sector, labor’s real wage will rise if technology is sufficiently “flexible”. By this is meant if the elasticity of substitution between labor and capital in the two sectors is high enough. A value of unity is more than sufficient. (On average a value exceeding the ratio of capital to labor shares will be enough).

4. Fragmentation and Loss of a Labor-Intensive Activity

Developed countries in the United States and Western Europe are fearful that technological advances in service sectors such as telecommunications and transportation will encourage previously vertically-connected production processes to fragment, with more labor-intensive segments losing out to foreign competition. Need this be a concern? Figure 6 helps to clarify the issue.

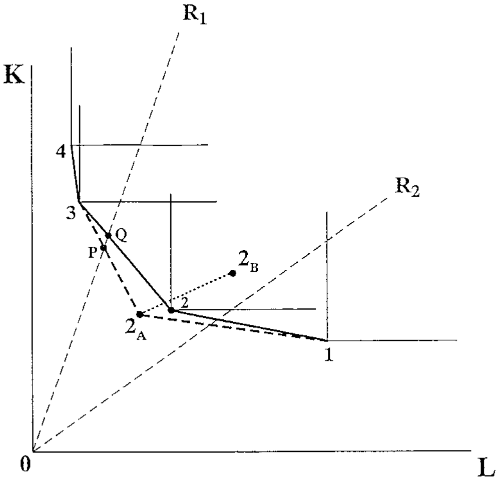

Figure 6. Fragmentation in Sector 2

For convenience, it is assumed in Figure 6 that each productive activity displays absolutely rigid technology in the sense that no substitution possibilities between labor and capital are available. Thus originally suppose the home country's Hicksian unit-value isoquant is made up of corner points for producing activities 1 through 4, and the linear segments connecting these points. This state of affairs is disturbed by developments in service activities (not shown) which allow vertically-integrated activity 2 to be fragmented into two fixed-coefficient activities, one more capital-intensive than the other. In particular, suppose that this finer division of productive activities allows world gains in productivity in that a more intensive application of the Ricardian doctrine of comparative advantage tends to result in a lower world price for the aggregate of the two components of commodity 2 than previously. This is revealed in Figure 6 by the two fragments 2_A and 2_B, and the fact that the convex combination of these two points lies above the corner of previously integrated activity 2. (Details of this fragmentation procedure are found in Jones and Kierzkowski 2001). Arbitrarily shown in Figure 6 is the dominance of capital-intensive activity 2_A over the labor-intensive component 2_B, ensuring that with fragmentation the latter activity lies strictly within the convex hull denoted by the dashed lines.

What are the consequences for factor prices and employment in the home country in this new, more fragmented world? This depends on the country's factor-endowment proportions. For example, if the capital/labor endowment ray is shown by $0R_2$, the wage/rental ratio falls. Indeed, the replacement of activity 2 by the fragment 2_A in the country's portfolio of production (it also produces commodity l) is akin, in its affect on factor prices, to a labor-saving technical progress in the country's capital-intensive activity. Thus the real wage unambiguously is driven down. Figure 7 explicitly reveals this loss in the real wage. (For a capital/labor endowment ratio between rays 02_A and 02, the drop in the real wage is especially severe since wages were originally higher when the country originally produces commodities 2 and 3). By contrast, the situation at home if it originally had the higher capital/labor endowment proportions shown by ray $0R_1$ is different. In this case the country is originally producing commodities 2 and 3, so that the replacement of integrated activity 2 by the more capital-intensive segment, 2_A, has its analogy in a technical progress in producing the labor-intensive commodity. This results in standard 2×2 fashion in an increase in the wage/rental ratio and, as Figure 7 illustrates, an increase in the real wage as well. For countries so capital abundant that commodity 2 is not initially produced, there results the standard improvement in the real wage as a consequence of the lowering of commodity 2's price to consumers.

Although this model is not designed to address the issue of aggregate employment (indeed it assumes factor prices represent market-clearing wages and returns to human and physical capital), it can show what happens to employment in sector 2, in which this country is shown to lose the labor-intensive fragment, 2_B, to world competition. The answer to this question depends on whether the country is relatively capital abundant, such as shown by ray $0R_1$, or labor-abundant, as shown by ray $0R_2$. In the latter case not only do wages fall, but sectoral employment shifts away from commodity 2 to more labor-intensive commodity 1. Consider the fate of a more capital-abundant country, the very type of country which is apt to be worried about the effect of losses of labor-abundant fragments on wage rates in a more competitive and fragmented world market. Its real wage rises, as previously noted, and employment of labor in the capital-intensive segment 2_A actually *exceeds* previous employment levels in the fully integrated activity 2. The reason: Point P in Figure 6 is a weighted average of points 3 and 2_A, with a greater weight given to 2_A than is given to 2 in point Q's weighted average of points 3 and 2. Finally, compare the shapes of the loci in Figures 4 and 7. If greater international competition forces down the price of commodity 2, it is the real wage in more capital abundant countries (producing 2) that is lowered. By contrast, increased fragmentation which causes a country to lose the labor-intensive fragment,

2_A, results in a lowered real wage not for more capital abundant producing countries, but for those which are more labor-abundant.

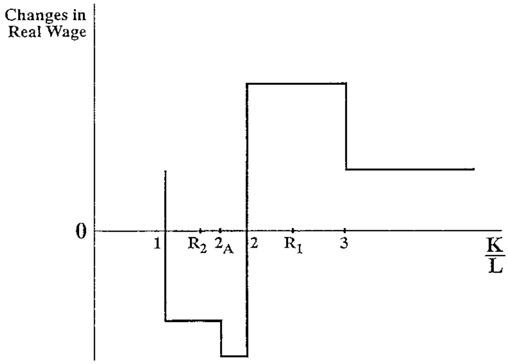

Figure 7. Fragmentation and Changes in Real Wage

5. Concluding Remarks

The analysis of the effects of changing terms of trade or a change in technology or the degree of fragmentation in world markets on a country's distribution of income stressed in these remarks is based on a multi-commodity trading world. Abandoning the standard assumptions of 2 × 2 international trade theory leads to a wider variety of results without any substantial increase in the difficulty of analysis. To be sure, a drop in the world price of a commodity produced in a country by labor-intensive techniques still spells difficulty for the return to unskilled labor. But even this conclusion needs to be qualified. For suppose that the price drop is itself the consequence not of new supplies of the commodity as new developing countries enter the world market, but rather of technological progress which is shared by the country in question. In such a case the price drop is accompanied by an *increase* in the real wage. Indeed, this was the analogy pointed out in the preceding section, in which reductions in costs of fragmentation caused a country to lose the labor-intensive segment of a previously vertically integrated activity, an activity which utilized labor-intensive techniques relative to another actively produced commodity.

A Heckscher-Ohlin world in which factors are mobile between sectors is one in which production is concentrated to a few commodities if trade allows consumption to be obtained from abroad. This implies that as prices fall for some traded commodities, many countries may experience a rise in real incomes for all factors because none of that commodity is produced. This was the source of gain in real wages at very low and very high capital/labor endowment ratios in Figures 4 and 7. Suppose instead there are many specific factors, indeed an $(n + 1) \times n$ version of the model in some country. Then all commodities are produced. However, the lower the price for any commodity, the less labor will be devoted to its production, so that once again the gains to workers as consumers will eventually exceed any losses in real wages as the price to local producers falls.

The specific-factors model is both simple and useful if a distinction is desired between human capital and physical capital as well as unskilled labor. For example, suppose for the American case that import-competing goods are produced with unskilled labor and physical capital whereas in the export sector the specific factor is skilled labor (human capital) and physical capital is mobile between sectors. If a fall in the price of imports is the primary shock coming from world markets, such a scenario suggests a rise in real wages for skilled workers, a fall in real wages for the unskilled, and not much real change in the return to physical capital. Not a bad fit for the American scene.

There is no doubt that changing conditions of international trade can have important repercussions on the distribution of income in all trading nations. And so can changes in other conditions, such as technical progress or advances in services which allow an international dispersal of previously vertically integrated components. These changes are more sensibly analyzed in models with many commodities. The competitive forces of trade can then encourage greater degrees of concentration so that even countries with similar technologies and factor skills but somewhat different endowment proportions can produce a different range of commodities. The effects of any world shocks on real wages and returns to human and physical capital may then be different from one country to another.

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3 Trade and Personal Distribution of Wealth and Income: Beyond the Stolper-Samuelson Theorem

Satya Das*

1. Introduction

It is well-known that major trade policy changes have serious distributional implications. This is why such changes are often controversial. The justly famous Stolper-Samuelson theorem, henceforth "*The Theorem*", is the theoretical center-piece, around which the effect of trade on distribution is understood and discussed. Published over sixty years ago (Stolper and Samuelson (1941)), it still enjoys a central status in trade theory. Perhaps for the first time, the supremacy of *The Theorem* is being questioned now amidst recent controversy on the trade-relative-wage nexus (Leamer (1996)). At the same time however, there is no serious alternative being proposed or developed (Burtless (1995)). Some continue to believe that *The Theorem* is an 'eternal truth'—something which must hold 'in the long run'. Within a broader factor endowment framework with more than two goods, Jones (1997) analyzes a wide variety of predictions other than *The Theorem*. At the worst, *The Theorem* is still the eye of the storm and hence enjoys its status in a different way.

The objective of this paper is not to challenge *The Theorem* but to 'stand on its shoulder' so-to-speak and attempt to explore the more complex territory of personal distribution of income and wealth. Specifically, it examines how international trade, based on difference in factor endowments, may affect personal distribution of wealth and income within a country, given its implication for functional distribution according to *The Theorem*. The modern market economy is quite different from the landlord

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/capitalist-or-labor class economy in the immediate post-Industrial-Revolution period. The transaction costs of participation in asset markets are quite small and many households provide labor services as well as own land/capital. Casual observations tell us that the proportion of households owning and trading in land/capital and common stocks (which provides ownership of land/capital indirectly) is increasing over time, and, it is a global phenomenon. Thus, in order to judge equity implications of policy changes, personal distribution seems more relevant as an object of study than functional distribution—with which trade theory has been preoccupied for a long time.

It is only very recently that the issue of trade policy and personal distribution of income has been taken up in the literature, e.g. Fischer and Serra (1996). It develops a Lucas-type endogenous growth model with human capital. Different households have different initial endowments of human capital which is partly consumed and partly passed on to the posterity. Freer international trade between countries have short term, but no long term, effects on wealth and income distribution. The emphasis is on income convergence across countries.

In contrast, this paper is entirely focused on the effect of trade on distribution (a) *in the long run* and (b) *without any consideration of growth*—exogenous or endogenous. In the process, our analysis also develops in a precise way (at least theoretically) the common notions of lower class, middle class and the upper class, whose sizes change responding to policy variations.

The basic scenario to be explored is the following. There are two countries, North and South, which possess the standard Heckscher-Ohlin characteristics. The North and South are respectively the relatively more land (or equivalently nonreproducible capital) and labor abundant countries. In each country land is tradable.[1] There are two goods differing in factor intensities, both factors are mobile between the two sectors, instantaneous utility function is the same across the two countries and satisfies homotheticity, and so on.

This scenario is exactly the same as in Mayer (1984) except that there is a market for land (and there are no political economy aspects). It is also similar to Eaton (1988) in that land is tradable; it is less general than Eaton's as reproducible capital is not considered but more general in that there are heterogeneous households or dynasties. Reproducible capital is ignored in order to focus entirely on the distributional aspects of an economy.

We interpret households as dynasties (we will see why). The number of dynasties and the total endowment of land are given. In particular, the dy-

1. Empirical evidence indicating that land is a significant component of wealth is provided by Goldsmith (1985) which is reproduced in Eaton (1988).

nasties differ in their propensity to accumulate land.[2] This is the source of heterogeneity and inequity in wealth and income. It is similar to Stiglitz (1969) and models of heterogeneous rate of time preference such as Uzawa (1968), Epstein and Hynes (1983), Lucas and Stokey (1984) and Das (1993). Those with greater propensity to accumulate hold more land in the steady state.[3]

We consider two types of model economies within the broad features just described. In one, our basic model, each dynasty is endowed with one unit of labor and thus there is only rental income inequality. In the other, labor supply is variable. Through wealth effect and because of varying propensity to accumulate, wage incomes ('earnings') are unequal. This model gives rise to the notion of lower, middle and upper classes. Those in the higher end of the propensity to accumulate hold so much of wealth (land) that, by the wealth effect, they decide not to work. They are pure landlords or capitalists and constitute the upper class. Intertemporal preferences are specified such that land holding is not 'necessary'. Thus in the lower end of the propensity to accumulate, there are dynasties which do not possess land at all. These are landless workers and define the lower class. Those in the middle hold land as well as work and constitute the middle class. They can be called 'working landlords' or 'working capitalists'. An important feature of this classification is that the size of each class is endogenous since labor-leisure choice and whether to hold zero or positive amount of land depend on the wage-rental ratio and return to capital. This is similar to the (five-) class structure developed by Roemer (1982). However, his classification is based on exogenously specified distribution of wealth endowments and hence on exogenous class sizes.[4] In summary, in contrast to a 'standard' static model, in our analysis both wealth distribution and class sizes are endogenous.

In this scenario, our analysis offers the following results.

(1) Free trade in commodities, compared to autarky, entails more wealth and income inequality in the North and less in the South.

(2) The above result holds in the basic model of rental income inequality. The extended three-class model predicts that free trade in goods leads to a *middle class squeeze* in the North and a *middle class expansion* in the South.

(3) Lastly, assuming a Benthamite utilitarian social welfare index, the resultant change in distribution due to free trade is a source of welfare loss for the North and welfare gain for the South.

2. There is of course no aggregate accumulation. Individuals however attempt to accumulate or decumulate.

3. The difference, which is not essential for our purpose, is that these works assumed reproducible capital. But their distributive implication is exactly the same as here with land or nonreproducible capital.

4. Eswaran and Kotwal (1989) apply Roemer's concepts to the credit market and develop an agrarian class structure.

We find result (2) particularly interesting. There is mounting empirical evidence that over the last two/three decades wealth and income inequalities have risen in many developed countries (e.g. Das (1993)). There is constantly a talk of middle class shrinkage. On the other hand, one also reads about middle-class boom in many developing countries following economic liberalization. Our analysis suggests that these phenomena is partly attributed to freer trade between developed and developing countries.

Section 2 develops our basic model and examines the effect of free trade on wealth and income inequality in the presence of rental income inequality only. The three-class model is developed in Section 3. Equity as well as aggregate welfare implications of free trade are examined. Section 4 concludes the paper.

2. The Basic Model

An economy is endowed with a given number of households (equal to H) and a given amount of land (equal to K). To begin with, consider a closed economy. The production side is of the standard HO (Heckscher-Ohlin) type. Let the two goods be denoted by x and y, respectively labor and land intensive.

On the household side there are dynasties indexed by h. Following Aghion and Bolton (1997) and Piketty (1997), everyone lives for one period. As soon as a person dies, a replica is born. Each individual derives utility from his/her own consumption and bequests he/she leaves. The overlapping generations setup is assumed away so as to separate inequity across households/dynasties from inequity in terms of age.[5] There is risk-aversion in terms of consumption (i.e. diminishing marginal utility from consumption) and in terms of overall utility from consumption and bequests. The latter is not essential; it will be used only in assessing aggregate welfare effects later in section 3.

At time t, a dynasty h's preferences are specified by the utility function

$$(1)\quad \begin{cases} \gamma \ln x_{ht} + (1-\gamma)\ln y_{ht} + s\ln(K_{ht+1} + h - a) & \text{when } K_{ht+1} \geq a - h \\ -\infty & \text{otherwise.} \end{cases}$$

where $0 < \gamma < 1$, $s > 0$ and

$$\text{(R1)}\qquad a \geq b.$$

5. The source of heterogeneity in our analysis is however different from that analyzed by the above mentioned authors as well as Banerjee and Newman (1991) —namely, risky returns on investment and lack of perfect insurance markets.

The parameter b will be introduced later. x_{ht} and y_{ht} are the respective consumption and K_{ht+1} is the amount of land bequeathed to the next generation. The first two terms represent felicity; γ is therefore the share of good x in the total expenditure:

$$x_{ht} = \frac{\gamma E_{ht}}{p_{xt}}; \qquad y_{ht} = (1-\gamma)E_{ht}, \tag{2}$$

where p_{xt} is the relative price of good x in terms of good y, the numeraire good, and, E_{ht} is the dynasty's total expenditure. The indirect static utility function is: $\Delta - \gamma\ln(p_{xt}) + \ln(E_{ht})$, where $\Delta \equiv \gamma\ln\gamma + (1-\gamma)\ln(1-\gamma)$. The intertemporal utility function is accordingly stated as

$$\Delta - \gamma\ln(p_{xt}) + \ln(E_{ht}) + s\ln(K_{ht+1}+h-a). \tag{3}$$

A dynasty's savings are in the form of bequests.

That the quantity of exactly what is being bequeathed affects utility represents "joy of giving" or "warm-glow" preferences over bequests (see Andreoni (1989) also, along with Fischer and Serra (1996), Aghion and Bolton (1997) and Piketty (1997)).[6]

The warm-glow bequest approach implies that land has an asset value as well as a direct commodity value. Therefore, the 'yield' on land (the rental) is not the only determinant of the asset price (price of land). Later this will imply that factor price equalization across countries would not imply asset price equalization.

The parameter s is just a coefficient, which we set to one henceforth. The dynasty type is indicated by h. Let its support be $(0, b)$, $b > 0$, and the density function be $f(h)$. There is no restriction imposed on this function, except that it is continuous. A higher value of h implies a lower marginal utility schedule of bequest, implying that, along the steady state, a dynasty with a higher h holds less land. Define mean h as

$$\bar{h} \equiv \int_0^b hf(h)dh.$$

The restriction $a > b$ implies that the marginal utility of bequest satisfies Inada condition for all h. Hence in equilibrium all dynasties will hold positive amount of land (to be relaxed in the three-class model). Borrowing is

6. This is in contrast to the Ricardian specification as in Barro (1974) where a parent's utility is, in part, a function of the child's utility, which is equivalent to to an infinite-horizon chain. See Aghion and Bolton for a discussion on why, in modelling bequests, the warm-glow approach may be preferred to the Ricardian approach.

prohibited.[7] Further, it will be assumed that

(R2) $$K > H\,(a-\bar{h}).$$

This states that the total endowment of land is not too small. The significance of this will be seen later.

Finally, that the value of h is the same over generations of any given dynasty captures the notion of dynasty itself in that a tradition or a practice is being passed on from one generation to the next.

In this section we assume that each dynasty possesses a unit of labor endowment which is offered to the labor market. Hence the total labor endowment is the number of dynasties, H. The total income of a dynasty equals $I_h = w_t + r_tK_{ht}$, where w_t and r_t are the respective factor rewards (in terms of good y). The price of land denoted by p_{kt}, the intertemporal budget constraint reads as

(4) $$E_{ht} + p_{kt}K_{ht+1} \leq w_t + (r_t + p_{kt})\,K_{ht}.$$

A dynasty maximizes (3) subject to (4). The first-order condition is

(5) $$\frac{E_{ht}}{K_{ht+1} + h - a} = p_{kt}.$$

Transitional Dynamics

Since there is no aggregate accumulation, in the aggregate an economy is the same as the standard, static HO economy; Q_{xt}, Q_{yt}, w_t, r_t and p_{xt} are all constant over time and henceforth will be indicated without the time subscript. These are determined by the two zero profit conditions, the two full employment conditions and one product market clearing condition. Next, we aggregate (4) and (5), eliminate E_t and obtain $wH+rK=p_{kt}(K+H\bar{h}-Ha)$, which implies that p_{kt} is constant over time also. Finally, we go back to (4) and (5), elimiate E_{ht} and express distributional dynamics as

(6) $$K_{ht+1} = \frac{a-h+\omega\rho+(\rho+1)K_{ht}}{2},$$

7. This can be relaxed by specifying the utility from bequest as $\ln(K_{ht+1}-D_{ht+1}/(r_{t+1}-p_{kt+1})+h-a)$, where D_{ht+1} is the debt passed on to the posterity, r_t is the yield (rental) on land at t and p_{kt} is the price of land at t. Thus $K_{ht+1}-D_{ht+1}/(r_{t+1}+p_{kt+1})$ is the net wealth bequeathed. The results of this paper remain unchanged as long as there is borrowing and lending inside a country but not across countries and there is a cap on debt such that negative bequests cannot be passed on.

where $\omega \equiv w/r$, and $\rho \equiv r/p_k$ is the rate of return on capital. Given (R1), i.e., $a \geq b$, it follows that $a \geq h$ for any h. This implies that K_{ht+1} as a function of K_{ht} has a positive intercept. Later it will be established that $\rho < 1$. Thus $0 < dK_{ht+1}/dK_{ht} < 1$. Hence for any h, there exists a unique steady state level of land holding and the adjustment process towards it is monotonic. From now on—in this economy as well as the model economies to be considered—we will confine ourselves to steady state only.

Steady State

Equating $K_{h+1} = K_{ht} = K_h$ in (6),

(7) $$K_h = \frac{\omega\rho + a - h}{1-\rho},$$

(8) $$\Rightarrow I_h = \frac{r(\omega + a - h)}{1-\rho},$$

Restriction (R1) implies that the numerators of these expressions are positive. As we shall see, (R2) would imply that, in equilibrium, $0 < \rho < 1$. Thus positive solutions of K_h and I_h are assured. These are decreasing in h.[8]

Eq. (7) is also the demand function for land. The following properties of this demand function would be important in understanding the model's prediction on wealth and income inequality.

1. The demand for land is an increasing function of ω by the 'income effect'.
2. The rate of return on land also has a positive 'price effect' on demand for land, which is decomposed into an income effect (represented by ρ as the coefficient of ω in the numerator of K_h) and a substitution effect (through ρ in the denominator).
3. The income effect of an increase in ρ equals $\omega/(1-\rho)$ and is the same for all dynasties. The substitution effect, equal to $(\omega\rho + a - h)/(1-\rho)^2$, is less for higher h or poorer dynasties.

Given these properties, consider the difference in land holding by any two dynasties. Suppose $h_1 < h_2$ so that $K_1 > K_2$. Then

8. As observed by the referee, substituting these into the utility function, it is easy to see that utility is also decreasing in h. This can be interpreted as saying that the rich (poor) choose to remain rich (poor). One can also say that the rich (poor) remain rich (poor) because of their behavioral difference.

(9) $$K_1 - K_2 = \frac{h_2 - h_1}{1-\rho},$$

which is an increasing function in ρ. All else remaining the same, an increase in ρ motivates both rich and poor to demand more land. Income effect is the same but the substitution effect is greater for the richer dynasties. Thus the difference between land holdings widens due to the substitution effect. This indicates that the variance of K_h increases with ρ.

The total demand for land equals $\int_0^b K_h f(h)dh$. Thus $\int_0^b K_h f(h)dh = K$ spells the land market clearing condition. In the light of (7),

(10) $$\frac{\omega\rho + a - \bar{h}}{1-\rho} = \frac{K}{H},$$

which essentially determines the price of land or equivalently ρ given w and r. Note that the left-hand-side is the mean demand for land. At $\rho = 0$, it equals $a - \bar{h}$ and as $\rho \to 1$, it approaches ∞. Hence there exists a unique solution of $\rho \in (0, 1)$, if $K > H(a - \bar{h})$. The last inequality is the same as our restriction (R2). Thus (R2) ensures that $0 < \rho < 1$.

Observe that the price of land is *not* a function of factor prices alone. In particular, it is not equal to the discounted value of the stream of yields (r). It is because land, in the form of bequest, provides utility directly—not just indirectly through the intertemporal budget constraint by being a source of rental income. Put differently, land has a direct commodity value also, implying that, in equilibrium, the price of land is affected by factor endowments.

Finally, how are wealth and income inequalities measured? We shall use the coefficient of variation. For a random variable z, the coefficient of variation is given by, $\sigma_z/\bar{z}$, the ratio of standard deviation to the mean. For this section, the results hold if we use Gini coefficient as well (see Appendix, Part 1). The model to be developed in the next section is more complicated however and tracking the Gini coefficient becomes a very difficult task.

2.1. Free Trade

All the relations described thus far hold for both North and South. Between them, $K_N/H_N > K_S/H_S$, so the land-abundant North has comparative advantage in the land intensive good, good y, and the labor-abundant South in good x. To fix ideas, suppose that in the free trade equilibrium both countries incompletely specialize and factor price equalization (FPE) holds. The Theorem then captures the effect of trade on functional distribution: ω decreases in the North and increases in the South. Turn now to the land market clearing condition (10). The aggregate demand for land being an increasing function of both ω and ρ, the variation in ω implies that ρ increases in the North and decreases in the South. Intuitively, in the North for example, a decrease in ω lowers the aggregate demand curve for land by the income effect and tends to push p_k down. In equilibrium, ρ increases; thus $d\rho/dp_x < 0$.

Once the effect on ρ is determined, the implications of trade for wealth and income inequality are immediate. The mean land holding is given by assumption. Hence the change in wealth inequality is entirely dictated by the change in its standard deviation. From (7), $\sigma_K = \sigma_h/(1-\rho)$, which is an increasing function of ρ. Since ρ rises (falls) in the North (South), it follows that wealth inequality increases (decreases) in the North (South).

The intuitive explanation is the following. Free trade leads to an increase (decrease) in the land rent in the North (South). This tends to push ρ higher (lower) in the North (South). As shown earlier (see (9)), an increase in ρ increases the dispersion of land holding. The average land holding remaining unchanged, the coefficient of variation increases (decreases) in the North (South).

Now, from (8),

$$\frac{\sigma_1}{\bar{I}} = \frac{\sigma_h}{\omega + a - \bar{h}}.$$

This is a decreasing function of ω. We already know that ω falls (rises) in the North (South). Thus income inequality moves the same way as does wealth inequality. In summary,

Proposition 1. *Free Trade in goods between North and South leads to more wealth and income inequality in the North and less in the South.*

Notice that a model of exogenous distribution of land would predict, on the basis of The Theorem, that, if, for example, ω decreases and r increases, there would be more income inequality. Thus, in some sense, The Theorem ‘anticipates’ more inequality in the North and less in the South. Our basic model of *endogenous* distribution reinforces this. However, a model of exogenous distribution of land is incapable, by definition, of predicting changes in wealth distribution—which our model does. Also, our analysis provides a definite mechanism through which both income and wealth distributions change. Furthermore, as we move on to the 3-class model in Section 3, it would be apparent that a model of exogenous distribution of land would have been unable to endogeneize class sizes.[9]

3. A Three-Class Model

Our basic model is extended now to incorporate labor income inequality as well as three classes of dynasties: workers, working landlords and landlords. This is done by allowing (a) variable labor supply decision and (b) by not allowing bequest to be ‘essential’ for all dynasties. As a result of (a) and (b), some dynasties obtain labor income only (the workers), some only rental income (landlords) and some both (working landlords). They are respectively the so-called lower class, upper class and the middle class respectively. As mentioned in the Introduction, this is related to Roemer’s (1982) class structure. The fundamental difference however is that the basis of heterogeneity in Roemer’s lies in heterogeneous wealth endowments that are given so that the class sizes are fixed also, whereas here preference heterogeneity is the primitive, and wealth holding and class sizes are endogenous.

Let a dynasty’s intertemporal utility be dependent upon current expenditure, bequest, and, in addition, leisure:

$$U_h = \Delta - \gamma \ln(p_{xt}) + \ln(E_{ht}) + s\ln(K_{ht+1} + h - a) + \ln(\overline{T} - L_{ht}), \tag{11}$$

where $\overline{T} \equiv$ the total time available per period and $L \equiv$ the labor time supplied. The index h varies from 0 to b with the same density function. Our parametric restrictions are however partly different:

$$K \geq H(a - \overline{h}), \tag{R2}$$

$$0 < a < b, \tag{R3}$$

$$\overline{T} \leq \widetilde{T}. \tag{R4}$$

The first one is (R2), same as in the basic model, which ensures the existence of equilibrium in the land market. (R3) contrasts (R1) and means that the Inada condition is not satisfied for all h. The implication is that bequest is not necessary for some high-h dynasties. These dynasties hold zero land in equilibrium. (Negative land holding or borrowing is not permitted.) The parameter $\widetilde{T}$ will be defined later.

A dynasty maximizes (11) subject to the intertemporal budget constraint $E_{ht} + p_{kt}K_{ht+1} \leq w_t L_{ht} + (r_t + p_{kt})K_{ht}$, and the nonnegativity constraints

9. Finally, note that Proposition 1 is a long term prediction regarding the effect of trade on distribution, in comparison to a similar short term prediction obtained by Fischer and Serra (1996).

$K_{ht} \geq 0$ and $L_{ht} \geq 0$. Assuming (for now) that nonnegativity constraints do not bind, the first-order conditions, along the steady state, are:

$$\frac{E_h}{K_h + h - a} = p_k; \quad \frac{\overline{T} - L_h}{K_h + h - a} = \frac{p_k}{w}.$$

Together with $I_h = wL_h + rK_h$, these equations solve K_h, L_h and I_h:

(12) $$K_h = \frac{\overline{T}\omega\rho + 2(a-h)}{2-\rho},$$

(13) $$L_h = \frac{\overline{T}(1-\rho)\omega + h - a}{(2-\rho)\omega},$$

(14) $$I_h = \frac{r}{2-\rho}(\overline{T}\omega + a - h).$$

Given our restrictions, it will be shown that $\rho < 1$. Thus, K_h and I_h are negatively related to h as in our basic model. The new feature here is the labor supply. Higher h implies less wealth, and, via wealth effect on leisure, more labor supply.

From (12) and (13), we derive the critical dynasties for whom the land holding or the labor supply is zero. Setting $L_h = 0$ and $K_h = 0$ in the respective expression, we have

(15) $$h_1 = a - \overline{T}(1-\rho)\omega,$$

(16) $$h_2 = a + \frac{\overline{T}\rho\omega}{2}.$$

Given $0 < \rho < 1$, $h_2 > h_1$. Let T be not so large, such that $h_1 > 0$ and $h_2 < b$ in the relevant range of comparison between autarky and free trade. This is our restriction (R4). The necessary condition for $h_2 < b$ is that $a < b$, which is our restriction (R3). We then have $0 < h_1 < a < h_2 < b$. (R3) and (R4), together with $\rho < 1$, imply the existence of all three classes of dynasties.

Note that the solutions for K_h, L_h and I_h stated above are valid for the middle class ($h_1 \leq h \leq h_2$). For the upper and lower classes, we solve the respective constrained optimization problem. The solutions are summarized in Table 1. Note that the upper class does not work and has rental income only, whereas the lower class does not possess land and has labor income only. The middle class possesses both.

Table 1. Solutions for Various Classes

	$0 \le h \le h_1$ upper class	$h_1 \le h \le h_2$ middle class	$h_2 \le h \le b$ lower class
K_h	$\frac{a-h}{1-\rho}$	$\frac{T\omega\rho+2(a-h)}{2-\rho}$	0
L_h	0	$\frac{\overline{T}(1-\rho)\omega+h-a}{(2-\rho)\omega}$	$\frac{\overline{T}}{2}$
I_h	$\frac{r(a-h)}{1-\rho}$	$\frac{r(T\omega+a-h)}{2-\rho}$	$\frac{r\overline{T}\omega}{2}$

It is interesting in passing that this 3-class classification results from the distribution of a single parameter, not from any joint distribution of parameters.

The 'demand functions' for land (bequest) have reasonable properties. It increases with ρ and there is a positive income effect when there is labor income. Moreover, it decreases with h. The supply function of labor does not have all the desirable properties one may wish it to have: with respect to the wage rate, it is increasing for low values of $h (h < a)$, decreasing for medium-range values of $h (a < h < h_2)$ and inelastic for higher values of h. These are results of income and substitution effects vis-a-vis consumption and demand for land. However, labor *income* increases with w, a desirable property, and, decreases or remains the same with respect to h. For the lower class, there is no intertemporal decision; hence labor supply is the same for all dynasties. Wealth (K_h) and income (I_h) as functions of h are exhibited in Figure 1.

Given different levels of land holding, the land market clearing condition is:

(17)
$$D(\rho,\omega) = \frac{1}{1-\rho}\int_0^{h_1}(a-h)f(h)dh + \frac{1}{2-\rho}\int_{h_1}^{h_2}\left[\overline{T}\rho\omega + 2(a-h)\right]f(h)dh = \frac{K}{H}.$$

We have (i) $D(0, \omega) = a - \overline{h}$, (ii) $D(\rho, \omega)$ increasing in ρ in (0, 1) and (iii) approaching ∞ as $\rho \to 1$.

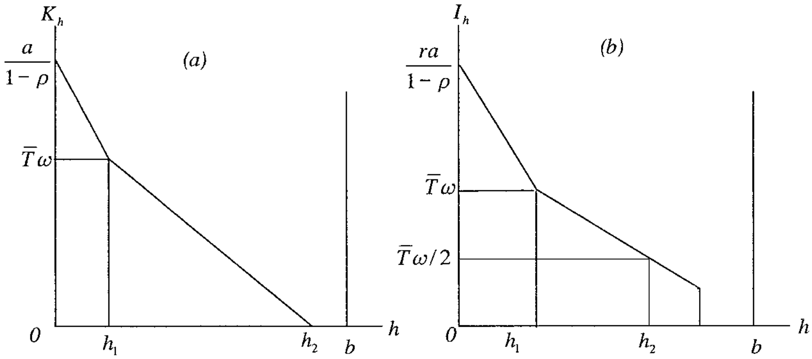

Figure 1. Autarky Equilibria: Endogenous Capital Stock

Hence a unique solution of ρ exists between (0, 1) as long as $K/H > a-\bar{h}$, which is our restriction (R2).

It is easy to verify that $\partial D/\partial\omega > 0$. Thus $d\rho/d\omega < 0$ as in the basic model. We can also express $D(\rho,\omega) = \bar{D}(\rho,\omega\rho)$ with $\partial\bar{D}/\partial\rho > 0$ and $\partial\bar{D}/\partial(\omega\rho) > 0$. Hence, totally differentiating the land market clearing condition, $d(\omega\rho)/d\rho < 0$ and therefore $d(\omega\rho)/d\omega > 0$; these comparative static properties will be used later.

The aggregate labor supply is variable in the economy. In view of Table 1, it equals

$$(18)\quad L = \frac{1}{(2-\rho)\omega}\int_{a-\bar{T}(1-\rho)\omega}^{a+\bar{T}\rho\omega/2}\left[\bar{T}(1-\rho)\omega + h - a\right]f(h)dh + \frac{\bar{T}}{2}\int_{a+\bar{T}\omega\rho/2}^{b} f(h)dh.$$

The elements of the model are all laid out. We now characterize autarky and free trade equilibria and compare.

3.1. Autarky and Free Trade

Unlike in the basic model, the aggregate behavior of an economy is *not* the standard HO Type, because of variable labor supply. The effect of a product price change on sectoral outputs has two components: (a) a movement along the PPF (production possibility frontier) and (b) a shift of the PPF. Effect (b) is akin to the Rybczinski effect and has two 'sub-effects'. A change in p_x affects ω via The Theorem which then affects the aggregate labor supply L; this is a 'direct effect'. Secondly, a change in ω affects ρ, which also has an impact on L; this is an indirect effect. From (18), we have

$$(19)\quad dL = \frac{d\omega}{(2-\rho)\omega^2}\int_{h_1}^{h_2}(h-a)f(h)dh - \frac{d\rho}{(2-\rho)^2\omega}\int_{h_1}^{h_2}(\overline{T}\omega + h - a)f(h)dh.$$

The coefficient of $d\omega$, the direct effect, is ambiguous, while, in view of the expressions of L_h in Table 1, the coefficient of $d\rho$, the indirect effect, is negative. The net effect of a change in ω—and hence a change in p_x—on L turns out ambiguous.

Now consider the effect of an increase in p_x on the output ratio, Q_x/Q_y. Given L, the ratio increases for standard reasons. By The Theorem, ω increases since sector x is labor intensive. From the land market clearing, we already have $d\rho/d\omega < 0$. Thus $d\rho < 0$, which tends to increase L. By the Rybczinski effect, Q_x/Q_y increases. This reinforces the standard effect. The effect through the direct impact of ω on L is ambiguous. Hence it is likely that the overall effect of p_x on Q_x/Q_y is positive. We assume so—which amounts saying that the own price-output response is positive.

In the demand side, homotheticity implies, as usual, that the ratio of consumption of good x to good y is negatively related to p_x. Thus autarky equilibrium is unique.

For the HO theorem of trade pattern to hold, it is now sufficient that, *at any given* p_x, Q_x/Q_y decreases as K/H increases. This indeed holds. Given p_x, ω is given. From the land market clearing condition, an increase in K/H increases ρ, which, in turn, decreases L. We have $K/L = (K/H)\cdot(H/L)$. Hence an increase in K/H coupled with a decrease in L implies an increase in K/L. By the Rybczinski effect, Q_x/Q_y decreases.

We assume once again that, although $K_N/H_N > K_S/H_S$, the difference is not large enough and FPE holds. The effect of free trade on functional distribution is then captured entirely by The Theorem: ω decreases in the North and increases in the South.

We first determine the impact on class sizes, in the light of (15), (16) as well as the signs of $d\rho/d\omega$ and $d(\omega\rho)/d\omega$, which are already discussed. Differentiating we have

$$(20)\qquad \frac{dh_1}{d\omega} = -\overline{T}\left(1-\rho-\omega\frac{d\rho}{d\omega}\right) < 0;\quad \frac{dh_2}{d\omega} = \frac{\overline{T}}{2}\cdot\frac{d(\rho\omega)}{d\omega} > 0.$$

In the North for example, ω decreases; hence h_1 increases and h_2 decreases, implying respectively that upper class and lower class sizes increase. Thus the middle class shrinks! The opposite happens in the South.

Proposition 2. *Free international trade between North and South leads to an increase (a decrease) in the sizes of upper and lower classes and a* *shrinkage (an expansion) of the middle class in the North (South).*

The intuition behind the last proposition is as follows. In the North for example, as ω decreases, the lowermost upper class dynasties decide not to work because of the substitution effect in the labor-leisure decision. This expands the upper class. By the income effect on demand for bequest (land), the lowermost middle class dynasties cannot afford to hold land. Hence they 'move' to the lower class and lower class expands also. As a result, the number of dynasties in the middle class falls. Our analysis indicates that the much talked about middle class squeeze in the North may be partly due to freer trade among North and South countries.

The implication for overall inequality is that it increases in the North and decreases in the South. The proof of it, somewhat complicated in this more general model, is relegated to Appendix, Part 2. We have

Proposition 3. *Proposition 1 continues to hold in the three-class model.*

3.2. Welfare

Suppose that initially the two economies are along their respective steady state in autarky, and there is a policy change in both countries to free trade. How are individual welfare levels and aggregate welfare affected? Whether it is individual or aggregate welfare, as long as there is some transitional dynamics, welfare losses or gains occur during the transition period and at the steady state. However, it is generally difficult to characterize the former since the speed of adjustment and its change to the regime change have to be accounted for. Furthermore, because the agents in the economy have finite lives, there is no natural discount factor to choose. Therefore, we shy away from analyzing welfare changes outside the steady state and limit ourselves to comparing *long-run* welfare levels: one steady state (autarky) vis-a-vis another (free-trade).

Individual Welfare

Land holding by the upper class, equal to $(a-h)/(1-\rho)$, is an increasing function of ρ, which increases in the North and falls in the South. Thus, land held by an upper class dynasty increases (decreases) in the North (South). The land rent also moves in the same way. Hence the income of the upper class, consisting of rental income only, moves in unison also.

From the utility function, it is clear that the upper class benefits (loses) in the North (South). By similar logic, the lower class loses (benefits) in the South (North). Note that because of the magnification effect, changes in commodity prices are dominated by factor price changes.

Labor supply and land holding are both continuous in h, and this continuity implies the following proposition:

Proposition 4. *There exists critical dynasties in the North and South (say h_N and h_S respectively) belonging to the middle class (at the autarky equilibrium) such that dynasties lower (higher) than h_N benefit (lose) as the economies move from autarky to free trade, and those lower (higher) than h_S lose (gain).*

Aggregate Welfare

In the presence of heterogenous preferences, the problems of interpersonal comparison of utility naturally arise. But they are no more severe than when preferences are the same, endowments are different and there is risk-aversion: at the margin the utility value of one dollar for one person may differ from that for another. The usual practice, in the presence of risk -aversion, is to use a Benthamite utilitarian index—the sum of utilities (which is as good as any other indicator).[10] We assume the same here; heterogeneous preferences, in principle, do not exacerbate the problem of interpersonal utility comparison. On the other hand, in the presence of inequality, the utilitarian index captures something which may be considered 'desirable', by putting higher weight on welfare as we go down from rich to the poor (the marginal weights being proportional to the risk-premia). This implies that, ceteris paribus, more inequality means less welfare. In other words, inequality is viewed not only through its possible impact on efficiency (although in the model economy at hand there is none) but also as a separate entity which adversely affects aggregate welfare.

Obviously then, the effect of free trade on aggregate welfare is governed by aggregate changes as well as by redistribution. In the present context there are two aggregate effects: the standard (production and consumption) gains from trade by both countries as well as the change in the total labor supply which is endogenous. The latter arises since only steady states or long-run effects are taken into consideration. This effect is however ambiguous because of the ambiguous effect of a change in ω on L as discussed earlier. The redistribution effect of trade on welfare follows readily from Proposition 3:

Proposition 5. *Given that social welfare function is utilitarian, the redistribution effect of trade on welfare is negative for the North and positive for the South.*

10. See for example Atkinson and Stiglitz (1980, ch. 13) and Strawczynski (1998)).

Put differently, redistributive effects of trade are a source of welfare loss (gain) for the North (South). In spirit, this goes against the popular belief in some ‘Southern’ countries that free trade with the North may not be ‘profitable’ proposition for them. Our model, on the other hand, argues that free trade moves the distribution in the ‘right’ way in the South. It is in the North where it moves the ‘wrong way’ and free trade may not be welfare improving because of it. A related implication is that to ensure a positive gain from trade for the North, free trade may have to be coupled with redistributive policies.

To save space however, the formal welfare analysis is relegated to Appendix, Part 3.

4. Concluding Remarks

This paper has examined the effect of international trade on distribution of wealth and income in an Heckscher-Ohlin world economy. The much celebrated Stolper-Samuelson Theorem is taken as the base upon which models of wealth and income distribution are constructed. In terms of modelling, we have walked on a thin line balancing between the richness of the $2 \times 2 \times 2$ trade model and general complexities in allowing for a continuous distribution of wealth and income on one hand and tractability on the other. Preference heterogeneity in a dynastic setting forms the basis of difference in wealth and income. In the process, we also develop a precise definition of the so-called lower class, middle class and upper class which invariably features in a discussion on wealth and income distribution.

By ‘the effect of international trade’, it is meant, as usual, a movement from autarky to free trade. Our central result is that free trade in goods between North and South increases inequity in the North and decreases that in the South. More specifically, the middle class shrinks and the other two classes expand in the North, and, the opposite holds in the South. Moreover, the redistribution effect of free trade on aggregate welfare is negative for the North and positive for the South.

There are some obvious routes that related future research can take. One is the allowance of reproducible capital and eventually endogenous growth. There are closed economy models of addressing the former issue (such as Aghion and Bolton (1977) and Piketty (1997)) and the latter (such as Alesina and Rodrik (1994), which assumes exogenous distribution, and Galor and Zeira (1993)). As mentioned earlier, an open economy model with land and reproducible capital (but with no endogenous growth or across-the-household distributional aspects) has been developed by Eaton (1988). As mentioned before, Fischer and Serra (1996) have developed an endogenous growth model with human capital, trade and inequality; but forces implying positive inequality in the long run are not considered.

Another obvious line of investigation should be to examine various political-economy aspects of trade and trade related policies when wealth and income distributions are endogenous. Mayer's (1984) analysis will be the natural point of reference.

There are two standard paradigms of trade: trade among dissimilar countries, such as the North-South trade examined in this paper, and trade among similar countries (the so-called North-North trade). That latter has been analyzed in a companion paper (Das (2000)), which incorporates capital accumulation (but not endogenous growth). The main finding there is that the degree of relative risk-aversion is a critical parameter that determines whether or not North-North trade implies more wealth and income inequality among Northern countries.

Our analysis abstracts from the implications of international borrowing and lending. It will be of interest to contrast the effects of free international movement of assets with those of free trade in goods.

Other sources of inequity than preference heterogeneity (e.g. idiosyncratic shocks to individual productivities or risky returns to land) should also be explored in the context of international trade.

It is hoped that future research will be directed toward some of these issues raised.

Appendix

Part 1

It is shown here that in our basic model the effect of trade on wealth and income inequality, summarized in Proposition 1, continues to hold if inequality is measured by the Gini coefficient.

In this model the Gini coefficients with respect to land holding and income are given by

$$g_K = 1 - \int_0^b \left[\int_h^b \frac{K_z}{K} f(z) dz \right] f(h) dh; \quad g_I = 1 - \int_0^b \left[\int_h^b \frac{I_z}{I} f(z) dz \right] f(h) dh .$$

Note that the inner integral runs from h to b rather than vice versa because wealth is less with higher h. We have

$$\frac{Kz}{K} = \frac{\omega\rho + a - z}{(1-\rho)K}; \quad \frac{I_z}{I} = \frac{\omega + a - z}{H(\omega + a - \bar{h})}.$$

Thus

$$d\left(\frac{K_z}{K}\right) = \frac{1}{(1-\rho)^2 K}\left[(1-\rho)\frac{d(\omega\rho)}{dp_x} + (\omega + a - z)\frac{d\rho}{dz}\right].$$

From (10) it follows that

(A1) $$(1-\rho)d(\omega\rho) = -(\omega\rho + a - \bar{h})d\rho\,.$$

Substituting this

$$d\left(\frac{K_z}{K}\right) = -\frac{d\rho / dp_x}{(1-\rho)^2 K}(z-\bar{h})\,.$$

Define $F(h) \equiv \int_0^h f(z)dz$ (the cumulative density function) and $\phi(h) \equiv \int_h^b \left(z-\bar{h}\right)f\left(z\right)dz.$ Then

$$\frac{dg_K}{dp_x} = \frac{d\rho / dp_x}{(1-\rho)^2 K}\int_0^b \left[\int_h^b (z-\bar{h})f(z)dz\right]f(h)dh = \frac{d\rho / dp_x}{(1-\rho)^2 K}\int_0^b \phi(h)f(h)dh$$

$$= \frac{d\rho / dp_x}{(1-\rho)^2 K}\left[\phi(h)F(h)\Big|_0^b + \int_0^b (h-\bar{h})f(h)F(h)dh\right],$$ integrating by parts.

The first term in the square bracket is zero as $\phi(b) = F(0) = 0$. The second term is simply Cov[h, $F(h)$], which is positive since $F'(h) = f(h) > 0$. Together with $d\rho/dp_x < 0$ (proved in the text), it follows that $dg_K/dp_x < 0$. In the South, p_x increases and thus g_K falls. Opposite holds for the North.

Turning to income inequality, we have

$$\frac{d(I_z / I)}{dp_x} = \frac{d\omega / dp_x}{H}\left(z-\bar{h}\right),$$

which has the same sign as of $d(K_z/K)/dp_x$ for any z, since $d\omega/dp_x > 0$. It follows that $dg_I/dp_x < 0$ also. So, income inequality moves the same way as does wealth inequality.

Part 2

The effects of trade on wealth and income inequality in the 3-class model are proved here. In general, let $z(h,\theta)$ be random, where h is a random variable with density $f(h)$ and support (b_1, b_2), and θ is a parameter. The coefficient of variation is given by

$$v_z = \left(\int_{b_1}^{b_2} \left[\frac{z(h,\theta)}{\bar{z}(\theta)} - 1 \right]^2 f(h) dh \right)^{1/2},$$

Thus

$$\frac{dv_z^2}{d\theta} = 2\int_{b_1}^{b_2} \left[\frac{z(\cdot)}{\bar{z}(\cdot)} - 1 \right] \frac{d[z(\cdot)/\bar{z}(\cdot)]}{d\theta} f(h) dh = 2\text{Cov}\left[\frac{d[z(\cdot)/\bar{z}(\cdot)]}{d\theta}, \frac{z(\cdot)}{\bar{z}(\cdot)} \right].$$

In our context, the change in wealth inequality due to a change in p_x is then given by

$$\frac{dv_K^2}{dp_x} = 2\text{Cov}\left[\frac{d[K_h / \overline{K}]}{dp_x}, \frac{K_h}{\overline{K}} \right].$$

But K_h is a decreasing function in h. Thus the covariance and hence

$$\frac{dv_K}{dp_x} \lesseqgtr 0 \quad as \quad \frac{d^2(K_h / \overline{K})}{dp_x dh} \lesseqgtr 0.$$

This is equivalent to

$$\frac{dv_K}{dp_x} \lesseqgtr 0 \quad as \quad \frac{d^2 K_h}{dp_x dh} \lesseqgtr 0.$$

Similarly for income inequality,

$$\frac{dv_I}{dp_x} \lesseqgtr 0 \quad as \quad \frac{d^2(I_h / \bar{I})}{dp_x dh} \lesseqgtr 0.$$

We next derive the signs of these cross partials.

Wealth Inequality

From Table 1, in the range $0 \leq h \leq h_1$,

$$\frac{dK_h}{dp_x} = \frac{a-h}{(1-\rho)^2}\frac{d\rho}{dp_x} \Rightarrow \frac{d^2K_h}{dp_x dh} = -\frac{1}{(1-\rho)^2}\frac{d\rho}{dp_x} > 0.$$

In the range $h_1 \leq h \leq h_2$,

$$\frac{dK_h}{dp_x} = \frac{\bar{T}(2-\rho)d(\omega\rho)/dp_x + \left[\omega\rho\bar{T} + 2(a-h)d\rho/dp_x\right]}{(2-\rho)^2} \Rightarrow \frac{d^2K_h}{dp_x dh} = -\frac{2}{(2-\rho)^2}\frac{d\rho}{dp_x} > 0.$$

Thus, in the range in which there is positive holding of land, the cross partial is positive. Therefore, $dv_K/dp_x < 0$. With p_x rising in the South, wealth inequality falls and opposite holds for the North.

Income Inequality

Turning to income inequality, the critical expression is the cross partial:

$$\frac{d^2(I_h/\bar{I})}{dp_x dh} = \frac{d^2(i_h/\bar{i})}{dp_x dh},$$

where $i_h \equiv I_h/r$ and $\bar{i} = \bar{I}/r$. We have

$$\frac{d\left(i_h/\bar{i}\right)}{dp_x} = \frac{\bar{i}di_h/dp_x - i_h d\bar{i}/dp_x}{\bar{i}^2} \Rightarrow \frac{d^2\left(i_h/\bar{i}\right)}{dp_x dh} = \frac{1}{\bar{i}^2}\left(\bar{i}\frac{d^2 i_h}{dp_x dh} - \frac{di_h}{dh}\frac{d\bar{i}}{dp_x}\right).$$

We have

$$\frac{di_h}{dh} = \begin{cases} -\frac{1}{1-\rho} < 0 & \text{for } 0 \leq h \leq h_1 \\ -\frac{1}{2-\rho} < 0 & \text{for } h_1 \leq h \leq h_2; \\ 0 & \text{for } h_2 \leq h \leq b. \end{cases} \quad \frac{d^2 i_h}{dp_x dh} = \begin{cases} -\frac{1}{(1-\rho)^2}\frac{d\rho}{dp_x} > 0 & \text{for } 0 \leq h \leq h_1 \\ -\frac{1}{(2-\rho)^2}\frac{d\rho}{dp_x} > 0 & \text{for } h_1 \leq h \leq h_2 \\ 0 & \text{for } h_2 \leq h \leq b. \end{cases}$$

Thus

$$\frac{d^2 i_h}{dp_x dh} \geq 0.$$

It is sufficient to show that $d\bar{i}/dp_x > 0$, or $d\left(I/r\right)/dp_x > 0$, which would imply

$$\frac{d^2(i_h/\bar{i})}{dp_x dh} > 0.$$

By definition, $I = wL + rK \Rightarrow I/r = \omega L + K$. Hence, $d(I/r)/dp_x = Ld\omega/dp_x + \omega dL/dp_x$. Using the expression for dL from section 3,

$$\frac{d(I/r)}{dp_x} = \left[\frac{1}{(2-\rho)\omega}\int_{h_1}^{h_2}\left\{(1-\rho)\bar{T}\omega + h - a\right\}f(h)dh + \frac{\bar{T}}{2}\int_{h_2}^{b} f(h)dh\right]\frac{d\omega}{dp_x}$$

$$-\frac{d\rho/dp_x}{(2-\rho)^2}\int_{h_1}^{h_2}\left\{\omega\bar{T} + h - a\right\}f(h)dh - \frac{d\omega/dp_x}{(2-\rho)\omega}\int_{h_1}^{h_2}(h-a)f(h)dh$$

$$= \left[\frac{(1-\rho)\bar{T}}{2-\rho}\int_{h_1}^{h_2} f(h)dh + \frac{\bar{T}}{2}\int_{h_2}^{b} f(h)dh\right]\frac{d\omega}{dp_x}$$

$$-\frac{d\rho/dp_x}{(2-\rho)^2}\int_{h_1}^{h_2}\left(\omega\bar{T} + h - a\right)f(h)dh > 0.$$

Part 3

It deals with the aggregate welfare effects of trade in the 3-class model. Given (11), the utilitarian social welfare index is given by

$$\text{(A2)}\quad U = H\left[\Delta - \gamma \ln(p_x)\right] + \int_0^b \left[\ln(I_h) + \ln(K_h + h - a) + \ln(\bar{T} - L_h)\right] f(h)dh.$$

For notational simplicity and without loss of generality, let H be normalized to one from now on. Technically, a change in the aggregate welfare due to international trade is a comparative statics of U with respect to p_x (keeping in mind that p_x decreases for the North and increases for the South). We have

(A3)

$$\frac{dU}{dp_x} = -\frac{\gamma}{p_x} + \int_0^b\left[\frac{dI_h/dp_x}{I_h} + \frac{d(K_h + h - a)/dp_x}{K_h + h - a} + \frac{d(\bar{T} - L_h)/dp_x}{\bar{T} - L_h}\right] f(h)dh.$$

We re-express the individual terms and come up with a convenient expression of dU/dp_x, which we can economically interpret. Consider first the term $\int_0^b \left[\left(dI_h / dp_x\right)/ I_h\right] f\left(h\right)dh.$ It can be restated as

$$\int_0^b \frac{dI_h / dp_x}{I_h} f(h)dh = \frac{1}{\bar{I}} \int_0^b \frac{dI_h}{dp_x} f(h)dh + \int_0^b \left(\frac{1}{I_h} - \frac{1}{\bar{I}} \right) \frac{dI_h}{dp_x} f(h)dh$$

$$= \frac{1}{\bar{I}} \frac{dI_h}{dp_x} - \frac{1}{\bar{I}} \int_0^b \left(I_h - \bar{I}\right)\left(\frac{1}{I_h} \frac{dI_h}{dp_x} \right) f(h)dh$$

(A4) $$= \frac{1}{\bar{I}} \left(Q_x + w \frac{dL}{dp_x} \right) - \frac{1}{\bar{I}} \mathrm{Cov}\left(I_h, \frac{1}{I_h} \frac{dI_h}{dp_x} \right),$$

where, recall that I and $\bar{I}$ are respectively the total and mean income. The term dI/dp_x has the envelop term Q_x and the effect of p_x on the aggregate labor supply. In the similar manner, one obtains

(A5) $$\int_0^b \frac{d(K_h + h - a)/dp_x}{K_h + h - a} f(h)dh = - \frac{1}{K + \bar{h} - a} \mathrm{Cov}\left(K + h - a, \frac{1}{K + h - a} \frac{d(K_h + h - a)}{dp_x} \right),$$

(A6) $$\int_0^b \frac{d(\bar{T} - L_h)/dp_x}{T - L_h} f(h)dh = - \frac{1}{\bar{T} - \bar{L}} \frac{dL}{dp_x} - \frac{1}{\bar{T} - \bar{L}} \mathrm{Cov}\left(\bar{T} - L_h, \frac{1}{\bar{T} - L_h} \frac{d(\bar{T} - L_h)}{dp_x} \right),$$

where the bar on the top indicates the respective mean. In particular, in deriving (A5), we have used the fact that $\int_0^b K_h f\left(h\right)dh = K,$ a constant. Substituting (A4)-(A6) into (A3) and noting that $C_x = \gamma I/P_x$, we have

(A7) $$\frac{dU}{dp_x} = \left(\frac{Q_x - C_x}{\bar{I}} \right) + \left(\frac{w}{\bar{I}} - \frac{1}{T - L} \right) \frac{dL}{dp_x} + \left\{ -\frac{1}{\bar{I}} \mathrm{Cov}\left(I_h, \frac{1}{I} \frac{dI_h}{dp_x} \right) - \frac{1}{K + \bar{h} - a} \mathrm{Cov}\left(K_h + h - a, \frac{1}{K_h + h - a} \frac{d(K_h + h - a)}{dp_x} \right) - \frac{1}{\bar{T} - \bar{L}} \mathrm{Cov}\left(\bar{T} - L_h, \frac{1}{\bar{T} - L_h} \frac{d(\bar{T} - L_h)}{dp_x} \right) \right\}.$$

The term inside the first pair of brackets is the standard efficiency effect of terms of trade change due to international trade: it is positive for the North and negative for the South. Since p_x decreases (increases) from the perspective of North (South), both countries benefit.

The term inside the second pair of brackets is the *aggregate labor supply effect* on welfare. This is ambiguous in sign. Using the expressions for I_h and L_h from Table 1 and aggregating, it is found that the coefficient of dL/dp_x is negative. However, as discussed earlier, dL/dp_x itself is ambiguous in sign.

Finally, the terms inside the last pair of curly brackets constitute the *redistribution effect* on welfare.[11] The signs of all covariance terms are negative and it is indeed possible to check this for all three classes. From Table 1 observe that I_h, $K_h + h - a$ and $\bar{T} - L_h$ are nonincreasing in h. Hence it remains to show that the terms $(1/I_h)(dI_h/dp_x)$, $[1/(K_h+h-a)][d(K_h+h-a/dp_x)]$ and $[1/\bar{T}-L_h][d(\bar{T}-L_h)/dp_x]$ are nondecreasing in h.

Turning to Table 1, in the range $0 \le h \le h_1$,

$$A \equiv \frac{1}{I_h}\frac{dI_h}{dp_x} = \frac{1-\rho}{r}\cdot\frac{d[r/(1-\rho)]}{dp_x} \Rightarrow \frac{\partial A}{\partial h} = 0.$$

Also, $K_h + h - a = (a-h)\rho/(1-\rho)$. Hence

$$B \equiv \frac{1}{K_h + h - a}\frac{d(K_h + h - a)}{dp_x} = \frac{1-\rho}{\rho}\cdot\frac{d[\rho/(1-\rho)]}{dp_x} \Rightarrow \frac{\partial B}{\partial h} = 0.$$

As $L_h = 0$ in this range of h, $\bar{T} - L_h = \bar{T}$, invariant with respect to h; hence $\partial C/\partial h = 0$, where

$$C \equiv \frac{1}{\bar{T} - L_h}\frac{d(\bar{T} - L_h)}{dp_x}.$$

In the range $h_1 \le h \le h_2$,

$$A = \frac{2-\rho}{r}\cdot\frac{[r/(2-\rho)]}{dp_x} + \frac{\bar{T}}{\bar{T}\omega + a - h}\frac{d\omega}{dp_2} \Rightarrow \frac{\partial A}{\partial h} = \frac{\bar{T}}{(\bar{T}\omega + a - h)^2}\cdot\frac{d\omega}{dp_x} > 0.$$

11. In the representative agent framework, all these terms are zero.

In this range,

$$K_h + h - a = \frac{\rho}{2-\rho}(\bar{T}\omega + a - h),$$

$$\bar{T} - L_h = \frac{\bar{T}\omega + a - h}{(2-\rho)\omega}.$$

Thus

$$B = \frac{2-\rho}{\rho} \cdot \frac{d[\rho/(2-\rho)]}{dp_x} + \frac{\bar{T}}{\bar{T}\omega + a - h}\frac{d\omega}{dp_x},$$

$$C = -\frac{1}{(2-\rho)\omega} \cdot \frac{d[(2-\rho)\omega]}{dp_x} + \frac{\bar{T}}{\bar{T}\omega + a - h} \cdot \frac{d\omega}{dp_x}.$$

It follows immediately that both $\partial B / \partial h$ and $\partial C / \partial h$ are equal to $\partial A / \partial h$ and hence positive.

Finally, in the range $h_2 \leq h \leq b$, these partials are zero. This completes the proof that all covariance terms in (A7) are negative, implying that the whole expression inside the pair of curly brackets is positive. This means that for the North and South respectively, it is a negative and a positive redistributive effect of free trade.

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4 Unilateralism in a Multilateral World*

Wilfred Ethier

International trade policy has a split personality. As the nations of the world have gradually and collectively adopted historically low levels of protection for more than half a century, they have gradually and individually initiated protectionist actions at an increasing pace. What's going on here?

1. Introduction

Contemporary international trade policy is built upon two pillars: *multilateralism* (the rounds of multilateral trade negotiations sponsored by the General Agreement on Tariffs and Trade (GATT) and the multilateral World Trade Organization (WTO)); *unilateralism* (rules—explicit and implicit—for national governments to respond to political pressures for protection).[1] This paper concerns the relationship between these two components and the nature of the system they jointly determine. I shall argue that

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1. A third pillar—regionalism—has been resurrected during the past decade, but I shall ignore this below because I have discussed it at length elsewhere (Ethier, 1998a, b). See Ethier (2004) for a discussion of why multilateralism is what it is, Ethier (2001) for an overview of multilateralism and unilateralism, and Ethier (1998c) for an overview of the relation between unilateralism, multilateralism, and regionalism.

neither can be properly understood in isolation, and that familiar tools of trade policy appear in a dramatically different light when the two are treated together.

My analysis will be positive, but conclusions will have normative applications. In particular, I shall address the following basic questions: How do the two components, and their interactions, determine the pace of trade liberalization? Why does unilateralism take the very special form that it does?

In what follows, I first describe the stylized facts of multilateralism and unilateralism. I next present a multi-country model with high initial tariff barriers. These initial barriers would not have been chosen by the policy makers in the model subsequently presented. Rather, the barriers are assumed to be a legacy of an earlier, different, regime (just as, in the decades since World War II, the world has had to deal with the protection resulting from the radically different inter-war years), but the existence of these barriers produces special interests that resist their removal. Governments negotiate successive tariff reductions in a sequence of periods—a caricature of the GATT negotiating rounds of the last 5-6 decades.

My model is very special but not arbitrary: I attempt to find the simplest structure consistent with the two concerns that have dominated tariff negotiations for centuries:

(i) Dealing with special interests that desire protection
(ii) Negotiators' concerns that the *ex post* environment may turn out significantly different from what they expected when they made the agreements.

This is achieved by the assumed sequence of moves within each period.

First, forward-looking labor allocates itself between the export and import-competing sectors, remaining for the rest of the period specific to the sector it has chosen. Next, governments negotiate tariff reductions. After this, a technology shock occurs. Then trade takes place, with the new technology and constrained by the negotiated tariffs. Because negotiations occur when labor is sector specific, there are special interests; because the negotiations occur before the technology draw, the governments do not then know to what environment the results of those negotiations will apply.

I describe a process of multilateral negotiation resulting in steady liberalization at a moderate rate. I next investigate the possible role of a system of rules allowing countries, whose import-competing sectors face competition from exports from countries with a favorable technology draw, to impose temporary protection. If such protection also benefits those countries whose exporters must compete with the countries with a favorable technology draw, while being acceptable to the latter (the 'insurance triangle'), it can accelerate the rate of liberalization and increase the allocation of resources to comparative-advantage sectors. But a time-consistency problem compounded by an externality ensures that negotiators would never themselves adopt such rules for their respective countries: The 'split personality' of trade policy is essential. In short, features remarkably similar to contemporary unilateralism turn out to be crucial, with subtle and essential relationships to multilateralism, that cannot be understood in a two-country context.

2. The Background

This section briefly describes the essential features of multilateralism and of unilateralism motivating the subsequent model.

2.1. The Stylized Facts of Multilateralism

I mean the entire GATT-WTO structure, but shall distill it into six stylized facts.

1 *Tariffs* are the instruments of protection.
2 The countries of the world *multilaterally* negotiate tariff reductions.
3 The negotiated liberalization is *gradual*.
4 Negotiated agreements feature *reciprocity*: the mutual exchange of concessions.
5 *Nondiscrimination* characterizes trading relations: each country is a most favored nation (MFN) of every other country.[2]
6 Punishments for alleged violations of past agreements have consistently been *commensurate with the violation*, that is, tit-for-tat.

Reducing multilateralism to these stylized facts is deficient in one way. Multilateral liberalization has increasingly shifted from the further reduction of already reduced tariffs to *broadening* liberalization into additional areas, notably agriculture, services, and intellectual property. Attention has necessarily shifted to government policies other than tariffs. Consideration of these would not alter the following argument, so I abstract from them and pretend that continued multilateral liberalization is only the continued reduction of tariffs.

In an earlier paper (Ethier 2004), I used a model like that which follows to show how, with initial high protection consisting only of tariffs, most of the other stylised facts—multilateral negotiations, gradual liberalization, reciprocity, and MFN—will develop endogenously, if government behavior is dictated by a political support function consistent with how governments claim to behave, and if reasonable substitutes for each country's exports are produced elsewhere. Therefore, in this paper, I shall simply take the stylised facts of multilateralism as given. Other authors have also discussed why multilateralism has the properties it has; see Staiger (1995) for a dis-

2. One country extends MFN status to another if the former agrees that goods from the latter will never face a duty higher than the duty applied to similar goods from any other country. In practice, this raises the issue of defining 'similar goods', but I shall abstract from such problems.

cussion of earlier contributions. The recent papers that come closest to addressing these same properties are Bagwell and Staiger (1999a, b).

2.2. The Stylized Facts of Unilateralism

Unilateralism consists of *rules for intervention* rather than *tariff rates*, and both the nature of the rules and the way they are used have been changing over time. The more important rules, and the changing use, are described in Appendix 1. Here I identify five stylised facts that characterize—more or less—a common denominator for the rules of unilateralism.[3]

2.2.1. Exporters are Compensated, at Least in Part

Rents generated by voluntary export restraints (VERs) accrue to the exporters, who administer the quotas. Usually, the exporting firms themselves capture the rents. Safeguards explicitly require that exporters be compensated, but the compensation is to the exporting c*ountry* rather than the exporting *firms.*

Antidumping and countervailing duties are ostensibly tariffs, but a closer look at how these instruments are actually used reveals that they also confer significant compensation.

Roughly one third of US antidumping petitions result in duties, about one third are rejected, and the others are withdrawn. Of these, many are withdrawn after a settlement between domestic and foreign firms. Typically, the foreign firms collectively undertake to raise prices or restrict exports. Prusa (1992) reports that withdrawn petitions restrict trade almost as much, on average, as petitions resulting in duties, implying that negotiated settlements are, on average, more restrictive than antidumping duties.

If, instead, a petition does produce an antidumping duty, the result is usually higher export prices, not tariff revenue. Tariffs collected are often rebated when authorities determine, *ex post*, that the goods were not, in fact, dumped.[4] The exporter, realising that the price in the importing country is going to rise by the dumping margin no matter what he or she does, raises the export price by that amount. The purpose of an antidumping law is *not* to impose temporarily a conventional tariff; it is to force exporters to raise prices. Just as with VERs, the exporters usually get the rents.[5]

I do not claim that unilateralism benefits foreign firms, or that it leaves

3. See also Hillman (1982, 1990).

4. But, in the USA at least, the importer will incur additional liability if it is determined that the goods were, in fact, dumped by more than the duty. This implies that it is riskier to buy goods from a country against which there is an outstanding dumping determination than from some other source at the same price.

5. Usually, but not always. Sometimes the duty is large enough to reduce imports drastically, or to eliminate them altogether, so that the higher price is little consolation to exporters. Sometimes, (particularly in Europe) administration hinders the ability of the exporter to capture the price rise. And countries not in the WTO may apply the label ‘antidumping law’ to any sort of protectionist measure.

them more or less indifferent. This is possible. But the first stylised fact of unilateralism is just that *countries denied market access receive significant —if only partial—compensation.*

It is curious that governments should want, in effect, to hand over tariff revenue to foreigners. But this is exactly what they do, routinely, in the conduct of unilateralism. Why? I shall argue that unilateralism is what it is because of successful multilateralism.

2.2.2. The Instruments Provide Temporary (at least in original intent) Protection

Temporary measures are not necessarily short-lived: they can be renewed. Renewals allow for adjustments and so add *flexibility* (relative to measures that require congressional action and/or multilateral negotiation).

2.2.3. The Restrictions are Discriminatory

Some industries have displayed a comprehensive web of voluntary export restraints (e.g. textiles and apparel), but individual VERs are bilateral and thus inherently discriminatory.

Antidumping and countervailing duty laws are WTO-consistent, but discriminatory, since they apply to the products of specific countries. Safeguards alone are nondiscriminatory. So it is significant that their use has greatly declined relative to that of the other three instruments and that, in the future, it will sometimes be permissible to employ them in a discriminatory manner.

2.2.4. Tariff-Quota Equivalence is High

The proposition of tariff-quota equivalence asserts that any equilibrium that can be supported by a tariff policy can also be supported by an appropriate quota policy, and *vice versa.* However, tariffs and quotas are seldom equivalent in fact. If an equilibrium is disturbed, the response depends on whether a tariff or a quota is in place, so if a policy must be implemented before all circumstances are known, it matters what tool is used. Unilateralism is one theater where tariff-quota equivalence is really relevant: each instrument seeks to attain a particular outcome with a restriction that can be readjusted frequently. So it matters little whether the restriction is quantitative.

5. Usually, but not always. Sometimes the duty is large enough to reduce imports drastically, or to eliminate them altogether, so that the higher price is little consolation to exporters. Sometimes, (particularly in Europe) administration hinders the ability of the exporter to capture the price rise. And countries not in the WTO may apply the label ‘antidumping law’ to any sort of protectionist measure.

2.2.5. The Restrictions are Designed by Officials Distinct from Those who Negotiate International Trade Agreements

This applies to some degree to most industrial countries, but most dramatically to the USA. For over 60 years, the Congress has repeatedly ceded to the executive considerable authority to set actual tariff levels via reciprocal trade negotiations and, throughout this period, the executive has consistently been less protectionist than Congress. Yet, at the same time, Congress has repeatedly revised the laws governing administered protection to limit executive discretion and to make protection a more likely response to petitions for relief.

3. The Model

I now describe a simple formal model of successive multilateralism. I will then inquire into the possibility of a role for unilateralism. I construct the model to reflect those features of the world that, in fact, have been of the most concern to policy makers. Since this is necessarily subjective to at least some degree, I shall, from time to time, pause to defend a modeling choice.

3.1. The Constituents

Assume two goods, A and B, one factor of production, labor (L), and $2N$ identical (almost) countries. Normalize $L = 1$ for each country. Everyone spends equally on the two goods. N countries have a comparative advantage in A and the other N in B. Labour productivity is αa in the comparative-advantage good and a in the other good, with $\alpha > 1$. I will examine symmetric equilibria in which each country makes the same allocation, ℓ, to the comparative advantage sector.

Assume a succession of periods. Labor is mobile between sectors across periods, but immobile within each period. Initially, each country starts with a common, historically given, tariff t on all imports and an initial state, a, of technology. The state of the world each period is indicated by (t, a), since t and a will remain common to all countries across the symmetric equilibria I consider. At the start of each period, countries differ from each other *only* in regard to which sector possesses a comparative advantage.

Technology is improving across periods. Since my topic is trade policy rather than growth, I am content to assume that this occurs at an exogenously determined rate, that is, $\Delta a/a = \beta - 1 > 0$. Technical progress, regardless of where it originates, spills over—subject to a qualification introduced below—to all countries: It constitutes an international externality.

3.2. Negotiators' Objectives

Governments may negotiate tariff reductions. I want an objective function accurately reflecting how government negotiators behave; I build on Corden's (1997, pp.74-76) description of a *conservative* social welfare function: governments avoid policies that would seriously harm any interest group. In particular, I assume that, in each period, each government's negotiators want to maximize

(1) $$\phi(\tau) = \Delta r_x(\tau) - \left[-\Delta r_m(\tau)\right]^{1+\gamma},$$

where τ denotes the rate of tariff reduction

$$\left(\frac{-\dot{t}}{1+t}\right),$$

Δr_x the negotiators' perception of the increase in the real reward of the factor specific to exports, and Δr_m the negotiators' perception of the increase in the real reward of the factor specific to imports.[6]

Appendix 2 shows that liberalization will cause $\Delta r_x > 0$ and $\Delta r_m < 0$, with a positive gain overall. So, liberalization will be desirable if either γ or the degree of liberalization is modest enough. The parameter γ measures the negotiators' averseness to allowing anyone to suffer a large loss: the *Corden sensitivity.*

3.3. Sequence of Moves within Each Period

At the start of each period, the common tariff and technology, (t, a), is inherited from the close of the previous period. The following sequence then takes place.

- First, L allocates itself among A and B. The allocations become specific for the rest of the period, so each worker decides which sector to enter based on his/her rational forecast of the real rewards that will be offered in the respective sectors during the current period.
- Second, the governments negotiate tariff reductions. These negotiations will be multilateral and feature nondiscrimination. I assume that each government, like the owners of L, does not look beyond the current period, but is forward-looking within that period.
- Third, some countries succeed in anticipating the technological improvement that will be generally realized at the end of the period: $n < N$ of the exporters of one of the goods will now have the large technology gain, $\Delta a/a = \beta - 1$, for their exportables. The identities of the good and of the specific exporters of that good that will succeed in anticipating the technological improvement is determined by a random draw (so, if

6. The results that follow would not be qualitatively affected if the objective function were over real incomes instead of over real rewards.

$\pi \equiv n/N$, then $\pi/2$ = the probability of early technical progress for each country). NB: The identity of the gainers (both which good and which countries) is determined *after* the negotiations.

- Fourth, tariff reductions are implemented and trade is realized. The latter will be described subsequently. In each country, tariff revenue is distributed to the populace in lump-sum fashion.
- Finally, the period ends, Δa is realized by all countries and both sectors for the next period, and the negotiated t becomes the initial t for the next period, when new governments will again determine policy.

I intend a period to correspond, in some rough fashion, to the time between the start of one GATT round and the start of the next. I have tried to build the simplest model I can that captures the two features that have always been paramount to those undertaking trade negotiations:

(i) The existence of divergent special interests.

(ii) Concern that any agreement might have unforeseen and unfavorable future consequences.

This is achieved by my description of within-period timing, which will be crucial to what follows. The assumption that factors are specific when negotiations take place produces the divergent interests.

The assumption that negotiations are conducted before the economic environment to which their results will apply is fully known serves to introduce the second paramount feature.[7] This point has, in fact, always been (since long before the GATT) of acute concern to policy makers. Trade agreements routinely included safeguards (then known as *escape clauses*) enabling participants to readjust their concessions should events not turn out as they had hoped. When the USA first established safeguards as a matter of law, material injury had to be due to increased imports *and* the latter had to be due to a prior trade concession. The GATT itself provided, in Article XXVIII, opportunities for the modification or withdrawal of concessions.

Introducing additional instruments could neutralize both features. Lump-sum transfers would deal with the first, and the ability to implement fully state-contingent trade agreements would do it for the latter. The absence of both instruments from my model does no violence to its realism.

4. Multilateralism

Labor allocates itself across sectors on the basis of a rational forecast of the rate of liberalization that governments will subsequently negotiate, and

7. For example, participants in prior GATT rounds had not known that Japanese automobile firms would become the most efficient producers in the late 1970s.

when those negotiations take place the allocation of labor is given. I first investigate what rate of liberalization will be negotiated for a given allocation ℓ, and then go backwards to investigate what labor, armed with an understanding of this relation between ℓ and liberalization, will actually do.

4.1. Multilateral Negotiations

What rate of tariff reduction will be negotiated? At the negotiations, governments know the allocation of resources, but they do not know which countries will be the leaders, the followers (whose exporters compete with the leaders), and the laggards (who import from the leaders) when the tariff reductions are implemented. I assume no external commitment mechanism: A government will actually implement the reduction it has agreed to only if, *ex post*, that government believes its interests will be served by doing so, taking into account credible threats of retaliation.

I assume the retaliation is tit-for-tat. That is, if Country 1 lowers its tariff 5% less than promised, its trading partners follow suit. Why tit-for-tat? The sixth stylised fact of multilateralism (*punishments for alleged violations of past agreements have consistently been commensurate with the violation, that is, tit-for-tat*) gives me little choice. When countries retaliate or threaten to retaliate against some alleged transgression by a trading partner, they consistently emphasize that the threatened retaliation is commensurate with the transgression (i.e., tit-for-tat). The WTO and the GATT before it have consistently operated on the premise that punishment should match violation. Countries have often squabbled over which tit matches what tat, or whether there was a tat in the first place, but as far as I know no country has ever challenged the principle. Given my goal of modelling countries as they actually behave, this makes the tit-for-tat assumption compelling.[8]

Note also that tit-for-tat punishment fits neatly into the present model. With the symmetric equilibria that I consider, such a threat will be well-defined.

Furthermore, the use of tit-for-tat in my model implies government behavior very much in the spirit of the Corden political support function I use. To see this, note that such a threat can support any negotiated tariff reduction which, *ex post*, every country wants to have generally adopted. However, it can support no reduction in excess of what any country regards, *ex post*, as optimal. Thus the outcome of the multilateral negotiation will be: the smallest of the various tariff reductions which, if generally adopted, would maximize *ex post* the objective functions of the respective

8. Adding a lag between deviation and retaliation would complicate the following algebra without affecting the essentials of the argument.

negotiating governments. That is, no government negotiator will be taking the risk that its import competing sector might have to take a bigger hit than that negotiator would have been willing to allow.

4.2. Negotiated Multilateral Liberalization

Let P_i and Q_i respectively denote international and domestic relative prices of B in terms of A, when the technical advance occurs first in good i, $i = A, B$. An asterisk distinguishes the country with a comparative advantage in B. Then, with t common to all countries,

$$Q_i = P_i(1+t), \qquad \frac{1}{Q_i^*} = \frac{1+t}{P_i}.$$

We have, recalling that ℓ denotes the labor allocated to the comparative-advantage sector, (see Appendix 2 for details),

$$P_A(\ell, t) = \pi(\beta - 1)\frac{\alpha\ell}{\alpha\ell + (1+t)(1-\ell)} + 1,$$

if A is the leader, and $P_i = P_B = 1/P_A$ if B is the leader. Then $P_A > 1 > P_B$.

The hypothesised spending pattern is consistent with the following indirect utility function:

$$v = Q^{-1/2} I, \tag{2}$$

where I denotes income in terms of good A. Factors are paid the values of their marginal products, so that their real rewards, using the utility function (2), are as follows, for a country with a comparative advantage in A:

$$r_x^L = \frac{\beta\alpha a}{Q_A^{1/2}}, \qquad r_x^F = \frac{\alpha a}{Q_A^{1/2}}, \qquad r_x^G = \frac{\alpha a}{Q_B^{1/2}}, \tag{3}$$

$$r_m^L = aQ_A^{1/2}, \qquad r_m^F = aQ_A^{1/2}, \qquad r_m^G = aQ_B^{1/2}, \tag{4}$$

Let

$$\tau^i = \left(\frac{-\dot{t}_i}{1+t}\right)$$

denote the rate of tariff reduction optimal *ex post* for a country that ends up in state i = L (leader), F (follower), or G (laggard). For simplicity, I consider a continuous-time approximation to the negotiated rate of tariff reduction. Then, the *ex post* value of each country's objective function reduces to

$$\phi(\tau) = -\frac{dr_x^i}{dt}(\tau) - \left[\frac{dr_m^i}{dt}(\tau)\right]^{1+\gamma},$$

where i denotes the state the country finds itself in *ex post*. If $\gamma = 0$, ϕ can be made arbitrarily large by making τ arbitrarily large: The government will want free trade at once. I will accordingly refer to the Corden sensitivity γ, which reflects the government's reluctance to let any sector experience a large hit, as the *willingness to protect*. Now

$$\frac{dr_x^L}{dt} = -\frac{\beta\alpha a}{2P_A^{1/2}}(1+t)^{-3/2} = -\frac{r_x^L}{2(1+t)},$$

and

$$\frac{dr_m^L}{dt} = -\frac{a}{2}(1+t)^{-1/2} P_A^{1/2} = -\frac{r_m^L}{2(1+t)},$$

etc. The first-order condition that τ maximize the objective function, given the value of P_i, reduces to

$$(\tau^i)^\gamma = \frac{-\left(\frac{dr_x^i}{dt}\right)}{(1+\gamma)\left(\frac{dr_m^i}{dt}\right)^{1+\gamma}(1+t)^\gamma},$$

where i = L, F, or G. Substituting yields

$$(\tau^L)^\gamma = \frac{\beta\alpha}{\left(\frac{a}{2}\right)^\gamma}\frac{Q_A^{-1-\frac{\gamma}{2}}}{1+\gamma}, \quad (\tau^F)^\gamma = \frac{\alpha}{\left(\frac{a}{2}\right)^\gamma}\frac{Q_A^{-1-\frac{\gamma}{2}}}{1+\gamma}, \quad (\tau^G)^\gamma = \frac{\alpha}{\left(\frac{a}{2}\right)^\gamma}\frac{Q_B^{-1-\frac{\gamma}{2}}}{1+\gamma}.$$

Since $\beta > 1$, $\tau^L > \tau^F$, and $Q_A > Q_B$ implies that $\tau^G > \tau^F$. Intuitively, leaders prefer a relatively liberal regime because of their technological advantage. Laggards take a hit in their import-competing sector, but this is ameliorated by a more favorable terms of trade. Followers, competing with the advantaged leaders in export markets, take the hit in their export sectors, with no terms of trade improvement.

Proposition 1. *The multilaterally negotiated rate of tariff reduction, τ^M, equals the rate most preferred, ex post, by those countries that turn out to be the followers:*

(5)
$$\tau^{\mathrm{M}} = \left[\frac{\alpha}{\left(\frac{a}{2}\right)^{\gamma}} \frac{1}{1+\gamma} \right]^{\frac{1}{\gamma}} \left[\frac{1}{P_A(1+t)} \right]^{\frac{1}{\gamma}+\frac{1}{2}}.$$

Proposition 1 in turn implies $\partial\tau^{\mathrm{M}}/\partial\gamma < 0$, $\partial\tau^{\mathrm{M}}/\partial\ell > 0$, and $\partial\tau^{\mathrm{M}}/\partial\tau < 0$. Thus,

Proposition 2. *A greater willingness to protect implies a smaller rate of tariff reduction, and the rate of tariff reduction accelerates over successive rounds.*

4.3. The Allocation of Resources

Consider next where labour, understanding the above negotiating process, will have chosen to locate. Let r_i, $i = x, m$, denote the expected quasi-rent of labour specific to sector i, where x refers to the sector in which a country has a comparative advantage. Then

(6)
$$r_i = \frac{\pi}{2} r_i^{\mathrm{L}} + \frac{1-\pi}{2} r_i^{\mathrm{F}} + \frac{1}{2} r_i^{\mathrm{G}},$$

where $r_i^{\mathrm{L}}, r_i^{\mathrm{F}}$ and r_i^{G} respectively denote the rent when the country is a technological leader, has a comparative advantage in the leading good but is not itself a leader (i.e. is a follower), and has a comparative advantage in the laggard good.[9]

The *ex post* real quasi-rents (3) and (4) imply the expected returns to the quasi-specific factors, *net* of tariff revenue:

$$r_x(P_A, t) = \frac{\alpha a}{2(1+t)^{1/2}} \left[\frac{\pi(\beta-1)+1}{P_A^{1/2}} + P_A^{1/2} \right],$$

$$r_m(P_A, t) = \frac{a}{2}(1+t)^{1/2} \left(\frac{1}{P_A^{1/2}} + P_A^{1/2} \right).$$

Here t has the value that labour expects to pertain after the subsequent negotiations: $t = t_1 - \tau^{\mathrm{M}}(1 + t_1)$, where t_1 denotes the tariff inherited from the previous period. Assume that labor allocates itself between sectors accord-

9. For example, in the early 1980s, the Japanese automobile firms, having developed 'lean' production methods, were the leaders, the high-cost European and fledgling Korean firms the followers, and the import-competing US firms the laggards.

ing to the relative expected quasi-rents. Note that $r_x(P_A, 0) > r_m(P_A, 0)$: If free trade were expected *ex ante*, no labor would allocate itself to the import competing sector. If in fact $r_m = r_x$,

$$\alpha \frac{\pi(\beta - 1) + P_A(\ell, t) + 1}{P_A(\ell, t) + 1} = 1 + t. \tag{7}$$

Let t^o solve this equation for $\ell = 1$. Then, when the forecast value of t falls at least to t^o, labour will allocate itself fully to the comparative advantage sector. I assume that, at this point, Δr_m receives zero weight in the government's objective function: Multilateral negotiations will deliver free trade.

Next, consider the responsiveness of the quasi-rents to the allocation of labor:

$$\frac{\ell}{r_x}\frac{\partial r_x}{\partial \ell} = \frac{1}{2}\frac{P_A - 1 - \pi(\beta - 1)}{P_A + 1 + \pi(\beta - 1)}\left(\frac{\ell}{P_A}\frac{dP_A}{d\ell}\right),$$

$$\frac{\ell}{r_m}\frac{\partial r_m}{\partial \ell} = \frac{1}{2}\frac{P_A - 1}{P_A + 1}\left(\frac{\ell}{P_A}\frac{dP_A}{d\ell}\right),$$

Now,

$$\frac{dP_A}{d\ell} = \frac{\partial P_A}{\partial \ell} + \left(\frac{\partial P_A}{\partial t}\right)\left(\frac{\partial t}{\partial \ell}\right) = \frac{\partial P_A}{\partial \ell} + \left(\frac{\partial P_A}{\partial t}\right)t_1\left(-\frac{\partial \tau^{M}}{\partial \ell}\right).$$

This expression is positive, by the definition of $P_A(\ell, t)$ and by Proposition 2. Thus r_m and r_x will be positively related to ℓ and r_x will increase proportionally less in response to a rise in ℓ than will r_m, so, in a neighborhood of $r_m = r_x$,

$$\frac{\partial r_x}{\partial \ell} < \frac{\partial r_m}{\partial \ell}.$$

This ensures stability of the process whereby labor allocates itself between sectors, in response to the rational forecast of t, to equilibrate the quasi-rents (see Figure 1).

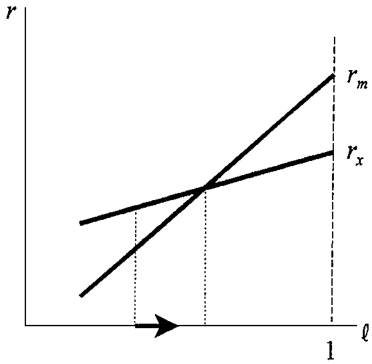

Figure 1

Proposition 3. *Suppose that t, the common tariff expected to prevail after this period's negotiations are complete, is greater than* t^o. *Then the equilibrium allocation of labour is determined by* (*7*).

Next, I investigate the implications for resource allocation of a common rate of tariff reduction. Implicit differentiation of (7) yields

$$\frac{d\ell}{dt} = \frac{\dfrac{[P_A(\ell,t)+1]^2}{\alpha\pi(\beta-1)} - \dfrac{\partial P_A}{\partial t}}{\dfrac{\partial P_A}{\partial t}} < 0,$$

by definition of $P_A(\ell, t)$.

Geometrically, the expectation of liberalization in the negotiations to come shifts the *ex ante* r_m schedule down and the *ex ante* r_x schedule up, implying that the equilibrium ℓ rises. When the expected tariff falls as low as t^o, it instantaneously falls to zero. All labor allocates itself to the comparative advantage sector.

The theory of gradual multilateral liberalization developed in this section can be interpreted as based on time inconsistency. Labour allocates itself to the comparative-disadvantage sector because it knows that, once it is allocated there, the government will not negotiate protection away. Could the government credibly commit to free trade, no labor would enter the comparative-disadvantage sector. Thus there would exist no interest opposed to free trade. Staiger and Tabellini (1987) provide a related analysis.

5. Unilateralism

The rate of multilateral tariff reduction is limited to the lowest reduction any country would prefer *ex post*. Perhaps, as Bagwell and Staiger (1990) argued in another context, a system of unilateralism can improve on this. Would such a system be developed and used? What would it look like? The following subsection argues intuitively what properties such a system should have to produce affirmative answers, and this is followed by a formal analysis.

5.1. The Potential for Unilateralism

Suppose countries establish, before some negotiating round, a rule stipulating circumstances under which, *after* the completion of negotiations and *after* the revelation of which goods and countries are the technological leaders, protection might be granted to beleaguered import-competing interests. Since the purpose is to preserve, at least partly, an outcome for special interests in the face of unanticipated developments, they should be either quantitative or sufficiently nimble in execution that it does not matter whether they are quantitative (i.e., tariff-quota equivalence).

The countries that turn out to be laggards could *ex post* apply such a rule. Would they wish to do so? Clearly they would not if they were confident that this would prompt retaliation: This would be a roll-back of the negotiated tariff reductions which are already less than what the laggards want *ex post*. So, would the leaders retaliate? Such a roll-back would move the common tariff reduction even further from what the leaders would want. Still, if the laggards unilaterally increase protection, the leaders are likely to retaliate. Unilateral protection would be *concession reneging*: Since the leaders do not receive all the market access they had bargained for, they will not want to grant all the access they have promised. If everyone realises the leaders will retaliate, such a rule would be of no value. It would be neither instituted nor used, *unless* the rule eliminates the motive to retaliate.

To make concession reneging acceptable, the rule could *compensate* the leaders. They need not be fully compensated, just enough so that they do not forsake the compensation by retaliating instead. Allowing them the trade rents generated by the unilateral measures would contribute to this. There may be a second source of compensation as well: a greater common tariff reduction, if unilateralism allows that to be negotiated.

To see when that might happen, consider the followers. They end up competing, at a disadvantage, with the leaders in the import markets of the laggards. The rents associated with unilateral protection would be worth much less to the followers, with no cost reductions, than to the leaders. Also, they would not gain from any increase in tariff reduction. So, prospects are dim that these countries would be compensated enough to forestall retaliation. More important, since the followers' preferences determine the rate of common tariff reduction, no increase would in fact take place; indeed, that rate may well decrease. Thus the whole case for unilateralism will unravel unless the interests of the followers are addressed. For this reason, the unilateral measures should be *discriminatory*. If they apply to the leaders but not to the followers, the latter would have nothing to retaliate against. The unilateral measures would, instead, enhance the ability of the followers to compete in the markets of the laggards. Consequently, they would now prefer a greater common rate of tariff reduction: the negotiated tariff reduction should increase.

The above argument assigns leaders, followers, and laggards distinct roles in the exercise of unilateralism, but the identification of these countries is fixed only for the current period. Thus the unilateral measures should be *temporary*—for the rest of the current period only.

Hypothesis. *Multilateralism may induce the introduction of tools of temporary unilateral protection that are quantitative, discriminatory, and give compensation to restrained exporters. Such an introduction might accelerate the rate of multilateral tariff reduction.*

Note that four of the five stylised facts of unilateralism have been utilised. I now turn to a formal analysis.

5.2. A Model of Unilateralism

I now model unilateralism as a rule allowing laggard countries, after the realisation of the technology draw, to apply temporary (i.e., for the rest of the current period only) quantitative restraints on imports from the leaders, allowing the latter the resulting trade rents. Let ρ denote the (randomly selected) fraction of the leaders whose imports will be restrained by all laggards. I treat ρ as exogenous and use it to index the *breadth* of unilateralism. Restrained leaders can export only $X_{RL} = \delta X_F + (1 - \delta)X_{UL}$, where X_F denotes the volume exported by followers and X_{UL} that exported by unrestrained leaders. The parameter $\delta (0 \leq \delta \leq 1)$, also exogenous, will index the *intensity* of unilateralism. This model reflects the properties both argued for in the previous subsection and described in Section 2.

Suppose the leaders have a comparative advantage in A. Then, with the assumed tastes, *followers* will be in equilibrium when

$$Q_A\left(B + \frac{X_F}{P_A}\right) = A - X_F. \tag{8}$$

Equilibrium for the *unrestrained leaders* requires

$$Q_A\left(B + \frac{X_{UL}}{P_A}\right) = A_L - X_{UL}, \tag{9}$$

where X_{UL} denotes exports of the unrestrained leaders and A_L production by the leaders of good A. For the *restrained leaders*

$$Q_A^{RL}\left(B + \frac{X_{RL}}{P_A}\right) = A_L - X_{RL}, \tag{10}$$

where Q_A^{RL} denotes the relative domestic price of imports for the restrained leaders. From (9) and (10), $X_{UL} > X_{RL}$, which implies that $Q_A^{RL} > Q_A$. X denotes the average level of A exports

$$X = (1-\pi)\,X_F + \rho\pi X_{RL} + (1-\rho)\,\pi X_{UL} = [1 - \pi(1-\rho\delta)]\,X_F + \pi(1-\rho\delta)\,X_{UL}.$$

Finally, for the *laggards,*

$$Q_A^*\left(B^* - \frac{X}{P_A}\right) = A^* + X.$$

Now, (8) and (9) imply

$$Q_A\left(B + \frac{X}{P_A}\right) = \tilde{A} - X,$$

where $\tilde{A} = [1 - \pi(1 - \rho\delta)]A + \pi(1 - \rho\delta)A_L$. From this and the above,

$$P_A(\ell, t; \rho, \delta) = \frac{\tilde{A} + (1+t)A^*}{B^* + (1+t)B},$$

so that $\partial P_A / \partial\rho,\ \partial Q_A / \partial\rho,\ \partial P_A / \partial\delta,\ \partial Q_A / \partial\delta < 0$.

Also,

$$X = \frac{\tilde{A}B^* + (1+t)^2 A^* B}{(2+t)\left[B^* + (1+t)B\right]}.$$

Furthermore, (8) and (9) imply

$$X_{UL} - X_F = \frac{A_L - A}{2+t},$$

while (8) and (10) give

(11) $$Q_A^{RL} = Q_A \frac{A_L - X_{RL}}{\hat{A} - X_{RL}},$$

where $\hat{A} = \delta A + (1-\delta)A_L$.

5.3. The Followers

Suppose that the breadth ρ of unilateralism is raised above zero, with δ fixed at some positive level. I now investigate whether, as expected, this will improve the fate of the countries that turn out to be followers by reducing competition in their export markets from the leaders. For a given common tariff t and rate of tariff reduction τ, the value of the objective function of each follower government will be

$$\phi(\tau) = \frac{\alpha a}{2} Q_A^{-1/2}\tau - \left(\frac{a}{2} Q_A^{1/2}\tau\right)^{1+\gamma}.$$

Each government, realizing its country is small, takes P_A as independent of its own actions, but this common value will be affected by the increase in ρ. Consider the marginal effect on the ϕ of each follower government of increasing ρ *after* τ has been implemented.

$$\left.\frac{\partial \phi^{\mathrm{F}}}{\partial \rho}\right|_{\tau} = -\frac{\frac{\rho}{Q_A}\frac{\partial Q_A}{\partial \rho}}{2\rho}\left[\frac{\alpha a}{2}\frac{1}{Q_A^{1/2}} + (1+\gamma)\left(\frac{a}{2}Q_A^{1/2}\right)^{1+\gamma}\frac{1}{\tau}\right]. \tag{12}$$

Then, since $\partial Q_A/\partial \rho < 0$, an increase in ρ will always raise the ϕ of each follower government, at any τ. So these governments would welcome the exercise of unilateralism, and they would prefer its breadth to be comprehensive ($\rho = 1$) and its intensity complete ($\delta = 1$). Furthermore, it follows from (5) that $\partial \tau^{\mathrm{M}}/\partial \rho > 0$, $\partial t^{\mathrm{M}}/\partial \delta > 0$, implying that a system of unilateralism will cause the negotiated liberalisation rate to increase and that the increase will be greater the greater the breadth and intensity of unilateralism.

Proposition 4. *If unilateralism without retaliation is introduced, the negotiated rate of liberalisation will increase, the governments of the countries that turn out to be followers will be better off, and these governments would wish unilateralism to be comprehensive and complete (which would also maximize the rate of liberalisation).*

5.4. The Unrestrained Leaders

I next investigate whether, as expected, the increase in ρ would benefit unrestrained leaders. Again, there are no surprises. For a given common t and rate of tariff reduction τ, the value of the objective function of each unrestrained leader government will be

$$\phi^{\mathrm{UL}} = \frac{\beta \alpha a}{2} Q_A^{-1/2}\tau - \left(\frac{a}{2}Q_A^{1/2}\tau\right)^{1+\gamma}.$$

So,

$$\frac{\mathrm{d}\phi^{\mathrm{UL}}}{\mathrm{d}\rho} = -\frac{\frac{\rho}{Q_A}\frac{\partial Q_A}{\partial \rho}}{2\rho}\left[\frac{\beta\alpha a}{2}\frac{1}{Q_A^{1/2}} + (1+\gamma)\left(\frac{a}{2}Q_A^{1/2}\tau^{\mathrm{M}}\right)^{1+\gamma}\frac{1}{\tau^{\mathrm{M}}}\right] + \frac{\partial \phi^{\mathrm{UL}}}{\partial \tau}\frac{\partial \tau^{\mathrm{M}}}{\partial \rho}. \tag{13}$$

The first term on the right-hand side of (13), which I call the *protective effect,* measures the gain to each unrestrained leader from decreased competition in export markets; this is similar to the right-hand side of (12) but larger, since $\beta > 1$. The second term, the *liberalising effect*, measures the effect on unrestrained leaders of the change in the negotiated tariff reduction implied by the increase in ρ. Since the negotiated rate of tariff reduction is always less than what the unrestrained leaders wish *ex post*, $\partial\phi^{\mathrm{UL}}/\partial\tau > 0$, and the previous subsection showed that $\partial\tau^{\mathrm{M}}/\partial\rho > 0$. Thus an increase in ρ will raise the ϕ of each unrestrained leader government via *both* effects. It would welcome unilateralism, and also prefers to be the only unrestrained leader (that is, that $\rho = (n-1)/n$), and to have the intensity of unilateralism complete.

Proposition 5. *If unilateralism without retaliation is introduced, the governments of the unrestrained leaders will be better off, and these governments will wish complete intensity and as few other unrestrained leaders as possible.*

5.5. The Restrained Leaders

The national income of restrained leaders, at domestic prices, equals

$$Q_A^{\mathrm{RL}}\left(B+\frac{X_{\mathrm{F}}}{P_A}\right)+A_{\mathrm{L}}-X_{\mathrm{F}}=(A_{\mathrm{L}}+Q_A^{\mathrm{RL}}B)+(tX_{\mathrm{F}})+\left(\frac{Q_A^{\mathrm{RL}}-Q_A}{P_A}X_{\mathrm{F}}\right).$$

The first term on the right is the value of production, paid to the workers as wages. The second term equals total tariff revenue, distributed in lump-sum fashion. The third term, which I denote below by R^{RL}, is the rent generated by the restraints, and I assume that this accrues to the export sector. Then the *ex-post* reward of labor employed in the export sector of the restrained leaders is

$$r_x^{\mathrm{RL}}=\left(Q_A^{\mathrm{RL}}\right)^{-1/2}\left(\frac{A_{\mathrm{L}}}{\ell}+\frac{R^{\mathrm{RL}}}{\ell}\right), \tag{14}$$

and labour in the import-competing sector will earn

$$r_m^{\mathrm{RL}}=a(Q_A^{\mathrm{RL}})^{1/2}. \tag{15}$$

After some manipulation, (14) and (15) yield

$$\frac{1+t}{r_x^{\mathrm{RL}}}\frac{\mathrm{d}r_x^{\mathrm{RL}}}{\mathrm{d}t}=-\frac{1}{2}\left(\frac{1+t}{Q_A^{\mathrm{RL}}}\frac{\mathrm{d}Q_A^{\mathrm{RL}}}{\mathrm{d}t}\right)+\frac{R^{\mathrm{RL}}}{A_{\mathrm{L}}+R^{\mathrm{RL}}}\left(\frac{1+t}{R^{\mathrm{RL}}}\frac{\mathrm{d}R^{\mathrm{RL}}}{\mathrm{d}t}\right)<0,$$

and

$$\frac{1+t}{r_m^{\mathrm{RL}}}\frac{\mathrm{d}r_m^{\mathrm{RL}}}{\mathrm{d}t}=-\frac{1}{2}\left(\frac{1+t}{Q_A^{\mathrm{RL}}}\frac{\mathrm{d}Q_A^{\mathrm{RL}}}{\mathrm{d}t}\right)>0.$$

Suppose that initially $\delta = 0$, with ρ set at some arbitrary positive value: unilateralism has no intensity. So the objective function of restrained leaders initially equals that of unrestrained leaders: $\phi^{\mathrm{RL}} = \phi^{\mathrm{UL}}$. Then consider the effect of $\mathrm{d}\delta > 0$ on the restrained leaders; denote this increment, in the absence of retaliation, by $\partial\phi^{\mathrm{RL}}/\partial\delta$. I assume that, should these (now effectively) restrained leaders retaliate, the laggards convert their unilateral measures into conventional (nondiscriminatory) tariffs, allowing themselves to appropriate R^{RL}, that is, unilateralism plus retaliation is equivalent[10] to a reduction in the rate of liberalisation τ. The incremental effect is accordingly

$$-\left.\frac{\partial\phi^{\mathrm{RL}}}{\partial\tau}\right|_{\delta=0,\tau=\tau^{\mathrm{M}}} = -\left.\frac{\partial\phi^{\mathrm{UL}}}{\partial\tau}\right|_{\tau=\tau^{\mathrm{M}}}.$$

Thus the restrained leaders will find retaliation tempting only if

$$\left.\frac{\partial\phi^{\mathrm{RL}}}{\partial\delta}\right|_{\delta=0} < -\left.\frac{\partial\phi^{\mathrm{UL}}}{\partial\tau}\right|_{\tau=\tau^{\mathrm{M}}}. \tag{16}$$

Now

$$\left.\frac{\partial\phi^{\mathrm{RL}}}{\partial\delta}\right|_{\delta|=0} = \frac{\mathrm{d}r_x^{\mathrm{RL}}}{\mathrm{d}\delta} + (1+\gamma)\left(\frac{a}{2}Q_A^{1/2}\tau^{\mathrm{M}}\right)^{\gamma}\frac{\mathrm{d}r_m^{\mathrm{RL}}}{\mathrm{d}\delta} + \frac{\partial\phi^{\mathrm{RL}}}{\partial\tau}\frac{\partial\tau}{\partial\delta}.$$

The effect of a marginal restraint on the return to labor in the export sector is

$$\left.\frac{\mathrm{d}r_x^{\mathrm{RL}}}{\mathrm{d}\delta}\right|_{\delta=0} = -\frac{1}{2}\frac{r_x^{\mathrm{RL}}}{Q_A}\left.\frac{\partial Q_A^{\mathrm{RL}}}{\partial\delta}\right|_{\delta=0} + Q_A^{-1/2}\frac{1}{\ell}\left.\frac{\partial R^{\mathrm{RL}}}{\partial\delta}\right|_{\delta=0}.$$

The first term on the right is the direct effect of the export restriction and the second term is the compensating emergence of trade rent. From (11),

$$\left.\frac{\partial Q_A^{\mathrm{RL}}}{\partial\delta}\right|_{\delta=0} = Q_A\frac{A_{\mathrm{L}} - A}{A_{\mathrm{L}} - X_{\mathrm{UL}}} + \frac{\partial Q_A}{\partial\delta},$$

10. Alternatively, the laggards might convert their unilateral measures into conventional tariffs that apply only to the products of the restrained leaders, i.e., that discriminate. But I will not consider this possibility as it would presumably make retaliation even more likely.

and from the definition of R^{RL},

$$\left.\frac{\partial R_A^{\mathrm{RL}}}{\partial \delta}\right|_{\delta=0} = \left(\left.\frac{\partial Q_A^{\mathrm{RL}}}{\partial \delta}\right|_{\delta=0} - \frac{\partial Q_A}{\partial \delta}\right)\frac{X_{\mathrm{UL}}}{P} = (1+t)X_{\mathrm{UL}}\frac{A_{\mathrm{L}} - A}{A_{\mathrm{L}} - X_{\mathrm{UL}}} > 0.$$

Then the net effect on the real reward of labor in the export sector reduces to

$$\left.\frac{\partial r_x^{\mathrm{RL}}}{\partial \delta}\right|_{\delta=0} = \frac{A_{\mathrm{L}} - A}{A_{\mathrm{L}} - X_{\mathrm{UL}}}\frac{Q_A^{-1/2}}{\ell}\left[(1+t)X_{\mathrm{UL}} - \frac{1}{2}A_{\mathrm{L}}\right].$$

This will be positive if the term in brackets is positive: a large enough initial export position will generate enough rent to compensate fully for the restrictions. Next, the effect on labor in the import-competing sector reduces to

$$\left.\frac{\partial r_m^{\mathrm{RL}}}{\partial \delta}\right|_{\delta=0} = \frac{1}{2}r_m^{\mathrm{RL}}\frac{A_{\mathrm{L}} - A}{A_{\mathrm{L}} - X_{\mathrm{UL}}}\left[\frac{(1-\pi)A + \pi(1-\rho)A_{\mathrm{L}} + (1+t)A^* + \pi\rho X_{\mathrm{UL}}}{(1-\pi)A + \pi A_{\mathrm{L}} + (1+t)A^*}\right].$$

So, labour in the import-competing sector benefits from unilateralism at a sufficiently small intensity. The overall effect on the objective function of the negotiators of restrained leaders is then

$$\frac{A_{\mathrm{L}} - X_{\mathrm{UL}}}{A_{\mathrm{L}} - A}\left.\frac{\partial \phi^{\mathrm{RL}}}{\partial \delta}\right|_{\delta=0} = Q_A^{-1/2}(1+t)\frac{X_{\mathrm{UL}}}{\rho} + \left.\frac{\partial \phi^{\mathrm{UL}}}{\partial \tau}\right|_{\tau=\tau^{\mathrm{M}}}\left(\frac{A_{\mathrm{L}} - X_{\mathrm{UL}}}{A_{\mathrm{L}} - A}\frac{\partial \tau}{\partial \delta} + 1\right) + (2+\gamma)\left(\frac{a}{2}Q_A^{1/2}\tau^{\mathrm{M}}\right)^{1+\gamma}$$
$$\times\frac{1}{\tau^{\mathrm{M}}}\frac{(1-\pi)A + \pi(1-\rho)A_{\mathrm{L}} + (1+t)A^* + \pi\rho X_{\mathrm{UL}}}{(1-\pi)A + \pi A_{\mathrm{L}} + (1+t)A^*} > 0.$$

Each of the three terms on the right is positive. Thus, as long as δ is sufficiently small, leaders will not only not be tempted to retaliate, they will also perceive the exercise of unilateralism as beneficial, according to the government negotiators' objective function.

Proposition 6. *Unilateralism, at any breadth, will necessarily be perceived as beneficial by the governments of restrained leaders, if the intensity is small enough.*

5.6. The Laggards

The value of the laggards' negotiators' objective function is

$$\phi^{\mathrm{G}} = \frac{1}{2}r_x^{\mathrm{G}}\tau^{\mathrm{M}} - \left(\frac{1}{2}r_m^{\mathrm{G}}\tau^{\mathrm{M}}\right)^{1+\gamma}.$$

But, since the laggards would potentially implement unilateralism, I now need to specify the objective function of the bureaucrats who would administer it. The fifth stylised fact of unilateralism (*The restrictions are designed by officials distinct from those who negotiate international trade agreements*) now becomes relevant. I accordingly allow administrators an objective function that, although of the same form as the negotiators' (1), has its own willingness to protect, μ. Thus the value of the laggards' administrators' objective function is now

$$\phi_A^{\mathrm{G}} = \frac{1}{2} r_x^{\mathrm{G}} \tau^{\mathrm{M}} - \left(\frac{1}{2} r_m^{\mathrm{G}} \tau^{\mathrm{M}} \right)^{1+\mu}.$$

Perhaps the easiest way to assess the importance of allowing administrators a distinct objective function of their own is to suppose initially that they do not have one and deduce the implications. So I initially suppose that $\mu = \gamma$ and, therefore, $\phi_A^{\mathrm{G}} = \phi^{\mathrm{G}}$.

The total marginal effect on ϕ^{G} of raising ρ above zero, assuming no retaliation, is

$$\frac{\mathrm{d}\phi^{\mathrm{G}}}{\mathrm{d}\rho} = \frac{\partial \phi^{\mathrm{G}}}{\partial \rho} + \frac{\partial \phi^{\mathrm{G}}}{\partial \tau} \frac{\mathrm{d}\tau^{\mathrm{M}}}{\mathrm{d}\rho},$$

where the first term on the right indicates the direct protective effect and the second the indirect liberalizing effect. Now,

$$\begin{aligned} \frac{\partial \phi^{\mathrm{G}}}{\partial \rho} &= \frac{\partial r_x^{\mathrm{G}}}{\partial \rho} + (1+\mu) \left[\frac{\partial r_m^{\mathrm{G}}}{\partial t} \tau^{\mathrm{M}} (1+t) \right]^{\mu} \frac{\partial r_m^{\mathrm{G}}}{\partial \rho} \\ &= \left\{ \frac{\partial r_x^{\mathrm{G}}}{\partial t} (1+t) + (1+\mu) \left[\frac{\partial r_m^{\mathrm{G}}}{\partial t} \tau^{\mathrm{M}} (1+t) \right]^{\mu} \frac{\partial r_m^{\mathrm{G}}}{\partial t} (1+t) \right\} \frac{1}{Q_A} \frac{\partial Q_A}{\partial \rho} = \frac{\partial \phi^{\mathrm{G}}}{\partial \tau} \frac{1}{Q_A} \frac{\partial Q_A}{\partial \rho}. \end{aligned} \tag{17}$$

The negotiated liberalization rate τ^{M} is less than what the laggards' negotiators most prefer *ex post*, if $\mu = \gamma$. Thus $\partial \phi^{\mathrm{G}} / \partial \tau > 0$, which implies that $\partial \phi^{\mathrm{G}} / \partial \rho > 0$. Since a higher rate of liberalisation is perceived as beneficial, a change in the welfare of exporters must, on the margin, dominate the accompanying change in the welfare of import-competitors.

But the indirect liberalising effect will be beneficial, again with $\mu = \gamma$. Thus unilateralism will, on balance, benefit the governments of laggards when the latter effect dominates, which will be so when

$$\frac{\mathrm{d}\phi^{\mathrm{G}}}{\mathrm{d}\rho} = \left(\frac{\partial \tau^{\mathrm{M}}}{\partial \rho} + \frac{1}{Q_A} \frac{\partial Q_A}{\partial \rho} \right) \frac{\partial \phi^{\mathrm{G}}}{\partial \tau} > 0,$$

which, in turn, will hold if and only if

$$\tau^{\mathrm{M}} > \frac{1}{1/\mu + 1/2}.$$

The right-hand side is strictly increasing in μ and τ^{M} and decreases in γ, ranging from infinity to zero. Thus, with μ constrained equal to γ, there exists a unique γ° with the property that unilateralism confers a net benefit on the laggards if and only if $\gamma < \gamma^{\circ}$.

But this is not all. Suppose that $\gamma < \gamma^{\circ}$ and that governments commit themselves to practice unilateralism should they become laggards. Whenever a country is a laggard, it then shoots itself in the foot, but this benefits all non-laggard countries, raising the rate of liberalisation. If γ is sufficiently close to γ°, the loss when a laggard will be dominated by the gain when not a laggard, so that, *ex ante*, every country is better off.

Proposition 7. *If $\mu = \gamma$ is not sufficiently greater than γ°, all countries can benefit ex ante, according to the objective function (1), if each country adopts unilateralism at some intensity. This will raise the rate of liberalisation.*

6. Implications of Unilateralism

The section examines the consequences for the international economy of a system of unilateralism.

6.1. The Effect of Unilateralism on Resource Allocation

The previous section examined the effect of unilateralism for a given pattern of resource allocation ℓ. However, if unilateralism exists, forward-looking labor will take into account when deciding where to locate. With a system of unilateralism in place, the real *ex-post* quasi-rents become as follows, for a country with a comparative advantage in *A*:

$$(18) \qquad r_x^{\mathrm{URL}} = \frac{\beta\alpha a}{Q_A^{1/2}}, \qquad r_x^{\mathrm{RL}} = \frac{\beta\alpha a}{(Q_A^{\mathrm{RL}})^{1/2}}, \qquad r_x^{\mathrm{F}} = \frac{\alpha a}{Q_A^{1/2}}, \qquad r_x^{\mathrm{G}} = \frac{\alpha a}{Q_B^{1/2}},$$

$$(19) \qquad r_m^{\mathrm{URL}} = aQ_A^{1/2}, \qquad r_m^{\mathrm{RL}} = a\left(Q_A^{\mathrm{RL}}\right)^{1/2}, \qquad r_m^{\mathrm{F}} = aQ_A^{1/2}, \qquad r_m^{\mathrm{G}} = aQ_B^{1/2},$$

and the expected returns accordingly become

$$(20) \qquad r_i\,(\ell;t,\rho,\delta) = \frac{(1-\rho)\pi}{2} r_i^{\mathrm{URL}} + \frac{\rho\pi}{2} r_i^{\mathrm{RL}} + \frac{1-\pi}{2} r_i^{\mathrm{F}} + \frac{1}{2} r_i^{\mathrm{G}},$$

for $i = x, m$. Here t denotes the common tariff rate expected (correctly) to prevail after the current round of negotiations—that is, $t = t_1 - \tau^{\mathrm{M}} (1 + t_1)$, where t_1 denotes the tariff inherited from the previous period—and ρ and δ denote the parameters of the system of unilateralism that is in place or expected (correctly) to be put in place. Given the values of these policy variables, the allocation of resources is determined by

$$r_x(\ell; t, \rho, \delta) = r_m(\ell; t, \rho, \delta).$$

Differentiate this expression implicitly to determine the effect of an increase in the intensity of unilateralism on the *ex-ante* allocation of resources.

$$\frac{\mathrm{d}\ell}{\mathrm{d}\delta} = \frac{\left(\frac{\partial r_x}{\partial \delta} - \frac{\partial r_m}{\partial \delta}\right)}{\frac{\partial r_m}{\partial \ell} - \frac{\partial r_x}{\partial \ell}} + \frac{\left(\frac{\partial r_x}{\partial t} - \frac{\partial r_m}{\partial t}\right)}{\frac{\partial r_m}{\partial \ell} - \frac{\partial r_x}{\partial \ell}} t_1 \frac{\partial \tau}{\partial \delta}.$$

The first term on the right is the direct effect of unilateralism on resource allocation, and the second term is the indirect effect due to the fact that the existence of unilateralism will alter the liberalisation expected (correctly) to be negotiated. Consider a differential increase of δ above zero, i.e. the introduction of unilateralism at an arbitrarily low intensity. Then, the discussion in Section 4 establishes that the denominators and the first bracketed term in the numerator of the second term on the right are each positive, and Proposition 7 establishes that $\partial \tau / \partial \delta > 0$. Thus the indirect effect is positive. So, consider the numerator of the first term on the right, the direct effect.

$$\frac{\partial r_x}{\partial \delta} - \frac{\partial r_m}{\partial \delta} = \frac{\rho \pi}{2}\left(\frac{\partial r_x^{\mathrm{RL}}}{\partial \delta} - \frac{\partial r_m^{\mathrm{RL}}}{\partial \delta}\right) + \left(-\frac{\partial Q_A}{\partial \delta}\right)\frac{a}{4} Q_A^{-1/2}$$
$$\times \left\{\alpha\left[(\beta - 1)\pi(1-\rho) + (1-\rho\pi)\right]Q_A - \frac{\alpha}{1+t} + (1-\rho) - \frac{1+t}{Q_A}\right\}.$$

Since $Q_A > 1$ and $\partial Q_A / \partial \delta < 0$, a sufficiently small value of ρ will guarantee that this term is positive: the direct effect of unilateralism, as well as the indirect effect, will be to reallocate resources toward the comparative advantage sector.

Proposition 8. *The introduction of unilateralism at a sufficiently small intensity and breadth will induce an increased allocation of labour to the comparative advantage sectors.*

6.2. The Insurance Triangle

Note two curious features of how unilateralism functions. First, unilateralism is appealing to governments if their willingness to protect (γ) is *low*, not high. This is because a lower willingness to protect produces a greater beneficial liberalising effect.

Second, unilateralism functions as a form of insurance. Unlike the literature on tariffs-as-insurance (Eaton and Grossman, 1985; Dixit 1987; 1989) though, the role for insurance is itself a product of a positive willingness to protect, and its value is not that a laggard government *itself* have something to fall back on (*ex post* such a government would prefer not to implement it—see below) but rather that its effect on *others* allows all to negotiate a greater rate of liberalisation.[11] Countries know that, should they turn out to be followers (the most reluctant liberalisers), their interests will be safeguarded by the efforts of the laggards to protect their own import-competing interests, and that these efforts will be acceptable to the leaders.[12] This cannot be appreciated in a two-country model. The insurance functions through a subtle interplay between all three groups: the *insurance triangle.*

If this is how unilateralism works, could it not take the form of export subsidies by followers, either instead of or along with, import protection by laggards? An answer will emerge below.

6.3. The Split Personality

The analysis thus far in this section, culminating in Propositions 7 and 8, has focused on the possibility that multilateralism might imply a role for unilateralism: causation has been from the former to the latter. But unilateralism, to be effective, also requires a multilateral component. This is because Proposition 7, by itself, does not get us far enough. The reason, in part, is time consistency.

Unilateralism will be effective only if countries choose to implement it when they become laggards. They benefit only when the beneficial indirect liberalising effect dominates the harmful protective effect. However, the former will be past history when the laggards decide whether to implement unilateralism. Thus the laggard governments, according to the negotiators' objective function, will decline to implement unilateralism *ex post.*

This time-consistency problem is compounded—and this is absolutely

11. There is a (very rough) analogy here with the role for trade adjustment assistance advanced by Fung and Staiger (1996).

12. Thus, in the early 1980s, the US automobile industry (laggards) acquired protection acceptable to the Japanese industry (leaders) and beneficial to the Europeans and Koreans (followers).

essential—by an *externality*. Governments with the objective function (1) would like, if $\gamma < \gamma^{\circ}$, to convince each other that they will practice unilateralism when they turn out to be laggards, because this would produce a higher rate of tariff reduction, to the *ex ante* benefit of all. However, all know that, *ex post*, the government of a laggard with the objective function (1) would not implement unilateralism. What if governments can pre-commit to implement unilateralism should they become laggards? Because the time consistency problem is compounded by an externality, no government would undertake such a pre-commitment *unilaterally*: The beneficial liberalising effect depends on a *general* adoption of unilateralism.

Proposition 9. *The introduction of unilateralism (raising ρ above zero) will have no effect, if implemented by authorities who have discretion and who set $\mu = \gamma$, because they will always decline ex post to implement it. Furthermore, no government negotiator with $\mu = \gamma$ would be willing unilaterally to delegate authority to implement unilateralism ex post to some other agent.*

Potentially, there are two ways around this problem, and both require a multilateral component to unilateralism. The first is simply to internalise the externality by having the countries *jointly* adopt binding unilateralism. That is, the latter could itself be the product of multilateral negotiation. (Or they might jointly bind themselves to subsidise exports whenever they turn out to be followers).

This does not correspond to reality, though: The fifth stylised fact of unilateralism (*The restrictions are designed by officials distinct from those who negotiate international trade agreements*) is at variance with this possibility. So consider instead the consequences of countries individually adopting unilateralism systems with $\mu \neq \gamma$. Let $\tau_A^G(\mu)$ denote the rate of liberalisation that is optimal, *ex post,* for administrators with a willingness to protect of μ, in a country that turns out to be a laggard.

Define $\mu(\gamma)$ to be the solution to

$$\tau_A^G[\mu(\gamma)] = \tau^M(\gamma).$$

Propositions 1 and 2 imply that $\mu(\gamma) > \gamma$. Further, Proposition 2 implies that, if $\mu \geq \mu(\gamma)$, the negotiated rate of liberalisation will be no less than what the laggard administrators most prefer *ex post*. Thus, from (17) $\partial\phi_A^G/\partial\tau < 0$, whence $\partial\phi_A^G/\partial\rho < 0$. Therefore, the administrators will indeed implement unilateralism when their countries turn out to be laggards: The time consistency problem disappears.

Proposition 10. *If $\mu \geq \mu(\gamma) > \gamma$, laggards will implement unilateralism and, at some intensity, this will benefit all other countries; if μ is suffi-*

ciently small, this will also benefit the laggards, according to the objective function (1).

Four comments are in order.

- For unilateralism to work, the willingness to protect of the administrators must not merely marginally exceed that of the negotiators, it must *significantly* exceed the latter.
- This is *not* an example of individual countries strengthening the bargaining positions of their negotiators by pre-committing to *ex post* action. The benefit of unilateralism to an individual country comes from the assurance that all *other* countries will practice it when they are laggards. Regardless of how forward-looking they may be, the negotiators of *no* country will wish their own country to adopt such a system of unilateralism. The fifth stylised fact of unilateralism (*The restrictions are designed by officials distinct from those who negotiate international trade agreements*) is absolutely critical here.
- The higher rate of liberalisation will be perceived as undesirable by the administrators, and, if μ is significantly great, this undesirable indirect effect from introducing a small ρ will necessarily overwhelm the direct protective effect: Unilateralism will be on the whole undesirable from the administrators' point of view. However, this has no effect on feasibility, because the liberalising effect will be past history when the administrators are called on to act. That is, such unilateralism will be time consistent.
- With unilateralism in place, there is no longer a possibility of subsidising the exports of followers, since any such subsidies would be neutralised by the laggards.[13]

6.4. The Compatibility Problem

If the restrictions must be designed by officials distinct from those who negotiate international trade agreements, can we be assured that the systems of unilateralism they adopt will possess the desired properties (i.e. the other stylised facts)? Since these officials would prefer unilateralism without complete retaliation rather than with it, and since Propositions 4, 5 and 6 continue to apply, the logic of this section, offering an explanation for those stylised facts, also continues to apply: the desired properties should be there. However, there is no reason to think that either the breadth, ρ, or the intensity, δ, of the unilateralism the officials provide will be desirable from the negotiators' point of view.

This is the *compatibility problem*: if unilateralism is not a deliberate multilateral creation (and, in fact, it is not) then it can be useful to the ne-

13. Countervailing duties, of course, do just that.

gotiators only if imposed by officials whose objectives are significantly at odds with those of the negotiators.

Once systems become common, they could be perceived as of potential benefit by government negotiators meeting together, even though no negotiator would have been willing to adopt such a system individually. An immediate implication of the compatibility problem (also in accord with actual experience) is that these negotiators have an incentive to expand multilateral negotiations to address the conduct of unilateralism.

Proposition 11. *Government negotiators will, together, have an incentive to accept unilateralism but also to include codes of conduct for it in their multilateral negotiations.*

7. Concluding Remarks

I have argued that unilateralism and multilateralism comprise a coherent international commercial system.

I have reduced each of these to a few basic principles, and discussed how they relate to each other. The essential argument follows.

- Multilaterally negotiated tariff reduction is limited by the smallest reduction any country will want *ex post*: that most advantageous to those countries who compete with the exports of the technological leaders.
- This pace can be accelerated, and the allocation of resources to the comparative advantage sectors can be increased, if those countries that import the exports of the technological leaders make universal use of temporary, quantitative, discriminatory protection compensating restricted exporters.
- Such unilateralism works by conferring a form of social insurance resulting from a subtle interplay between three distinct sets of countries: the *insurance triangle.*
- The use of such a system is constrained by a time—consistency problem *compounded by an externality.*
- With unilateralism adopted by countries individually rather than collectively, to be useful, it must be designed by officials significantly more willing to protect than are the negotiators themselves, who would be unwilling to delegate such authority: trade policy needs its 'split personality'.
- This *compatibility problem* implies an incentive to address the conduct of unilateralism multilaterally.

This theory of unilateralism depends critically on the existence of a multilateral world. The key concepts—the insurance triangle, time-consistency compounded by an externality, the necessity of a split personality, the compatibility problem—cannot be understood at all in a two-country environment.

The process of multilateral trade liberalisation generates a potential motive for protectionist policy tools with exactly those properties that I have argued do in fact constitute contemporary unilateralism. This in turn requires—again in accord with actual experience—a multilateral component. It all fits together.

Appendix 1: Instruments of Unilateralism

Unilateralism consists of rules, or instruments, that may be explicit or implicit. This appendix describes several of the most important instruments, and then describes how their nature and their application has been changing over time.

The Instruments

I describe four prominent instruments.

1 *Voluntary export restraints* (VERs)[14] fall outside both national laws and international agreements. The Uruguay Round made them more extralegal than ever. The following instruments, 'administered protection', are provided for in many national laws and sanctioned by the WTO.

2 *Antidumping duties* Dumping[15] is pricing for export below either the cost of production or the price for comparable domestic sales. Antidumping laws provide a two-pronged investigation: determination of the dumping margin, if any; determination of material injury to domestic import-competing firms. If both determinations are positive, a temporary duty equal to the dumping margin is imposed on the good from the country whose firms have dumped. The national interest plays no role, and (in the USA) the President cannot decline to impose the duty. These laws define certain behaviour as objectionable and force import prices up when it occurs. Whether the behaviour *should* be objectionable is beside the point: arbitrary circumstances determine which import-competing interests may obtain temporary protection.

3 *Countervailing duties* apply to imports subsidised for export. Administration is similar to that of antidumping laws.

4 *Safeguards* provide[16] temporary protection for domestic industries harmed by increased imports. Again, a material injury test is applied. But, in the USA, the President may decline to impose a duty. More generally, duties imposed should be nondiscriminatory and should not increase protection overall: duties should be reduced (in a nondiscriminatory way) on goods that are important exports of the exporting countries

14. See Harris (1985), Kostecki (1987), Krishna (1989), and Ethier (1991a, b).

15. See Ethier (1991b, 1993, 1994), Prusa (1992), Baldwin and Steagall (1994), and Tharakan and Waelbroeck(1994).

16. See Ethier (1994).

most affected by the safeguard measures.

This list of four instruments excludes other tools, notably those for aggressive export expansion (e.g. Super 301 in the USA). These are more characteristic of the USA than of other countries. Also, I have analysed these before (Ethier and Horn, 1996), and this paper concerns unilateralism as protection.

Changing Instrument Use

Use of these instruments has changed dramatically. First, usage has greatly increased since the 1960s. With the freedom to conduct traditional tariff policy progressively constrained by multilateral agreements, protectionist pressures have increasingly found outlets in the new protectionism.

Second, multilateral negotiation is broadening to encompass unilateral actions. The Tokyo Round established voluntary codes for the conduct of administered protection, and these were made mandatory for WTO members by the Uruguay Round. Curiously, though, the code for safeguards has been loosened. Countries are now allowed, sometimes, to use them much as VERs have been used. The final outcome is far from clear.

Third, individual countries have continually changed their laws. These changes have generally reduced administrative discretion and made protection more likely.

Fourth, the mix among the instruments has changed dramatically, with the number of safeguard cases declining absolutely as well as relatively and the number of countervailing-duty and (especially) antidumping cases exploding.

Appendix 2: Prices

Relative Commodity Prices

Recall that everyone spends half of his/her income on each good. Then, if A, B, A^* and B^* denote national production levels and M each nation's trade in B,

$$Q_i(B+M)=A-P_i M \qquad \text{and} \qquad Q_i^*(B^*-M)=A^*+P_i M.$$

These expressions can be rewritten as

$$P_i(1+t+1)M = A - P_i(1+t)B \qquad \text{and} \qquad \frac{P_i(1+t)}{(1+t)}M = \frac{B^*P_i}{1+t} - A^*.$$

Thus

$$\frac{A}{P_i(2+t)} - \frac{(1+t)B}{2+t} = M = \frac{B^*}{2+t} - \frac{(1+t)A^*}{(2+t)P_i}.$$

These, in turn, imply:

$$P_i = \frac{A + (1+t)A^*}{B^* + (1+t)B},$$

and

$$M = \frac{AB^* - (1+t)^2 A^*B}{(2+t)\left[A + (1+t)A^*\right]}.$$

P_i will assume one of two alternative values, depending on which good is the technological leader. Since $A = [\pi\beta + (1-\pi)]\,\ell\alpha a$, $B = (1-\ell)\,a$, $A^* = (1-\ell)\,a$, and $B^* = \ell\alpha a$,

$$P_i = P_A(\ell, t) = \pi(\beta - 1)\frac{\alpha\ell}{\alpha\ell + (1+t)(1-\ell)} + 1,$$

if A is the leader, and $P_i = P_B = 1/P_A$ if B is the leader. Then $P_A > 1 > P_B$.

Real Rewards

The responsiveness of rents to the common tariff vector t is

$$\frac{1+t}{r_x}\frac{\partial r_x}{\partial t} = -\frac{1}{2}\left[1 - \frac{1}{1+\frac{\alpha}{1+t}\frac{\ell}{1-\ell}}\frac{(P_A - 1)}{P_A}\frac{\pi(\beta-1)-(P_A-1)}{P_A + 1 + \pi(\beta-1)}\right] < 0,$$

$$\frac{1+t}{r_m}\frac{\partial r_m}{\partial t} = -\frac{1}{2}\left[1 - \frac{1}{1+\frac{\alpha}{1+t}\frac{\ell}{1-\ell}}\frac{(P_A-1)^2}{P_A(P_A-1)}\right] > 0.$$

These imply, when $r_m = r_x$, $\partial r_x/\partial t + \partial r_m/\partial t < 0$.

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5 Trade, Income Transfers, Developing Countries, and the Core

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1. Introduction

Individual nations or groups of them may find that protection is preferable to free trade and will hence strive to prevent the implementation of a liberal trading order. We have argued in Kowalczyk and Sjöström (1994) that a natural solution concept for the problem of implementing a worldwide trade agreement is the *core* which is defined as the collection of situations no nation or coalition of nations, whether actual or potential, could or would *block*, i.e., prevent from being implemented. We showed further, in that paper, for a many-country model of international trade in monopoly goods, that implementing a core allocation may require that nations transfer income to each other. We derived an explicit formula for income transfers (sidepayments) between nations which together with the formation of the grand coalition ("free trade") would support a Pareto optimal trading situation, in particular the Shapley value. Since the Shapley value constitutes a core allocation in that model, our transfer mechanism supports an allocation in the core.[1]

* We thank the organizers of the Kobe Conference for the opportunity to present this work, and Noritsugu Nakanishi and conference participants for helpful comments. We have benefited also from comments at the Berlin EEA Meetings. This paper provides an extended presentation of the results in Kowalczyk and Sjostrom (2000).

1. Raymond Riezman (1985) considers the core in a three-country exchange model where a single nation or a customs union can block global free trade. Inés Macho-Stadler, David Pérez-Castrillo, and Clara Ponsati (1998) discuss the core in a three-country model under varying assumptions regarding the weighting of nations' sources of income. Both papers rule out sidepayments between nations.

Another transfer scheme has been discussed in the international trade literature. Thus Earl Grinols (1981), in further development of work on compensation by Jean Grandmont and Daniel McFadden (1972), and on customs unions by Michihiro Ohyama (1972) and Murray Kemp and Henry Wan (1976), showed that assigning to each country its pre-change trade vector ensures that no nation loses by integrating into a customs union which sets its *compensating common tariff*, i.e., the tariff that leaves trade with non-member nations and hence their welfare unaffected.[2] None of these papers considered the core.

This paper analyzes the properties of the Grinols transfer mechanism in our model of monopoly trade. We show that (i) Grinols transfers go from countries with small profit losses from integration to those with large profit losses, (ii) Grinols transfers, when combined with the global trading arrangement, constitute a core allocation, (iii) Grinols and Shapley value transfers are identical except that Shapley transfers adjust for differences in reduced deadweight losses, and (iv) Grinols transfers constitute minimal compensation necessary to reach the core. The Shapley value has the desirable properties that it is a central point in the core, and that it shares the gains from cooperation equally, and thus can be obtained as the solution to a non-cooperative bargaining game. Yet, we propose that Grinols transfers may be preferable to our Shapley transfer mechanism since Grinols transfers are easier to calculate and hence implement, and since Grinols transfers may, in some circumstances, be kinder to developing countries as these countries tend to experience large gains in deadweight losses from liberalization and hence with Grinols transfers would receive larger or pay smaller net transfers than with the Shapley transfer scheme.[3]

2. The Model

We consider the world of monopoly trade introduced in our previous paper. Thus assume a world of n countries indexed by i. The representative consumer in country i has, and strives to maximize, the following quasi-linear preferences where c_o^i is consumption of a non-taxed numeraire good, c_j^i is consumption of good j, and θ_j^i is a taste parameter:

2. Jaroslav Vanek (1965) introduced this concept.

3. In the present model of monopoly trade, a country loses monopoly profits in foreign markets from joining those nations in trade agreements. In a more general environment where, in addition, the imports of some goods are taxed, a country's national income could also be changing from trade liberalization, whether comprehensive as in a multilateral agreement or preferential as in a customs union, via changed terms of trade or changes in trade flows. Sidepayments could then be needed to compensate for the net loss in national income from the combined effect from these changes.

(1) $$u^i\left(c^i\right) = c_0^i + \sum_{j=1}^{n} \frac{\left(c_j^i\right)^{\theta_j^i}}{\theta_j^i}, \quad 0 < \theta_j^i < 1, \qquad i, j = 1,\ldots, n.$$

Each consumer i is endowed with $\bar{l}_o^i$ units of good zero which can be consumed, sold to the single domestic firm as an input, or given away as income transfers. If I^i denotes consumer i's full income (which equals $\bar{l}_o^i$ if i does not receive any transfers of income), and p_j^i is the domestic price of good j in country i, consumer i's budget constraint becomes

(2) $$c_0^i + \sum_{j=1}^{n} p_j^i c_j^i = I^i, \qquad i = 1,\ldots, n.$$

The solution to the consumer's problem implies that country i demand for non-numeraire good j is

(3) $$c_j^i = \left(p_j^i\right)^{1/\left(\theta_j^i - 1\right)}, \qquad i, j = 1,\ldots, n.$$

Substitution of these demands into (2) for all goods j then yields demand for good 0 as the residual.

Country i has only one firm. It produces x^i units of good i, and faces given technology as expressed by the constant input-output coefficient β^i. Its labor demand is therefore

(4) $$l_o^i = \beta^i x^i, \qquad i = 1,\ldots, n,$$

which also defines its total costs since, in equilibrium, the wage rate must equal the unit price of the numeraire good.

We assume that markets are segmented, and that firm i can sell x_j^i units of good i to foreign country j at unit price $(p^e)_i^j$. Firm i profits are then given by

(5) $$\pi^i = \sum_{j=1}^{n} \left[\left(p^e\right)_i^j - \beta^i\right] x_j^i, \qquad i = 1,\ldots, n.$$

Since the price elasticity of demand implied by (3) is $\left[-1/\left(\theta_j^i - 1\right)\right]$, the mark-up price charged by firm i in market j is

(6) $$\left(p^e\right)_i^j = \frac{\beta^i}{\theta_j^i}, \qquad i, j = 1,\ldots, n.$$

In an equilibrium in which governments do not intervene, firms will charge everywhere the prices given by this rule. In the remainder of the paper we analyze the scope for policy intervention and coordination in which nations agree to price at cost and use Grinols income transfers.

3. Trade Agreements and the Policy Game

We assume that the policy instrument at hand is a government-enforced price ceiling and we define a *trade agreement* between two countries i and j as an agreement to apply such ceilings at marginal cost on the exports to each other's markets.[4] Country i gains consumer surplus equal to δ_j^i as $(p^e)_i^j$ is reduced from the monopoly mark-up price in (6) to cost β^j, and it loses profits π_j^i on its exports to market j. Country j experiences an analogous welfare calculus from integration with country i. Since an agreement eliminates the deadweight loss from monopoly pricing, the increase in consumer surplus in j must exceed i's profit loss, that is, $(\delta_i^j - \pi_j^i)$ is positive by the deadweight loss triangle, as is illustrated in Figure 1. The collective gains to the two countries from a trade agreement, $(\delta_j^i - \pi_i^j) + (\delta_i^j - \pi_j^i)$, are thus positive. However, a country may find its gains in consumer surplus to fall short of the lost profits abroad from the agreement and would thus not enter into it unless it were compensated through a sidepayment. A final property of our model is that *the grand coalition*, i.e., the world-wide trade agreement, is Pareto optimal since it equates price with marginal cost for every good in every country. We assume that the purpose of GATT/WTO is to aid countries in establishing the grand coalition of world-wide marginal cost pricing.

We view the world economy as a *transferable utility game where the set of players* is the collection of nations $N = \{1, ..., n\}$, and a coalition K is a (preferential) trade agreement in the sense discussed above with $|K|$ members, where $K \subseteq N$. Coalition K can guarantee itself a payoff given by *the characteristic function* $v(K)$ which is a mapping from all subsets of N into a real number. A vector of payoffs y is said to be *blocked* by coalition K if $\sum_{i \in K} y^i < v(K)$. The *core* is the set of payoff vectors that is blocked by no coalition. It is important for the application of the character-

4. With the assumed constant elasticity import demand, an *ad valorem* import tariff leaves price constant but reduces import volume while a specific import tariff reduces the firm's perceived elasticity and thus worsens the importer's terms of trade. Thus governments would not want to use import taxes. A specific import subsidy would raise both the importer's welfare and the exporting firm's profits, as discussed in Kowalczyk and Skeath (1994). An import price ceiling would also be used unilaterally by any government, and it would, therefore, lead to a non-cooperative Pareto optimal equilibrium. Since the focus of our analysis is the use of sidepayments (income transfers) as an instrument in supporting cooperation, we will here, as we did in our earlier paper, rule both of these policies out.

istic function approach that a coalition not affect the payoffs of other nations. This requirement is satisfied in our model since the preferential trade agreements we consider do not cause price changes on trade with non-members due to the assumptions of separable demand, zero income effects, and constant costs for non-numeraire goods.

4. Grinols Transfers and the Core

Grinols (1981, p.262) proposes a transfer scheme where "[T]he compensation to each country is given by its pre-union trade vector." He stresses (p.260) that it has the property that "[Using] world prices for evaluation each and every country breaks even under the proposed scheme, receiving a transfer which has zero value. [...] Using post-union internal prices for valuation, member nations may have to pay or receive a net transfer."

Lemma. *In a model of international trade of monopoly goods, Grinols transfers T_G^i are*

$$T_G^i = \sum_{j \neq i} \left(\pi_j^i - \pi_i^j \right), \qquad i = 1, \ldots, n. \tag{7}$$

Proof

Consider an initial situation where country i is a member of no trade agreement. Since country j charges the mark-up price implied by equation (6), it follows from (3) that i's demand for and hence imports of good j is

$$c_j^i = \left(\frac{\beta^j}{\theta_j^i} \right)^{1/\left(\theta_j^i - 1\right)}, \qquad i, j = 1, \ldots, n. \tag{8}$$

Switching i and j in the above equation determines country j's imports from i and hence i's exports. Finally, country i may also be trading good zero in the initial equilibrium in order to settle its trade balance. Evaluated at the prices of the initial equilibrium the corresponding trade in good zero, m_o^i, equals

$$m_0^i = \sum_{j \neq i} p_i^j \left(\frac{\beta^i}{\theta_i^j} \right)^{1/\left(\theta_i^j - 1\right)} - \sum_{j \neq i} p_j^i \left(\frac{\beta^j}{\theta_j^i} \right)^{1/\left(\theta_i^j - 1\right)}, \qquad i, j = 1, \ldots, n. \tag{9}$$

Denote the transfers recommended by Grinols by T_G^i. When evaluated at "post-union domestic prices," which for our problem equal marginal cost, Grinols transfers become

$$T_G^i = \sum_{j \neq i} \beta^j c_j^i - \sum_{j \neq i} \beta^i c_i^j + m_0^i, \qquad i, j = 1, \ldots, n. \tag{10}$$

Substituting into this from equations (8) and (9) finally yields, after some manipulations which are summarized in the Appendix, expression (7).
Q.E.D.

Thus Grinols transfers imply that country i receives compensation for the profits it loses from the grand coalition forming while country i pays compensation to its trading partners for their profit losses in i's market.

We define S_j^i to be consumer surplus from good j in country i when country j charges only marginal cost on its sales to i. If the grand coalition forms without sidepayments country i's payoff is

$$\Phi^i(N,v) = \bar{l}_0^i + \sum_{j=1}^{n} S_j^i, \qquad i = 1, \ldots, n. \tag{11}$$

Hence, the grand coalition with Grinols sidepayments implies that country i's payoff is

$$\Phi^i(N,v) = \bar{l}_0^i + \sum_{j=1}^{n} S_j^i + \sum_{j=1}^{n} \left[\left(\pi_j^i - \pi_i^j \right) \right], \qquad i = 1, \ldots, n. \tag{12}$$

The main result of the paper can now be shown:

Proposition. *Forming the grand coalition, and implementing the vector of international side-payments* $T_G(N, v)$ *which assigns to country* i *the net transfer*

$$T_G^i = \sum_{j \neq i} \left(\pi_j^i - \pi_i^j \right), \qquad i = 1, \ldots, n, \tag{7}$$

will bring GATT/WTO into the core.

Proof
See Appendix.

We discussed in our earlier paper under which conditions sidepayments are needed to implement the grand coalition, and we showed, in particular, that the grand coalition could form without the use of sidepayments if countries are similar. We showed also that the transfer scheme which gives to country i the net transfer

(13) $$T^i = \frac{1}{2}\sum_{j \neq i}\left[\left(\pi^i_j - \delta^i_j\right) - \left(\pi^j_i - \delta^j_i\right)\right], \qquad i = 1, ..., n,$$

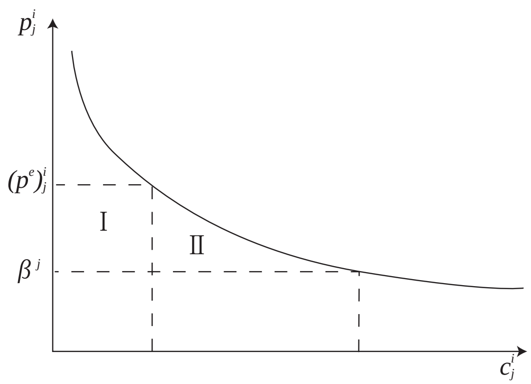
supports the Shapley value, another core allocation of this world economy, with payoff to country i given by

(14) $$\Phi^i(N,v) = \bar{l}^i_0 + \sum_{j=1}^{n} s^i_j + \frac{1}{2}\sum_{j=1}^{n}\left[\left(\pi^i_j - \delta^i_j\right) - \left(\pi^j_i - \delta^j_i\right)\right], \quad i = 1,..., n.$$

At first glance, the main difference between Shapley and Grinols transfers appears to be that the latter ignores any effects on consumer surplus. However, consider again Figure 1. When integrating, country j loses profits π^j_i equal to area I while country i gains consumer surplus δ^i_j equal to areas I and II. Let ε^i_j be the deadweight loss given by area II, and hence $\delta^i_j = \pi^j_i + \varepsilon^i_j$. Substituting this into (14), and similarly for profits earned in j and the corresponding consumer surplus in j, (14) can be rewritten as

(15) $$T^i = \sum_{j \neq i}\left(\pi^i_j - \pi^j_i\right) + \frac{1}{2}\sum_{i \neq j}\left(\varepsilon^j_i - \varepsilon^i_j\right), \qquad i = 1,..., n.$$

Figure 1



Thus our earlier Shapley transfers are equivalent to Grinols' scheme except for a term comparing reductions in deadweight losses between nations. The two transfer schemes imply, therefore, different distributions of the aggregate global gains from the grand coalition forming relative to an initial situation of no trading clubs. From the earlier definition of S^i_j as the consumer surplus in i on good j when j is priced at cost, and δ^i_j as the gain in consumer surplus in i when good j's price is reduced from mark-up to cost, $(S_j^i - \delta_j^i)$is consumer surplus in i when good j is priced at mark-up. Thus country i's payoff in the initial situation of no trade agreements equals

$$\Phi^i(N,v) = \bar{l}_0^i + \sum_{j=1}^{n}\left[\left(S_j^i - \delta_j^i\right) + \pi_j^i\right], \qquad i = 1,..., n. \tag{16}$$

Denote the gains to country i from moving from this situation to the grand coalition with Shapley payoffs by g_S^i, and let g_G^i be the gains from moving from no trading clubs to the grand coalition with payoffs implied by Grinols transfers. Subtracting (16) from (14) to obtain the former, and (16) from (12) to obtain the latter, and substituting for $\delta_j^i = \pi_i^j + \varepsilon_j^i$, for all i and j, yields

$$g_S^i = \frac{1}{2}\sum_{j=1}^{n}\left(\varepsilon_j^i + \varepsilon_i^j\right), \qquad i = 1,..., n, \tag{17}$$

and

$$g_G^i = \sum_{j=1}^{n}\varepsilon_j^i, \qquad i = 1,..., n. \tag{18}$$

Thus the Shapley value implies that country i gains half of each of its trading partners' consumption gains in return for keeping only half of its own consumption gains while the Grinols scheme implies that country i retains its own consumption gains but does not obtain a share in the trading partners' gains.[5] The magnitude of ε_j^i is in part determined by the curvature of the demand curve for good j, and in part by the cost of producing good j. Given our choice of policy instrument, the curvature of country i's demand curve for good j is not affected directly by country i policy, and it is therefore through firm j's pricing decision that income is forgone in that market in the initial equilibrium. It is an interesting feature of the Grinols mechanism that firm j, and thus country j, do not share in the gains from

5. The finding that country i's payoff increases by its own consumption gains is consistent with that of Grinols (1981) for a country joining a customs union of the type discussed by Kemp and Wan (op. cit.), and Ohyama (op. cit.) in an Arrow-Debreu-McKenzie world economy. If the world economy, rather than being an endowment economy (as in Grinols' example) or one of constant costs (as in our model), exhibits variable cost then the change in country i's payoff should be augmented with country i's production gains, which is the non-negative change in value of production as firms adjust output; see Grinols (1987).

reduced deadweight loss created by the reduction of the price of good j. The Shapley transfers, on the other hand, do share these gains, although at the price that country j's own gains must be shared with others in return.

5. Discussion and Conclusion

We discussed in our earlier work how the Shapley value has the properties of being a central point in the core and of sharing equally the gains from cooperation and thus having a non-cooperative foundation. Grinols transfers do not share, in general, these properties—indeed, we are not aware of a non-cooperative approach that would yield the payoffs implied by the grand coalition with Grinols transfers. It could therefore be viewed as surprising that Grinols transfers succeed in supporting a core allocation even though they ignore deadweight losses. And indeed, Grinols transfers barely make it, as they constitute, in general, the minimum transfers required to implement a core allocation: When integrating, a country loses the profits earned in foreign markets, it gains consumer surplus on imports. Its profit losses are its only losses. For every profit loss there is a corresponding gain in foreign consumer surplus. Those gaining can and will be willing to pay to compensate for the lost profits. Smaller compensation might not suffice to induce undistorted trade; larger compensation taxes consumer gains more. Thus Grinols transfers favor consumers over firms relative to Shapley transfers. If mark-ups are higher in developing than in developed countries then developing countries stand to gain relatively more in consumer surplus from the grand coalition forming than do developed countries.[6] But then Grinols transfers would be preferred to Shapley transfers by those who wish to favor developing countries since Grinols transfers do not tax these regained deadweight losses while Shapley transfers do.[7] Add to this that Grinols transfers are informationally efficient relative to Shapley transfers since the former do not require estimates of deadweight losses or demand curves (calculations which could be both difficult and contentious in an international bargaining situation), and Grinols trans-

6. While we do not analyze tariffs or quotas, developing countries do tend to be more protective than are developed countries, and they should therefore experience larger price changes and hence consumption gains (and production gains) from trade liberalization than developed countries.

7. However, and as was the case in our analysis of Shapley transfers, even with Grinols transfers it is possible that payments go from low to high income countries if the former gain and the latter lose from the grand coalition forming. We recognize that many readers might find this feature unappealing. However, in our work, sidepayments play the sole purpose of inducing nations to cooperate, and the payments will never exceed the gains from cooperation. In other words, a country—whether poor or not—will only be willing to be a net contributor to the financial mechanism if it is better off at the grand coalition with transfers than at the *status quo* or at any other attainable situation.

fers appear preferable to our original transfer scheme, derived from the Shapley value, at least by those who wish to favor developing nations.

We recognize that our approach of viewing the problem as one of cooperative game theory has many limitations including that we ignore strategic considerations. This is unrealistic to the extent trade flows are choice variables. Nevertheless, we view the main result of this paper—that there exists a transfer mechanism, Grinols transfers, which has attractive properties compared to those we derived from the Shapley value—as bringing our investigation of international sidepayments as a means to helping establish a liberal trading order a small step closer to implementation.

Appendix

Derivation of Equation (7)

Substituting (6) into (3) gives initial demand for non-numeraire good j. Substituting the resulting demands into equations (8) and (9) which, in turn, are substituted into (10) then yields

$$\text{(A1)}\quad T_G^i = \sum_{j\neq i}\beta^j\left(\frac{\beta^j}{\theta_j^i}\right)^{1/(\theta_j^i-1)} - \sum_{j\neq i}\beta^i\left(\frac{\beta^i}{\theta_i^j}\right)^{1/(\theta_j^i-1)} + \sum_{j\neq i}\left[\left(\frac{\beta^i}{\theta_i^j}\right)^{\theta_j^i/(\theta_j^i-1)} - \left(\frac{\beta^j}{\theta_j^i}\right)^{\theta_j^i/(\theta_j^i-1)}\right],$$

$$i, j = 1,\ldots, n,$$

or

$$\text{(A2)}\quad T_G^i = \sum_{j\neq i}\left(\beta^j\right)^{\theta_j^i/(\theta_j^i-1)}\left[\frac{1}{\theta_j^i}^{1/(\theta_j^i-1)} - \frac{1}{\theta_j^i}^{\theta_j^i/(\theta_j^i-1)}\right] - \sum_{j\neq i}\left(\beta^i\right)^{\theta_i^j/(\theta_i^j-1)}\left[\frac{1}{\theta_i^j}^{1/(\theta_i^j-1)} - \frac{1}{\theta_i^j}^{\theta_i^j/(\theta_i^j-1)}\right],$$

$$i, j = 1,\ldots, n.$$

But

$$\left[\frac{1}{\theta_j^i}^{1/(\theta_j^i-1)} - \frac{1}{\theta_j^i}^{\theta_j^i/(\theta_j^i-1)}\right] = \frac{1}{\theta_j^i}^{\theta_j^i/(\theta_j^i-1)}\left[\frac{1}{\theta_j^i}^{(1-\theta_j^i)/(\theta_j^i-1)} - 1\right] = \frac{1}{\theta_j^i}^{\theta_j^i/(\theta_j^i-1)}\left[\theta_j^i - 1\right],$$

$$i, j = 1,\ldots, n.$$

Hence (A2) can be written as

$$\text{(A3)}\quad T_G^i = -\sum_{j\neq i}\left(\beta^j/\theta_j^i\right)^{\theta_j^i/(\theta_j^i-1)}\left(1-\theta_j^i\right) + \sum_{j\neq i}\left(\beta^i/\theta_i^j\right)^{\theta_i^j/(\theta_i^j-1)}\left(1-\theta_i^j\right),$$

$$i, j = 1,\ldots, n.$$

But using equation (A8) in our earlier paper this can be rewritten as

$$\text{(A4)} \qquad T_G^i = -\sum_{j \neq i} \pi_i^j + \sum_{i \neq j} \pi_j^i = \sum_{j \neq i} \left(\pi_j^i - \pi_i^j \right), \qquad i, j = 1, \ldots, n,$$

which is equation (7) of the text.

Proof of Proposition

Define S_j^i to be consumer surplus from good j in country i when country j charges only marginal cost on its sales to i. From the earlier definition of δ_j^i as the gains in consumer i surplus from country j reducing its price on i to marginal cost, it follows that $(S_j^i - \delta_j^i)$ is consumer i surplus on good j when j charges its mark-up price in country i. Coalition K is (weakly) better off with the grand coalition and Grinols transfer than at an arbitrary alternative situation if

$$\text{(A5)} \qquad \sum_{i \in K} \bar{l}_0^i + \sum_{i \in K} \sum_{j=1}^{n} S_j^i + \sum_{i \in K} T_G^i \geq v(K), \quad \forall K, K \subseteq N.$$

Substituting

$$\sum_{i \in K} T_G^i = \sum_{i \in K} \sum_{j \notin K} \left(\pi_j^i - \pi_i^j \right) \text{ and } v(K) = \sum_{i \in K} \bar{l}_0^i + \sum_{i \in K} \sum_{j=1}^{n} S_j^i - \sum_{i \in K} \sum_{j \notin K} \delta_j^i + \sum_{i \in K} \sum_{j \notin K} \pi_j^i, \quad \forall K, K \subseteq N,$$

into this yields

$$\text{(A6)} \quad \sum_{i \in K} \bar{l}_0^i + \sum_{i \in K} \sum_{j=1}^{n} S_j^i + \sum_{i \in K} \sum_{j \notin K} \left(\pi_j^i - \pi_i^j \right) \geq \sum_{i \in K} \bar{l}_0^i + \sum_{i \in K} \sum_{j=1}^{n} S_j^i - \sum_{i \in K} \sum_{j \notin K} \delta_j^i + \sum_{i \in K} \sum_{j \notin K} \pi_j^i, \quad \forall K, K \subseteq N,$$

or

$$\text{(A7)} \qquad \sum_{i \in K} \sum_{j \notin K} (\pi_j^i - \pi_i^j) \geq \sum_{i \in K} \sum_{j \notin K} (\pi_j^i - \delta_j^i), \quad \forall K, K \subseteq N,$$

or

$$\text{(A8)} \qquad \sum_{i \in K} \sum_{j \notin K} \delta_j^i \geq \sum_{i \in K} \sum_{j \notin K} \pi_i^j, \quad \forall K, K \subseteq N,$$

which holds in this model since $\delta_j^i \geq \pi_i^j$ for all i, j. It follows that coalition K will not block the proposal to implement the grand coalition with Grinols transfers.

The Grinols transfer scheme will be said to be *feasible* if $B = \sum_{j \neq i} T_G^i \geq 0$, i.e., if governments collect at least what they pay out. But $B = \sum_i \sum_{j \neq i} (\pi_j^i - \pi_i^j) = 0$ since $\sum_i \sum_{j \neq i} \pi_j^i = \sum_i \sum_{j \neq i} \pi_i^j$ are both equal to total profits earned in foreign markets by all the world's firms.
Q.E.D.

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6 Endogenous Corrections of Economic Policies under Majority Voting

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1. Introduction

The economic policies of democratically governed countries reflect the conflicting economic interests of heterogeneous populations. Political pressures to adjust policies arise when at least some individuals experience changes in their economic interests. The most direct cause of economic interest changes are exogenous events, such as increased competitiveness of foreign economies, oil price shocks, natural catastrophes, or consumer taste changes. Indeed, most major economic policy changes can be seen as immediate and direct responses to such exogenous events.

In addition to these major, immediate policy responses, one observes minor, but quite frequently occurring corrections of existing economic policies. The origin of existing policies can be traced back to an exogenous event that occurred some time in the past. The need to correct policies might arise much later and quite frequently, with no new exogenous development occurring. Although each policy correction tends to be small, the total impact of many corrections over a longer time period is often quite sizable.

The specific purpose of this paper is to shed light on the time path of economic policy adjustments when policy changes are frequent, small, and corrective in nature rather than one-time, large, and immediate responses to exogenous events. At a more general level, the paper emphasizes the im-

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portance of *time* in the political choice of economic policies. The standard political economy approach is essentially timeless. Given the diverse characteristics of individuals, such as factor ownership, preferences, and age, and the economy-describing parameters, such as overall factor endowments, production technologies, world prices, and prevailing economic policies, these individuals' economic interests in policies are determined independent of the specific time at which they participate in the political process. This paper, in contrast, demonstrates how peoples' economic interests adjust over time, even though their individual characteristics and the economy's parameters remain constant. At a given time, a person's economic interests in policies are closely tied to current and expected prices in factor as well as commodity markets which, in turn, are linked to the economy-wide allocation of factors of production. The standard political economy approach assumes timeless relationships between these prices, the allocation of factors, and the economy's parameters. This paper, on the other hand, focuses on the need for time in reallocating factors and on the resulting time-dependence of individual economic interests, as well as actual collective policy choices. The short-run economic policy responses to exogenous changes, therefore, must be distinguished from the long-run responses, and account must be taken of frequent corrective policy adjustments in between.

The story of the policy adjustment process is a story of how losers of past economic policy actions might react to cut their losses. Given an economy's allocation of factors, an initial political choice of economic policies reflects the relative strengths of individuals and groups whose economic interests are diverse. Over time, all participants in the political process experience changes in their economic interests because some losers of past policy actions shift their economic resources and political weight to the winning side, thereby upsetting the prevailing political balance. In general, losers of political actions have some ability to react to newly adopted policies, even though these reactions might be delayed. Provided some adaptive reactions on the part of losers are possible, the initial winners will be hurt. Frequent, small policy corrections by the policy-controlling winners can be seen as attempts at retaining as much as possible of gradually eroding gains.

A large segment of the political economy literature ties the self-interests of individuals permanently to the performance of the industry which employs their factor of production[1]. Factors are treated as industry specific, and economic policies that favor a certain industry simultaneously favor its specific factor owners. Those who gain from a policy retain these gains as

1. See, for example, the classic model of Findlay and Wellisz (1982), in which landowners, whose resource is specific to food, and capital owners, whose resource is specific to manufactures, lobby for protectionist trade policies.

long as the policy remains in effect. The policy, in turn, remains in effect as long as no new exogenous event disturbs the prevailing political equilibrium.

A smaller segment of the literature adopts models in which factors are perfectly mobile among industries[2]. An individual factor owner's interests are no longer tied to the industry which employs the factor. Instead, a factor owner's economic interests are tied to the fate of all other individuals who own the same factor, independent of where and how it is employed. Economic interests of individuals and policy choices of society, however, are still permanent reactions to exogenous events.

Neither the assumption of perfect industry specificity nor the assumption of perfect mobility between industries reflects reality well. In most real world situations, the interests of factor owners are partially and temporarily tied to the interests of the industries which employ them. Typically, individuals find the reallocation of factors to be costly and time consuming. Furthermore, one observes that the cost of reallocating a given factor is not the same for all people. Factor owners are heterogeneous and their opportunity costs of switching employment among sectors might vary greatly. This paper introduces partial mobility of factors, which enables some, but not all, people to escape the fate of being employed by a losing industry.

A political economy model of corrective policy adjustments requires that factors of production are both heterogeneous and partially mobile. Heterogeneity of factor owners generates the conflicting interests which guide the actions of players in the political game. Partial factor mobility generates the need for frequent policy corrections. The political economy literature has explicitly modeled factor heterogeneity, but not partial factor mobility. The international trade literature has explicitly modeled partial factor mobility, but not heterogeneity of factor owners[3]. This paper develops a new model of partial factor mobility in which heterogeneous factor owners make rational choices as to whether and when they will move their factor to another sector. We employ a simple, two-sector, small, open economy framework. Each industry employs workers as the only providers of productive factors. Different from the standard Ricardian model, however, labor is not homogeneous. One industry is assumed to require *low-skill*, repetitive, assembly-line work, while the other one is assumed to require *high-skill*, adaptable, problem-solving work. Workers can offer these services to either industry, but their capacity to do so varies among them. They are born with different innate abilities. Some individuals are relatively better suited for low-skill work, while others are relatively better suited for

2. This is the case in Heckscher-Ohlin type models in which workers and capital owners compete for policies independent of the industries that employ them. For a direct democracy model with perfectly mobile factors, see Mayer (1984).

3. Neary (1982), Mussa (1978, 1982), and Grossman (1983) have developed different approaches to deal with the issue of imperfect and partial factor mobility.

high-skill work. Given a person's abilities, he or she will consider the two industries' wages and seek employment in that industry which promises the highest present value of income.

When current and expected industry wages change, incentives arise for at least some workers to switch to the other industry. Job switching is feasible but neither costless nor instantaneous. Although a person has the ability to work in the other industry, this ability must first be converted into marketable labor services before employment can start. The conversion of ability into marketable labor services requires learning of tasks to be performed at the new job. Learning is costly because it is time consuming. While a person is learning a new task, he or she cannot be working at the same time. Accordingly, job switching entails a learning period during which income from the presently held job is diminished[4]. The learning period's duration is not exogenously given, but can be chosen by potential job switchers. In our model, people with different innate abilities vary with respect to the optimal duration of learning periods. Consequently, a one-time disturbance results in a gradual rather than instantaneous reallocation of labor that eventually leads to a new long-run equilibrium.

This paper employs a direct democracy political process in which policy choices are made through majority voting, and there is only one issue to be decided on. The single issue under consideration is a production tax imposed on or subsidy paid to the firms of one of the industries. Under the usually made assumption of individuals' single-peaked policy preferences, the median voter dictates the outcome. The median voter-determined policy choice is made through a referendum and remains in force for one period. At the beginning of the next period a new referendum is conducted. It provides an opportunity to either confirm or correct the previously chosen policy.

The paper sheds light on the adjustment paths of three variables: the value of the politically chosen production tax or subsidy, the incomes of individual workers in the winning industry, and the value of national income as a whole. Concerning the choice of production tax or subsidy, the median voter will always opt for subsidization of his or her industry, but preferences for the degree of subsidization are shown to change over time. The ultimate long-term policy will be different from the immediate short-term policy that had been adopted as a first response to an exogenous disturbance. The direction of the policy revision, however, crucially depends on the ability of individuals to switch their labor service to the subsidized, expanding industry. We explicitly assume that every person has the same ability to provide low-skill labor services, but that the ability to provide high-skill labor services is quite unevenly distributed. If the subsidized in-

4. Each job switcher will be learning new tasks and performing the old job at the same time. But different job switchers do this in different proportions.

dustry employs low-skill, assembly-line labor services, then the politically chosen production subsidy will decline over time. If the expanding industry employs high-skill, problem-solving labor services, then the politically chosen production subsidy will rise over time.

The initial industry affiliation of the median voter determines which industry becomes the winning industry. Workers in the winning industry greatly gain in the short run when a production subsidy is adopted through the first referendum. Over time, as the number of workers in the winning industry rises and in the losing industry declines, the negative-sum nature of the political game inevitably lowers these initial gains of the median voter[5]. The policy corrections of future referenda cannot reverse this decline in gains; they can only ameliorate them.

Any non-zero production subsidy distorts this small, open economy and reduces its national income at world prices. The initial distortion deepens and the loss in national income worsens over time, as more resources move into the subsidized sector. If the initial production subsidy rate overshoots the long-run target, later policy corrections moderate that loss in income which would have come about at a constant subsidy policy. The opposite will hold when the initial production subsidy rate undershoots the long-run target.

2. A Two-Sector Economy with Heterogeneous Labor

This section constructs a simple general equilibrium production model in which a one-time disturbance leads to a gradual reallocation of resources. There is heterogeneity of resource ownership and the optimal timing for reallocating an individual's resource is not the same for all people.

The economy under consideration is small and open, and its two competitive industries have production functions:

$$X(t) = L_X(t)/a_X, \quad Y(t) = L_Y(t)/a_Y. \tag{1}$$

The variable $j(t)$ denotes output of good $j = X, Y$ in time period t, $L_j(t)$ indicates the number of labor efficiency units employed by industry j, and a_j is a technology parameter that expresses the amount of labor required to

5. The political process of economic policy formation is a negative-sum game for two reasons. First, the politically decisive individual or group maximizes its own rather than society's welfare. The adopted policy introduces a distortion that reduces the nation's consumption possibilities. Second, the political process itself is resource consuming, as Tullock (1967), Bhagwati (1982), and others have emphasized; the political actions of individuals and groups use up resources but add nothing to the economy's value of output. This paper focuses on the distortion component of the negative-sum game by pointing out that damage from the distorting policy grows over time.

produce one unit of good j. Production technologies remain constant for all time periods under consideration.

Both industries are perfectly competitive. The corresponding zero profit condition is:

(2) $$a_j w_j(t) = p_j(t),$$

where $w_j(t)$ is the wage rate paid per labor efficiency unit in industry j and $p_j(t)$ is the domestic price of good j during period t. Good Y is chosen as the numeraire and an ad valorem production subsidy (tax), paid to (collected from) firms in industry X during period t, is denoted by $s(t) > 0$ (< 0). In period t, the domestic price of good X in terms of good Y is stated as:

(3) $$p(t) = \pi[1 + s(t)],$$

where π is the world price of good X. The world price is given and remains constant for the small country under consideration. The production tax or subsidy, on the other hand, is determined through the domestic political process and might vary over time.

Labor is supplied by the country's N people whose lifetimes are assumed to be infinite. All people have the same time preference, the common discount factor being $0 < \delta < 1$; and all people have perfect foresight concerning the rational choice of future production taxes and subsidies as determined through the political process. The latter assumption implies that people, when acting as workers and voters, make their current employment and voting decisions in correct anticipation of future economic policy adoptions, as well as of future employment choices.

People are heterogeneous. They vary with respect to their innate abilities to provide labor services to the two industries. Specifically, person i has abilities:

(4) $$[L_X(i), L_Y(i)],$$

where $L_j(i)$ expresses the number of labor efficiency units individual i is capable of supplying to industry j, provided the requisite training has been completed. We assume that one industry employs assembly-line, *low-skill* labor while the other industry employs problem-solving, *high-skill* labor. The distinguishing feature of *low-skill* labor is that every person is equally capable of providing it. Should industry X be the *low-skill* labor industry, then $L_X(i)$ is the same for all i. Conveniently, we set $L_X(i) = 1$ in this case. *High-skill* labor, on the other hand, cannot be provided equally well by all individuals. Some people are far more talented in performing problem-solving work than others. We explicitly assume that abilities for work in the high-skill industry are uniformly distributed, on the interval (0, 1). Should industry Y be the *high-skill* labor industry, then L_Y is uniformly distributed with density 1 for $0 < L_Y < 1$ and 0 elsewhere.

At the time of the disturbance each person is employed in one of the two industries and nobody can benefit from switching employment. Disturbance of this long-run equilibrium creates incentives for, at least, some individuals to move to the other industry. Switching employment, however, is not costless. It requires time-consuming training to fully develop a person's innate ability for work in the new industry. A person, currently employed in industry Y and intent on switching to industry X, must sacrifice one hour of work in industry Y for each hour of training for industry X. A fixed number of tasks has to be learned, but the total time required to learn these tasks is not constant; it critically depends on the number of time periods over which the learning process is stretched. Following Alchian (1959)[6], we assume that total training cost is larger the fewer the number of time periods within which all training is to be completed[7]. Training cost is measured in terms of income lost when work in industry Y is reduced. More precisely, we define $0 \leq c(\tau) \leq 1$ as the fraction of a time period which a person must spend on training in each period when the entire training lasts for τ periods. If training is to be completed in period τ, worker i sacrifices

(5) $$c(\tau) w_Y(t) L_Y(i)$$

of income in period $0 < t < \tau$, and the present value of total training cost becomes:

(6) $$\gamma(\tau) L_Y(i) = \left[c(\tau) \sum_{0}^{\tau} \delta^t w_Y(t) \right] L_Y(i).$$

The assumption that total training cost decreases the longer the time span for training completion implies that $\gamma(\tau) > \gamma(\tau + 1)$.

The assumption that total training cost decreases with time is quite realistic for shorter time spans, but unrealistic for very long time horizons. Accordingly, we add the restriction that lengthening the time horizon for training lowers total training cost up to period T only. For simplicity's sake, total training cost is assumed to become zero when training is ex-

6. Alchian (1959) appears to have been first in explicitly introducing time as a variable in describing the relationship between cost and output. Alchian postulates that total cost rises at an increasing rate with the speed at which output is produced. In our model, output is measured in terms of completed training schedules.

7. Total training time is the number of periods over which training takes place times the amount of time spent on training during each of these periods.

tended to the full T periods; that is

$$\gamma(T) = 0. \tag{7}$$

The implication of the above-made set of assumptions is that many individuals might make the decision to switch industry employment exactly at the same time but that they will begin work in the new industry at very different times. Some complete their training quicker and switch earlier than others, resulting in a gradual rather than instantaneous reallocation of resources after an exogenous shock. How a person chooses the time of switching is examined next.

2.1. The Employment Decision

The economy's long-run equilibrium is disturbed at the beginning of time period 0. The disturbance might, for example, be the result of a newly legislated production subsidy paid to firms in industry X. The workers of industry X receive a higher wage and industry Y workers assess their incentives to switch industry employment. The latter consider current wages, as well as wages anticipated in future periods, whereby their foresight is assumed to be perfect. Based on equations (2) and (3), period t wage rates paid by the respective industries are:

$$w_X(t) = \pi\left[1 + s(t)\right]/a_X \quad \text{and} \quad w_Y(t) = 1/a_Y. \tag{8}$$

Person i, currently employed in industry Y and providing $L_Y(i)$ labor efficiency units, will receive a present value income of

$$\left[L_Y(i)/a_Y\right]\sum_0^{\infty}\delta^t, \tag{9}$$

if he or she remained in industry Y. Alternatively, if the individual switched to industry X, with work starting at the beginning of period τ, the person first would train for τ periods and remain partly employed by industry Y before performing full-time work in industry X from period τ on. Accounting for training cost during the first τ periods, as expressed by equation (6), the present value income of individual i, when switching from industry Y to X at time τ, is:

$$\left[L_Y(i)/a_Y\right]\left[\sum_0^{\tau}\delta^t - a_Y\gamma(\tau)\right] + \left[\pi L_X(i)/a_X\right]\left\{\sum_{\tau}^{\infty}\left[1 + s(t)\right]\delta^t\right\}, \tag{10}$$

where the first term measures income from old, part-time work in industry Y up to period τ and the second term indicates income from the new, industry X job for all subsequent periods. Worker i has an incentive to switch employment in period τ if two conditions are satisfied. First, the value of the expression in equation (10) must exceed that of the expression in equation (9) for at least some $\tau < T$; that is, there must be a time when switching is better than not switching. Second, the difference between these two expressions, which states the net benefit from switching, must be at least as high for period τ as for any other time period; that is, period τ must be the optimal switching period.

The net benefit from switching in period τ, denoted as $B(i, \tau)$ and obtained by subtracting equation (9) from (10), can be stated as:

$$(11) \quad B(i,\tau) = \{L_X(i)/a_Y\}\left\{A\pi\sum_{\tau}^{\infty}[1+s(t)]\delta^t - e(i)\left[a_Y\gamma(\tau) + \sum_{\tau}^{\infty}\delta^t\right]\right\},$$

where $A = a_Y/a_X$, and $e(i) = L_Y(i)/L_X(i)$ indicates the *ability* bias of person i for work in industry Y. The higher the value of $e(i)$, the better suited a person is for work in industry Y. If, for example, industry Y were the high -skill industry, then a high value of $e(i)$ would mean that person i is relatively capable of performing high-skill tasks. Equation (11) reveals that, ceteris paribus, a person's net benefit from leaving industry Y and switching to X is less the greater his ability bias for work in industry Y.

The net benefit function $B(i, \tau)$ is assumed to be strictly concave with respect to switching periods for all $\tau < T$; that is,

$$(12) \quad \Delta B(i,\tau) - \Delta B(i,\tau-1) < 0, \quad \text{where}$$

$$(13) \quad \begin{aligned} \Delta B(i,\tau) &= B(i,\tau+1) - B(i,\tau) \\ &= \{L_X(i)/a_Y\}\delta^{\tau}\{-A\pi[1+s(\tau)] + e(i)[1-\delta^{-\tau}a_Y\Delta\gamma(\tau)]\}, \end{aligned}$$

measures the change in net benefit as switching is postponed by one period. In interpreting equation (13), it should be noted that the present value of total training cost declines up to period T, making $\Delta\gamma(\tau) = [\gamma(\tau + 1) - \gamma(\tau)] < 0$ for any time before T. Person i, born with ability bias $e(i)$, finds it optimal to switch industry employment in period τ if

$$(14) \quad \Delta B(i,\tau-1) > 0 \text{ and } \Delta B(i,\tau) < 0,$$

that is, if the benefit from switching cannot be increased by entering industry X either earlier or later than period τ. All individuals whose ability bias value satisfies equation (14) will definitely switch in period τ. In addition to those definite switchers, there are marginal switchers in period τ, whose ability bias is denoted by $e(\tau)$. The marginal switcher is indifferent between switching in periods τ and $(\tau+1)$, as $\Delta B(\tau, \tau) = 0$. Using equation (13), the identity of the marginal switcher in period τ is determined by:

(15) $$e(\tau) = \{A\pi[1+s(\tau)]\} / [1-\delta^{-\tau} a_Y \Delta\gamma(\tau)].$$

The Appendix shows that strict concavity of $B(i, \tau)$ implies that the marginal switcher's ability bias is lower in period τ than period $\tau + 1$, for all relevant switching periods. Accordingly, the initial exogenous disturbance to the economy results in a gradual reallocation of labor that follows a well-defined pattern of sequential job switching. The time period in which individuals switch jobs to industry X is inversely related to their ability bias for work in industry Y; the less a person's relative ability for work in industry Y, the faster he or she will switch employment to industry X. Accordingly, the order of marginal switchers, from the period of the disturbance in the very short run until the adjustment is completed in the long run, can be described by:

(16) $$e(0) < e(1) < e(2) < .... < e(T).$$

The identity of a given period's marginal switcher, and therefore the period level of industry X employment and production, can be affected through a change in that period's production subsidy, $s(\tau)$. As one can see from equation (15), an increase in the value of the subsidy rate, $s(\tau)$, raises the value of $e(\tau)$ and thereby expands the number of people who will join industry X in period τ.

2.2. Employment, Industry Output, and National Income

The economy is populated by N people. It was shown above that the critical variable for determining the allocation of workers between industries at a given time is the marginal job switcher's ability bias for that period, measured by $e(\tau)$. In order to determine total industry production, we furthermore must specify whether a given industry employs high-skill or low-skill labor. In the low-skill industry, the identity of individual employees is irrelevant, as all people are able to provide exactly one unit of efficiency labor. In the high-skill industry, on the other hand, the identity of individual employees is of great importance for determining output; the most capable people are hired first and industry expansion is possible only by adding less productive workers.

Here we are going to explicitly develop the case in which industry X employs low-skill labor. Hence, $L_X(i) = 1$, while $L_Y(i)$ is uniformly distributed on the interval (0, 1). In time period τ, all people with ability bias $e(i) = L_Y(i) \geq e(\tau)$ work in industry Y; the remaining population is employed in industry X. Denoting the number of people employed in industry $j = X, Y$ by N_j, their respective period τ employment levels are:

$$N_X(\tau) = e(\tau)N \quad \text{and} \quad N_Y(\tau) = [1 - e(\tau)]N, \tag{17}$$

where $0 < e(\tau) < 1$.

To determine industry output, we make use of the production functions of equation (1). Since each employee of the low-skill industry X provides exactly one efficiency unit of labor, such that $L_X = N_X$, period τ output of industry X is:

$$X(\tau) = e(\tau)N/a_X. \tag{18}$$

In industry Y, each individual with ability bias equal to or greater than $e(\tau)$ provides $e(\tau) \leq e(i) \leq 1$ units of efficiency labor. Since L_Y is uniformly distributed, and $L_Y(i) = e(i)$, industry Y produces:

$$Y(\tau) = \left[1 - e(\tau)^2\right]N/[2a_Y]. \tag{19}$$

The industry output equations of (18) and (19) must be amended when good X is produced by a *high-skill* and good Y by a *low-skill* work force. In this case, ownership of labor efficiency units for work in industry X, $L_X(i)$, is uniformly distributed on the interval (0, 1), and $L_Y(i) = 1$ for each person. Noting that $e(i) = 1/L_X(i)$ in this case, the two industries' output equations become:

$$X(\tau) = \left[1 - 1/e(\tau)^2\right]N/[2a_X] \quad \text{and} \tag{18'}$$

$$Y(\tau) = N/[a_Y e(\tau)]. \tag{19'}$$

No matter which industry employs high-skill labor, the marginal switcher's ability bias, $e(\tau)$, rises over time as more workers move into industry X. During this adjustment process, the amount of good $Y(\tau)$ that must be sacrificed to gain an extra unit of $X(\tau)$ is $e(\tau)/A$ since:

$$[e(\tau)/A][dX(\tau)/de(\tau)] + [dY(\tau)/de(\tau)] = 0. \tag{20}$$

Clearly, the rate at which good Y is sacrificed for good X rises over time as people with relatively high skills for work in industry Y make the employment switch later than people with relatively low skills.

3. The Political Choice of Production Taxes and Subsidies

For this small, open economy, the world price of good X, π, is given and beyond control of the political process. The country's people, however, are able to vote on a production subsidy for period t, $s(t) > 0$, or tax, $s(t) < 0$, which affects the domestic price faced by firms, $p(t)$. Political choices are made through majority voting, and all individuals are assumed to participate in the voting. The initial vote takes place at the beginning of period zero. For convenience sake, it is assumed that, prior to this initial vote, economic policies were chosen through autocratic methods by a benevolent dictator; the resulting social welfare-maximizing policy, therefore, was $s = 0$. It follows from equation (15), interpreted for a long-run equilibrium in which $\Delta\gamma(.) = 0$, that the pre-voting marginal worker's ability bias was given by $\underline{e} = A\pi$. Whatever the initial referendum's outcome, the newly established democratic process permits follow-up referenda at the beginning of each subsequent period. Each time, voters can either confirm or correct their earlier made choice of a production policy for industry X.

At each referendum, person i knows which production policy is most preferred by him or her. The person would impose this policy on the rest of the economy if politically empowered to do so. This most preferred production policy maximizes the present value of person i's spendable income. Spendable income is gross wage income adjusted for redistributed tax revenues in the case of production taxes and income taxes collected for the financing of subsidy payments. Worker i, employed in industry j, receives gross wage income $L_j(i)w_j(t)$ during period t, where $w_j(t)$ was defined in equation (8).

If the government pays out production subsidies, it finances them through a factor income tax that is assumed to be *unbiased.* The tax is unbiased in the sense that it does not affect any person's income share; each person's net factor income share, evaluated after collecting income taxes to finance the subsidy, is the same as his or her gross factor income share, calculated on the basis of factor income before the collection of income taxes[8]. This unbiasedness feature of the income tax is assumed to be constitutionally guaranteed; and it is not subject to voting in each of the referenda. In case the government imposes production taxes, the redistribution of the collected tax revenues is also unbiased.

At the initial vote, it is industry X which is assumed to employ more

8. This assumption, frequently made about trade taxes in the political economy of international trade literature, serves the purpose of separating the political choice of a production tax or subsidy from the choice of an income transfer or tax system. For an application in the context of trade taxes, see Mayer (1984). Note that in our model of temporarily part-time working job-switchers, the base for collecting income tax is income a person is capable of,rather than actually, producing. Correspondingly, the variables X, Y and I express potential rather than actual values

than half of the labor force. The initial referendum's median voter, therefore, comes from industry X. Person i, of industry X, receives spendable income:

(21) $$I(i,t)=\phi_X(i,t)I(t)=\{L_X(i)\pi/a_X\}\{1+[s(t)Y(t)]/[p(t)X(t)+Y(t)]\},$$

during period t, where $\phi_X(i, t) = [L_X(i)w_X(t)]/[p(t)X(t) + Y(t)]\}$ measures the ith person's gross factor income share and $I(t) = [\pi X(t) + Y(t)]\}$ expresses potential national income at world prices. Note that, in deriving equation (2l), we made use of equation (3).

The initial vote is taken at the beginning of period zero. The ith voter's most preferred production subsidy, denoted by $s^{*i}(0)$, is that value of $s(0)$ which maximizes his (her) present value of net income[9].

(22) $$\sum_0^\infty I(i,t)\delta^t.$$

Accounting for equation (2l), the optimization problem can be reduced to:

(23) $$\max_{s^i(0)}\sum_0^\infty \delta^t [s(t)Y(t)]/[p(t)X(t)+Y(t)].$$

It is immediately clear from equation (23) that the ith voter's optimal choice of $s(0)$ is the same for all workers who are already employed in industry X. Importantly, the policy choice is independent of the innate abilities of the industry X worker in general and the politically decisive median worker in particular. The median voter's optimal policy choice, made through a referendum at the beginning of period 0, is indicated by $s^*(0)$.

The first-order conditions of the above-stated optimization problem imply that:

(24) $$s^*(0)=\{Y(0)[\pi X(0)+Y(0)]\}/\{[\pi e(0)][e(0)X(0)/A+Y(0)][dX(0)/de(0)]\},$$

where we substituted equation (20), as well as $de(0)/ds(0)=e(0)/[1+s(0)]$, derived from equation (15), and where all variables on the right-hand side

9. In doing so, the political choices of future production policies are correctly anticipated.

are evaluated at $s^*(0)$. Depending on the type of skills employed by industry X, we furthermore have:

$$(25)\quad dX(0)/de(0) = \begin{Bmatrix} X(0)/e(0) & \text{when industry } X \text{ is low-skill} \\ AY(0)/e(0)^2 & \text{when industry } X \text{ is high-skill.} \end{Bmatrix}.$$

The most obvious conclusion to be drawn from equation (24) is that all workers of industry X, including the median voter, choose a production subsidy, $s^* > 0$, rather than a tax, as their most preferred policy; all terms on the right-hand side of equation (24) must be positive.

The median voter's choice of a production subsidy, $s^*(0) > 0$, creates a distortion, evidenced by a decline in national income at world prices, $I(t)$. To show this decline, we first recall that, prior to the initial vote, the marginal job switcher's ability bias was $\underline{e}$. Enticed by the production subsidy, the least-efficient workers of industry Y immediately engage in extensive training and switch to industry X in period 0 already. As a result, the marginal switcher's ability bias rises to $e(0) > \underline{e}$. This short-term effect of the subsidy lowers national income at world prices right away; but the reallocation of labor continues over time, further raising the ability bias of the marginal job switcher and further lowering national income.

The relationship between national income at world prices and the marginal switcher's ability bias can be seen by differentiating $I(t) = [\pi X(t) + Y(t)]$ with respect to $e(t)$ and solving for

$$(26)\quad dI(t)/de(t) = \{\pi - [e(t)/A]\}\{dX(t)/de(t)\} < 0 \text{ for all } e(t) > \underline{e} = \pi A.$$

The referendum choice of a production subsidy at the beginning of period 0 unleashes adjustments that are felt long after period 0. If the adopted production subsidy $s^*(0)$ were to remain constant for all future periods, more workers, with increasingly higher ability bias for work in industry Y, would move from Y to X. The adjustment process is completed in period T, when all workers who have any kind of incentive to switch have completed their training[10]. During this adjustment process, both the nation as a whole and the winners in the first referendum, the political control-exerting industry X workers, become worse off. The gradual decline in the entire nation's well-being follows from equation (26) since $e(t)$ rises over time. The decline in spendable income of industry X workers,

10. Nobody has an incentive to stretch out training beyond period T since $\Delta\gamma(t) = 0$ for $t \geq T$. It follows from equation (15) that in long-run equilibrium the ability bias of the marginal switcher is $e(T) = A\pi[1 + s(T)]$.

on the other hand, can be seen from evaluating $I(i, t)$ in equation (22). With $e(t)$ rising over time, $Y(t)$ must decline, while national income at domestic prices, $[p(t)X(t) + Y(t)]$, must rise. The latter follows from

$$(27) \qquad d\left[p(t)X(t)+Y(t)\right]/de(t)=\left[\delta^{-t}a_Y\Delta\gamma(t)\right]\left[dY(t)/de(t)\right]>0,$$

where we made use of equations (20) and (15) and we recall that $\Delta\gamma(t) < 0$. Hence, the advantage for industry X workers of exerting political control diminishes over time.

This gradual decline in period income for the politically influential median voter, evaluated at a constant subsidy rate, raises the question of whether the median voter will try to revise the subsidy rate at the next referendum, at the beginning of period 1. In answering this question, we first note that the median voter of the follow-up referendum remains a worker who was already employed by industry X before the first referendum. His objective is to choose that value of $s(1)$ which maximizes $\sum_1^\infty \delta^t I(i,t)$, again correctly anticipating future optimal subsidy rate choices of $s^*(2)$, $s^*(3)$, etc. Analogous to equation (24), the first-order conditions imply that:

$$(24') \quad s^*(1)=\left\{Y(1)\left[\pi X(1)+Y(1)\right]\right\}/\left\{\left[\pi e(1)\right]\left[e(1)X(1)/A+Y(1)\right]\left[dX(1)/de(1)\right]\right\},$$

where all variables on the right-hand side are evaluated at $s^*(1)$.

In order to see if and how the median voter adjusts his or her production subsidy choice, we examine whether the right-hand side expression of equation (24'), evaluated at $s^*(0)$ (rather than $s^*(1)$), is larger, the same as, or smaller than the right-hand side expression of equation (24), also evaluated at $s^*(0)$. If the former exceeds the latter, then $s^*(1) > s^*(0)$; if the former falls short ofthe latter, then $s^*(1) < s^*(0)$. Going beyond the first two periods, we make this comparison for all periods $0 \leq t < T$ in order to establish whether subsidy rates rise or decline over time until the adjustment process is completed at time T. With this mind, we examine how

$$(28) \quad \left\{Y(t)\left[\pi X(t)+Y(t)\right]\right\}/\left\{\left[\pi e(t)\right]\left[e(t)X(t)/A+Y(t)\right]\left[dX(t)/de(t)\right]\right\},$$

evaluated at $s^*(t)$, changes over time as $e(t)$ rises.

The time path of production subsidies, chosen by the median voter, is crucially dependent on the skill-type of workers in the policy-controlling industry X. It will be shown next that it makes a great deal of difference whether industry X is a low-skill or high-skill industry. If it is a low-skill industry, every new worker who leaves industry Y provides exactly the same additional labor input to industry X. If it is a high-skill industry, early job switchers add more labor efficiency units to industry X than late job switchers and expansion of industry X over time attracts workers with increasingly lower productivity.

When industry X is low skill, equation (28) reduces to:

$$\text{(28')} \qquad \left\{Y(t)\left[\pi X(t)+Y(t)\right]\right\} \Big/ \left\{\left[\pi X(t)\right]\left[e(t)X(t)/A+Y(t)\right]\right\},$$

after substituting $dX(t)/de(t) = X(t)/e(t)$ from equation (18). Over time, as $e(t)$ rises, both terms in the numerator decline, while both terms in the denominator rise. Accordingly, the politically chosen production subsidy must decline over time when workers gradually move from the high- to the low-skill industry. The initially chosen production subsidy overshoots the ultimate long-run choice, and the distortion becomes less than it would be at a constant subsidy rate.

When industry X is high skill, equation (28) reduces to:

$$\text{(28'')} \qquad \left\{e(t)/[\pi A]\right\}\left[\pi X(t)+Y(t)\right] \Big/ \left[e(t)X(t)/A+Y(t)\right],$$

where we substituted $dX(t)/de(t) = AY(t)/e(t)^2$ from equation (18). Again it is the case that the value of the denominator rises and the second braced term of the numerator declines as $e(t)$ increases. These downward pulling forces, however, are more than offset by an increase in the term $e(t)/A$, as shown in the Appendix. Accordingly, the politically chosen production subsidy for a high-skill industry increases over time when more workers move from the declining low-skill to the expanding high-skill industry. The initially chosen production subsidy undershoots the ultimate, long-run production subsidy and the distortion becomes more severe than it would have been at a constant subsidy rate.

4. Concluding Remarks

This paper formulated a simple, general equilibrium production model with partial factor mobility in which factor-owning voters decide on a production tax or subsidy through majority voting. The median voter's policy choice changes over time in response to labor becoming increasingly mobile. In the short run, when little labor reallocation is feasible, the winners of the political game can grab huge benefits by imposing a distorting subsidy. As some labor slowly moves to the winning sector, the impact of the distortion deepens and both national income and well-being of the winners decline. The winners again and again correct past policies to retain as much as possible of their gains. When the winning industry is made up of people whose skills are easily acquired, the winners must cut back on the subsidy over time. When the winning industry is made up of people whose skills are increasingly difficult to find, the response is to raise the subsidy[11].

This model formulates a very specific type of resource reallocation, namely retraining of existing resources. Alternative models also can bring out the feature that factor owners react to current policies and thereby set the stage for the choice of different future policies. An alternative model might emphasize that resources have a finite lifetime and that, over time, old workers and old capital are replaced by new workers and new capital. New generations of factors are fully mobile when making employment decisions, whereas old generations of factors have become sector specific. In such a political economy model, the median voter of different referenda comes from different generations. The basic issue to be resolved through the political process, namely how policies are corrected over time as resource use adapts to prevailing policies, remains the same, however.

A third type of model might consider resource reallocation not just within a country but also between countries. The losers of a political policy choice might leave the country and thereby limit the gains to the winners even more. This is most likely when resources are owned in the form of pure human capital. Again, such emigration tends to be gradual and the winners must react to it by adjusting their policies.

Appendix A. The Marginal Switcher's Ability Bias Over Time

The marginal switcher of period τ, identified as $i = \tau$, is indifferent between switching in period $\tau + 1$ and τ, such that $\Delta B(\tau, \tau) = 0$. Combined with the strict concavity property of the net benefit function, as stated in equation (12), this implies that:

$$\text{(Al)} \quad \Delta B(\tau,\tau-1) = \left[L_X(i)/a_Y\right]\delta^{\tau-1}\left\{-A\pi\left[1+s(\tau-1)\right]+e(\tau)\left[1-\delta^{-\tau+1}a_\gamma\Delta\gamma(\tau-1)\right]\right\} > 0.$$

Use of equation (15) for $e(\tau-1)$ and substitution of $e(\tau-1)$ in (A1) implies that $e(\tau) > e(\tau-1)$.

11. In neither case can the correction of the subsidy reverse the decline of the winners' income over time, as can be seen from differentiating equation 2l with respect to $e(t)$, after substitution of the optimal subsidy rate.

B. Adjustment of the Expression in Equation (28") Over Time

Differentiating equation (28") with respect to $e(t)$ yields:

$$\text{(A2)} \qquad \frac{s(t)}{e(t)}\left\{1-\frac{Y(t)\left[1-\pi A/e(t)\right]}{\left[\pi X(t)+Y(t)\right]}-\frac{e(t)X(t)}{\left[e(t)X(t)+AY(t)\right]}\right\},$$

where we made use of equations (18'), (19'), (20), and (26) and we note that the value of the expression in equation (28") equals $s(t)$. The sign of (A2) is the same as the sign of the terms inside the brace which, in turn, has the sign of

$$\text{(A3)} \qquad \begin{aligned}&\left[\pi X(t)+Y(t)\right]-\left[e(t)X(t)/A+Y(t)\right]+\left[\pi A/e(t)\right]\left[e(t)X(t)/A+Y(t)\right]= \\ &\left[\pi A/e(t)\right]\left[e(t)X(t)/A+Y(t)\right]\left[s(t)-e(t)/(\pi A)+1\right].\end{aligned}$$

Substituting for $e(t)/(\pi A)$ from equation (15) and noting that $\Delta\gamma(t) < 0$, one can seethat the sign of (A3) is always positive. Hence, the expression of (28") rises over time.

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7 Lobbying for Tariff Protection and Allocation of Entrepreneurial Resources

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1. Introduction

According to the conventional analysis (see, for example, Todd Sandler, 1992) of the roles of pressure groups in policy formulation, one can expect that, under representative democracy, "the small exploits the large". This is because under institutions of representative democracy, government officials and political parties have needs that can be better satisfied by cohesive coalitions, because, compared with "diffuse" coalitions, these are less prone to defection and free-riding. Olson (1965) argued that small group size is advantageous in influencing policies. An implication of this is that the degree of concentration of an industry should be positively correlated with the extent of trade protection it receives. Empirical studies have however failed to give conclusive support for this hypothesis[1]. (See the surveys by Baldwin (1984), Hillman (1989, chapter 11), and Potters and Sloof (1996)).

Recently, Hillman et al. (2001) considered the theoretical foundations for the source of the above-mentioned empirical ambiguities. They reviewed the literature and developed a model of lobbying in which entre-

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1. Potters and Sloof (1996, pp.417-418) summarize the diversity of the extensive empirical evidence as follows: "Most scholars indeed find an increased scope for political influence with higher degrees of concentration, but there are many that find no effect or even a negative effect. Equally ambiguous are the results of the use of numbers for the free rider effect. A large number of participants to collective action is usually hypothesized to increase the free riding problem. Sometimes indeed a negative effect of numbers on influence is reported. More often, however, a positive effect is found. Hence there appears to be relatively little direct empirical support for the Olson (1965) influential theoretical study on collective action."

preneurs must allocate their limited resources (such as time) between political activities and internal control activities. In their model, domestic oligopolists supply their output for the domestic market, and lobby for *quota protection* against imports. They assumed that the quota is binding, and therefore in their model it is irrelevant whether foreign firms are oligopolists or perfectly competitive. The purpose of the present paper is to extend their model to the case where lobbying results in *tariff protection* rather than import quota. It is a well-known result that there is a fundamental non -equivalence between tariff and quota protections when domestic firms are oligopolists (see Vousden (1990)). Furthermore, when foreign firms are also oligopolists, then it would seem that, unlike the quota case, the ratio of domestic firms to foreign firms becomes a key parameter that influences the equilibrium amounts of lobbying.

Lobbying by individual firms for tariff protection is an instance of private contribution to a public good. *If* the contributions by firms are purely monetary, then the cost of contributions is only an income loss, and in such a situation, there seems to exist a parallel between a model of lobbying by firms and the familiar model where consumers voluntarily contribute for the provision of a public good (see Cornes and Sandler (1996)). Given that the public good is a normal good, when any given consumer increases his or her Nash contribution, the substitution and income effects on the contribution decisions of other consumers are in opposite directions. Therefore a larger contribution by one consumer needs not decrease the contribution of other consumers. An increase in group size (by adding new prospective contributors to the public good) therefore may result in an increase or decrease in total contribution. Furthermore, the total contribution by all individuals to provision of a public good is independent of the distribution of income among those consumers who are not at a corner solution (Warr (1983), Kemp (1984), Bergstrom, Bloom and Varian (1986)).

Hillman (1991), and Hillman et al. (2001), model lobbying by owners of firms who allocate time between the privately beneficial activity of monitoring internal production activities, and lobbying that yields the public-good benefit of increased protection for the entire industry. Firm owners have different comparative advantages in these activities. In Hillman (1991), the domestic industry consists of price-taking firms in a competitive world market. The world price of import-competing output is exogenously given, and the domestic price is determined by the given world price plus the tariff level obtained as a consequence of lobbying efforts. The strategic interdependence among firms is thus only with respect to contributions to influence policy, and not with respect to rivalry in the product market. This permits the industry seeking protection to be placed within the broader context of a competitive small-country model of international trade.

In Hillman et al. (2001), domestic firms are oligopolists. They are heterogeneous in terms of costs and lobbying ability (see also Long and Soubeyran (1996)). The instrument of protection is an import quota that is endogenously responsive to the total amount of resources contributed by domestic firms to influencing policy. The amount of resources that an oligopolist devotes to lobbying influences the cost structure of the oligopoly. In their model, it is assumed that either each firm faces a resource constraint, or each firm faces an increasing schedule of cost of funds that are to be allocated between political activities and internal cost-reducing activities. Because of these factors, as well as the oligopolistic market structure and the endogeneous determination of domestic price, contributions by firms to lobbying no longer have the characteristics of contributions to a "pure" public good. The industry equilibrium is therefore dependent on the characteristics of the lobbying technology and the domestic demand function. Hillman et al. (2001) asked the following questions (i) What are the properties of the equilibrium allocations of resources between privately profitable monitoring and collectively beneficial lobbying activities? (ii) Can the ranking of firms' profitability be reversed by the introduction of lobbying possibilities? And most basically (iii) Does the model lend support to the conventional wisdom that one should expect a positive correlation between the degree of concentration of an industry and its ability obtain protection?

In the present model of lobbying for tariff (rather than quota) protection, we ask the same questions. The results turn out to be very similar, though not identical to those obtained by Hillman et al. (2001). For the case of cooperative lobbying, we in fact obtain stronger results than the corresponding ones in Hillman et al. (2001).

Section 2 presents the model. We consider the outcomes when lobbying by firms is non-cooperative and cooperative in Sections 3 and 4 respectively. The final section offers some concluding remarks.

Before proceeding with the model, it is important to note that our endogenous-policy specification, which is in the same vein as Hillman et al. (2001), is quite general: it does not presuppose any one particular mechanism which translates lobbying inputs into endogenous policy outcomes. It is assumed that an increase in the resources available to the industry to influence policy enhances the lobbying effectiveness. The model is thus consistent with (a) an underlying political-support function of an incumbent government (for example Hillman (1982)) or (b) influence over candidates' trade policy platforms in the context of political competition (Hillman and Ursprung (1988), Mayer (1998)). With the notable exception of Hillman et al. (2001), in neither type of specification in the literature do we find an investigation of the collective-action incentives associated with industry concentration with which we are concerned[2]. As remarked by Hillman et al. (2001),

"in the micro-foundations for political support proposed by Grossman and Helpman (1994), either an industry has been successful in perfectly in-

2. The issue is also not addressed in the surveys by Magee (1984) and Rodrik (1995).

ternalizing collective action problems to permit collectively optimal political behavior, or otherwise the industry is not at all politically active. Hence, in Grossman-Helpman, the issue of the market structure of the industry, and the consequences for collective action in responding to the policy maker's readiness to "sell protection", do not at all arise. In models where trade policy is endogenously determined as the equilibrium outcome of political competition (as in Hillman-Ursprung (1988)), market structure implicitly affects the competing candidates' policy platforms, but in a rather simple way because of the homogeneity of firms; the political competition models can in principle address the issue of the relation between concentration and effectiveness of policy influence, but only in the sense of measurement of industry concentration in terms of the number of identical firms composing the industry."

2. The Model

We consider a "home-market model" with n oligopolistic firms producing a homogenous good. The first k firms are domestic firms and the remaining $n - k = k^*$ firms are foreign firms. Let K and K^* be the index sets of domestic and foreign firms respectively: $K = \{1, 2, ..., k\}$ and $K^* = \{k+1, ..., k+k^*\}$. We denote their outputs by q_i, $i \in K$, and q_f^*, $f \in K^*$. We define aggregate output of the domestic firms, and that of the foreign firms, by

$$Q = \sum_{i \in K} q_i, \quad Q^* = \sum_{f \in K^*} q_f.$$

Both Q and Q^* are sold in a single market: that of the home country. The inverse demand function is $P = P(Z)$, where $Z = Q + Q^*$, with $P' < 0$.

The marginal cost of firm i is c_i. We assume that c_i is independent of q_i, but is dependent on m_i, the amount of resources spent on internal cost-reducing activities (such as monitoring or R&D). We assume that $c_i(0) = \bar{c} > 0$ and $c_i'(m_i) < 0$. Domestic firm i has a *fixed* amount h_i of resources, of which m_i is used in cost-reducing activities and $a_i = h_i - m_i$ is used for lobbying. (Alternatively, one could consider the case where the amount h_i can be chosen, but the firm must incur a cost $\Omega(h_i) \geq 0$ to obtain h_i, and Ω', the marginal cost of obtaining h_i, is an increasing function of h_i; the results of this paper apply to this case, with only minor modifica-

3. Note that if the resources are funds rather than entrepreneurial time, then the fixity of h_i or the increasingness of $\Omega(h_i)$ imply that there is some sort of capital market imperfection in the background. It is well known that capital markets may be ridden by moral hazard and adverse selection problems. In the finance literature, many authors have suggested that credit rationing is a response to asymmetric information, and rising marginal cost of loans is a reflection of firm-specific risks, which make the market consider the I.O.U. s issued by the firm as a special asset without perfect substitutes.(See Milne 1975, Hellwig 1989, and Bester and Hellwig 1987.)

tions[3].)

The time allocation formulation does reflect an important feature of real world lobbying. As Hillman et al. argued,

"While a great deal of lobbying activities are undertaken by hired professional lobbyists, the importance of entrepreneurial time in lobbying and in public relation activities is also well recognized in the business world. The frequent public appearances of well-known individuals such as Lee Ioccoca and Bill Gates are not without opportunity costs in terms of internal controls. In Canada, when chief executive officers are chosen, an important criterion is their connection with Ottawa."

Unlike Hillman et al., in the present model, we assume that firms lobby in order to convince the government to impose a *tariff rate* t on the imported of good. We postulate that t is an *increasing function* of aggregate lobbying effort, $A = \sum_{i \in K} a_i$ and that there is diminishing returns to lobbying:

$$t'(A) > 0, \;\; t''(A) \leq 0.$$

We envisage a two-stage game. In Stage 1, the a_i's are chosen, either cooperatively or non-cooperatively, and this determines both the tariff rate t, and the amount $m_i = h_i - a_i \geq 0$ which is spent on internal cost-reducing activities. In Stage 2, given t, domestic firms choose non-cooperatively their output levels, and so do foreign firms. (This is in sharp contrast with Hillman et al. (2001), where the behavior of the foreign firms is not modelled.) As usual, we use the backward solution method, and solve the game in Stage 2 first. It is a simple Cournot game, with heterogenous firms.

Firm i's unit cost is $c_i(m_i) = c_i(h_i - a_i) \equiv \theta_i(a_i)$ which we denote by θ_i for short. Since $c_i' < 0$, $\theta_i'(a_i) > 0$. This indicates that if the firm allocates more resources to lobbying activities, then less cost reduction will be achieved. Firm $i \in K$ takes as given the tariff rate t and the total output of all other firms which we denote by Z_{-i}. It chooses q_i to maximize profit

$$\pi_i = P(Z_{-i} + q_i)q_i - \theta_i q_i. \tag{1}$$

The first order condition is

$$q_i P'(Z_{-i} + q_i) + P(Z_{-i} + q_i) = \theta_i. \tag{2}$$

The second order condition is

$$q_i P'' + 2P' \leq 0. \tag{3}$$

Similarly, for foreign firm $f \in K^*$, we have

$$q_f P'(Z_{-f} + q_f) + P(Z_{-f} + q_f) = c_f + t(A) \equiv \theta_f(A).$$

Summing the first order conditions for all firms yields

(4) $$ZP'(Z) + nP(Z) = C \equiv k^* t(A) + \sum_{i \in K} \theta_i(a_i) + \sum_{f \in K^*} c_f \equiv C.$$

It follows from equation (4) that industry output Z is a function of the sum of unit costs, C, which depends on the whole vector $a = (a_1, ..., a_k)$ and on A, which is the sum of the elements of vector a. Let us denote the left-hand side of (4) is assumed to be decreasing in Z. This condition may be expressed as

(5) $$E < n + 1.$$

where E is the elasticity of the slope of the demand curve. Condition (5) is one of the usual stability conditions of a Cournot equilibrium, see Dixit (1986). From equation (4) we obtain the equilibrium output Z as a function of the a_i

(6) $$\frac{\partial Z}{\partial a_i} = \frac{k^* t'(A) + \theta_i'}{[-P'][E - n - 1]} < 0.$$

As indicated by equation (6), lobbying by firm i has two effects on equilibrium industry output. An increase in a_i will increase the tariff rate t, thus reducing the outputs of foreign oligopolists. In addition, an increase in a_i means that, for a *given* h_i, less resources will be available for cost-reducing activities in firm i, hence its production cost will rise, reducing its equilibrium output. Note that while t depends only on the *sum* of the a_i's, the variable C depends on the whole vector $a = (a_1, ..., a_k)$ and *not just on the sum* of the a_i's. It follows that the model of Bergstrom, Blume and Varian (1986), which postulates that for each agent i, only a_i and the sum of the contributions of other agents matter, *does not apply* to our more complex model.

The equilibrium output of firm $i \in K$ is

(7) $$q_i = \frac{P[Z(a)] - \theta_i(a_i)}{[-P']},$$

and its equilibrium profit is

(8) $$\pi_i = \{P - \theta_i\}\ q_i = [-P']\ q_i^2 = \frac{1}{[-P']}[P - \theta_i]^2.$$

Similarly, for the foreign firms $f \in K^*$,

(9) $$q_f = \frac{P[Z(a)] - c_f - t(A)}{[-P']} \equiv \frac{P[Z(a)] - \theta_f}{[-P']},$$

and

(10) $$\pi_f = \{P - \theta_f\}\ q_f = [-P']\ q_f^2 = \frac{1}{[-P']}[P - \theta_f]^2.$$

These expressions will be useful in the analysis that follows.

3. Non-Cooperative Lobbying

Domestic firms may behave non-cooperatively or cooperatively in allocating resources to lobbying activities. In this section we consider the former case, leaving the latter case to Section 4. The non-cooperative lobbying case is an instance of a class of problems known as "the private provision of a public good." A *special case* of this class of problems has been considered by Bergstrom, Blume, and Varian (1986), who base their analysis on the assumptions that (i) in the production of the public good, only the sum of the contributions, $A \equiv \sum a_i$, matters, and that (ii) the payoff to each player depends only on this sum, A, and on his own contribution, independently of how much each of the other players contributes. Because of their restrictive assumptions, their model cannot be applied to our problem, where each firm i's payoff depends not only on A but also on C, and the latter is a function of the vector $a = (a_1, ..., a_k)$, not just of the sum A.

To proceed further, we follow Hillman et al. (2001), and focus on three types of functional relationship between c_i and m_i. Let us write

$$c_i(m_i) = \bar{c} - r_i(m_i),$$

where $r_i(m_i)$ may be Interpreted as the reduction in unit cost due to monitoring.

Specification 1. Increasing returns to monitoring.

$$r_i(m_i) = \delta_i m_i^{\alpha}, \quad \alpha > 1, \quad \delta_i > 0, \quad 0 \leq m_i \leq h_i.$$

Specification 2. Decreasing returns to monitoring.

$$r_i(m_i) = \delta_i m_i^{\alpha}, \quad 0 < \alpha > 1, \quad \delta_i > 0, \quad 0 \leq m_i \leq h_i.$$

Specification 3. Constant returns to monitoring.

$$r_i(m_i) = \delta_i m_i, \quad \delta_i > 0, \quad 0 \le m_i \le h_i.$$

Recall that $m_i = h_i - a_i$. Then

$$\theta_i(a_i) = \overline{c} - r_i(h_i - a_i), \tag{11}$$

and $\theta_i'(a_i)$ measures the marginal opportunity cost of lobbying, because an increase in a_i raises production cost, as entrepreneurial resources are diverted away from monitoring. From (8), firm i's profit in stage 2 is

$$\pi_i = [-P']q_i^2 = [-P']\left[\frac{P[Z(a)] - \theta_i(a_i)}{[-P']}\right]^2. \tag{12}$$

Given the a_j's ($j \neq i$), firm i chooses a_i to maximize (12) subject to the constraints $h_i - a_i \ge 0$ and $a_i \ge 0$. From the Lagrangian function

$$L = \pi_i + \lambda_i [h_i - a_i] + \mu_i a_i,$$

we obtain the first order condition

$$\frac{\partial L}{\partial a_i} = \frac{\partial \pi_i}{\partial a_i} - \lambda_i + \mu_i = 0.$$

At an interior maximum, we have

$$\theta_i'(a_i) = \frac{[\theta_i' + k^* t'](s_i E - 2)}{2(E - n - 1)}, \tag{13}$$

where s_i is firm i's market share:

$$s_i \equiv \frac{q_i}{Z}.$$

Equation (13) is intuitive appealing: at an interior maximum, an increase in the amount of resources devoted to lobbying will increase production cost by θ_i', and this must be equated to the marginal gain from lobbying (the right-hand side of (13)), which reflects the increase in price (modified for factors such as market share, and the effect of a price rise on revenue) brought about by a tariff increase. (In general, the maximum may occur at a corner: zero contribution to lobbying, if $\theta_i'(0)$ exceeds the marginal gain; or maximum contribution, $a_i = h_i$, if $\theta_i'(h_i)$ is smaller than the marginal gain. In what follows, we restrict attention to interior maxima.)

It is useful to re-write first order condition (13) as

(14) $$s_i E = 2 - 2\gamma_i\,[n + 1 - E]\,,$$

with γ_i being defined by

(15) $$\gamma_i \equiv \frac{\theta_i'(\hat{a}_i)}{\theta_i'(\hat{a}_i) + k^* t'(\hat{A})},$$

where all the derivatives are evaluated at the Nash equilibrium, and the hat over a variable indicates its equilibrium value. Equation (14) establishes a relationship between firm i's equilibrium market share s_i to γ_i, which is a measure of its comparative advantage in monitoring.

One of our aims is to find out how the heterogeneity among firms with respect to lobbying skills affect their relative contributions and their profits. Following Hillman et al. (2001), we make use of several measures of comparative and absolute advantage.

(i) A measure of **absolute advantage** in monitoring: If $\delta_i > \delta_j$ then we say firm i has absolute advantage in monitoring over firm j.

(ii) A measure of **comparative advantage** in monitoring: Firm i is said to have comparative advantage in monitoring over firm j if and only if $\gamma_i > \gamma_i$, where γ_i is defined by (15). This definition is motivated by the idea that a firm that has comparative advantage in monitoring would have a high θ_i', i.e., a high marginal cost of undertaking lobbying activities.

Several remarks are in order. Firstly, an equivalent ranking can be obtained by the following definition

(16) $$\beta_i = \frac{1}{\gamma_i} - 1.$$

If $\beta_j > \beta_i$ then firm j is said to have **comparative advantage in lobbying.** Note that $\beta_j > \beta_i$ if and only if $\gamma_i < \gamma_i$. Secondly, it should be noted that

(17) $$sgn\left[\gamma_i - \gamma_j\right] = sgn\left[\theta_i'(\hat{a}_i) - \theta_j'(\hat{a}_j)\right],$$

where *sgn* means ‘the sign of’. Thirdly, under Specification 3 (constant returns to monitoring), $\gamma_i > \gamma_i$ if and only if $\delta_i > \delta_j$. Thus, under constant returns to monitoring, comparative advantage *amounts to the same thing* as absolute advantage.

The Case of Linear Demand

We now present some results for the case of linear demand, $P = P^0 - bZ$, where $P^0 > 0$, and $b > 0$.

Proposition 3.1. *Assume linear demand and "increasing returns" in monitoring (i.e., specification 1). Then*

(a) *at an interior Nash equilibrium of the lobbying game for "tariff" protection, firms that are less efficient in monitoring in absolute terms (low δ_j) will devote more entrepreneurial resources to monitoring, and achieve lower cost and greater profit than other firms. Thus, the availability of lobbying opportunities* **reverses the ranking of firms' profitability** *if the Nash equilibrium is interior.*

(b) *there may exist a corner solution which also has the property of profitability ranking reversal.*

Proof

(a) From (13), at an interior equilibrium (with $E = 0$)

$$\theta_i'(\hat{a}_i) = \alpha \delta_i m_i^{\alpha-1} = \theta_j'(\hat{a}_i) \equiv B,$$

where B is the common value at equilibrium, for all domestic firms. It follows that if $\delta_i > \delta_j > 0$, then,

$$\frac{m_j}{m_i} = \left[\frac{\delta_i}{\delta_j}\right]^{1/(\alpha-1)} > 1,$$

since $\alpha > 1$.

Therefore

$$c_j(m_j) = \bar{c} - Bm_j < c_i(m_i).$$

Thus, for any pair of firms (i, j) withr $\delta_i > \delta_j > 0$ and $h_i = h_j$, in the absence of lobbying opportunities, firm i has lower cost and thus higher profit than firm j, but, when lobbying opportunities become available, at an interior Nash equilibrium, firm i will have higher cost and thus lower profit than firm j.

(b) To prove part (b), it suffices to provide a numerical example. Such an example can be constructed, see Hillman et al. (2001). □

Proposition 3.1 is similar to its counterpart in the quota case analysed in Hillman et al. (2001). We may explain Proposition 3.1 as follows. If there are no lobbying opportunities then, other things being equal, firms with a higher δ will have lower costs and therefore higher outputs and profits.

When lobbying opportunities become available, these large firms will tend to divert a lot of entrepreneurial resources to lobbying activities, because they expect a large gain from the rise in price that accompanies a higher tariff. Consider two domestic firms, 1 and 2, where firm 1 is more efficient in monitoring ($\delta_1 > \delta_2$). Then firm 1's marginal-cost-of-lobbying schedule, $\theta'_1(a_1)$ is everywhere above that of firm 2 if h_1 is equal to or is not too different from h_2. These schedules are downward-sloping because $\alpha > 1$. Firm 1, anticipating that the equilibrium $\hat{a}_2$ is small (the hat denotes the equilibrium value), perceives correctly that its marginal-benefit-of-lobbying schedule is quite high. Therefore it chooses a high $\hat{a}_1$. Firm 2, knowing that $\hat{a}_1$ is high, perceives its marginal-benefit-of-lobbying schedule to be quite low, so its low $\hat{a}_2$ is justified. The outcome is almost a free-ride for firm 2.

For the case of decreasing returns in monitoring, then it can be shown that profitability ranking is not reversed when lobbying opportunities for tariff protection are available. (The same result was obtained by Hillman et al. in the quota case.)

Proposition 3.2. *Assume linear demand and decreasing returns in monitoring (i.e., specification 2). Then, at an interior Nash equilibrium, firms that are less efficient in monitoring in absolute terms (low δ_j) will devote less entrepreneurial time to monitoring, and achieve higher cost and lower profit than other firms.*

We now turn to the question of whether an increase in the number of firms will reduce the aggregate lobbying effort for tariff protection. The answer is given by Proposition 3.3, which is somewhat different from the quota case.

Proposition 3.3. *Assume that the demand function is linear, $P = a - bZ$, and that all domestic firms are identical. Then an increase in the number of firms, without changing the endowment h_i of each firm, will reduce aggregate lobbying effort for tariff protection if and only if $a\theta''(a)/\theta'(a) < k/k^*$ (i.e., iff the elasticity of θ' is less than the ratio of domestic firms to foreign firms[4]).*

Proof

The first order condition (13) may be re-written as

$$t'(A) = \left[\frac{E(2 - s_i) - 2n}{Es_i - 2}\right]\frac{\theta'_i(a_i)}{k^*}.$$

4. In the quota case, the condition is the elasticity of θ' is less than unity.

With linear demand and identical firms, at a symmetric equilibrium this condition becomes

$$\left(1-\frac{k}{n}\right)t'(A)=\theta'\left(\frac{A}{n}\right).$$

This equation yields

$$\frac{dA}{dk}=\frac{1}{D}\left[\frac{A}{m^2}\theta''-\frac{1}{n}t'\right],$$

where

$$D=\frac{1}{m}\theta''-\left(1-\frac{k}{n}\right)t''>0,$$

because, in the linear demand case, the second order condition obtained from (13) implies $-D<0$.

It follows that

$$sgn\left(\frac{dA}{dk}\right)=sgn\left[\varepsilon-\frac{k}{k^*}\right],$$

where

$$\varepsilon\equiv a\,\theta''(a)/\theta'(a)$$

is the elasticity of θ'. □

We now turn to the non-linear demand case.

The Case of Non-Linear Demand

When the demand function is linear, it is convenient to make use of condition (14).

The following proposition relates the comparative advantage in monitoring with equilibrium market shares and profits.

Proposition 3.4. *Assume non-linear demand. Then at an interior Nash equilibrium,*

(a) If the demand curve is locally concave (E < 0), then firms that have greater "comparative advantage" in monitoring will have greater market shares and greater profits.

(b) *If the demand curve is locally convex ($E > 0$), then firms that have greater "comparative advantage" in monitoring will have smaller market shares and smaller profits. (In other words, the availability of lobbying opportunities "reverses" the profit ranking.)*

Proof

From (14)

$$s_i - s_j = \frac{2(\gamma_j - \gamma_i)[k + 1 - sE]}{E}. \tag{18}$$

Thus

$$sgn[s_i - s_j] = sgn[-E]\, sgn[\gamma_i - \gamma_j], \tag{19}$$

that is, $s_i - s_j$ has the same sign as that of $\gamma_i - \gamma_j$ if $E < 0$, and has opposite sign as that of $\gamma_i - \gamma_j$ if $E > 0$. Finally, from

$$\pi_i[-P']q_i^2 = [-P']Z^2 s_i^2. \quad \square \tag{8}$$

Remark

In order to understand the intuition behind Proposition 3.4, we must explicate the role of E. The following lemma, reported in Collie (1993) and Long and Soubeyran (1997), is useful for that purpose.

Lemma 3.1. *If $E < 0$ [respectively, $E > 0$] so that the demand curve is concave [respectively, convex], then an exogenous increase in tariff will expand the equilibrium output of lower cost domestic firms by more [respectively, by less] than that of higher cost domestic firms.*

Proof

Assume without loss of generality that firm i has lower cost than firm $j (c_j - c_i > 0)$. From (7) and (6),

$$q_i - q_j = \frac{1}{[-P']}(c_j - c_i),$$

and hence

$$\frac{d}{dt}\left[q_i - q_j\right] = \frac{1}{\left[-P'\right]^2}(c_j - c_i)P''\left[\frac{\partial Z}{\partial t}\right],$$

which is positive if $E < 0$. $\square$

It follows from Lemma 3.1 that if $E < 0$ then lower cost firms have a stronger incentive to contribute to lobbying. They devote more resources to lobbying, while still maintaining lower production costs. When firm 1 has a comparative advantage in monitoring, its marginal cost of lobbying, θ_1' is higher. If it expects a_2 to be small in equilibrium, then its marginal benefit curve (as a function of a_1) is also high (recall that E is negative) and in equilibrium, its contribution to lobbying could be slightly more than that of firm 2, without harming its cost ranking. In the opposite case where $E > 0$, all domestic firms still gain from lobbying, but the higher cost firms expand more relative to the lower cost firms.

4. The Cooperative Case

Let us turn to the case where firms coordinate their lobbying activities in the first stage, even though they are Cournot rivals in the product market in the second stage. This specification is in the spirit of the theory of semi-collusion (as exemplified by the works of Friedman and Thisse (1993), Fershtman and Gandal (1994), Nalebuff and Brandenburger (1996), among others), which is based on the observation that firms often cooperate in some spheres (such as R&D) while compete in other spheres.

Analysis of cooperative case can be complicated because in the first stage of the game there are incentives for firms to change the cost structure within the industry so as to reduce rivalry in the second stage. In other words, allocation of lobbying efforts now serves two distinct purposes: (i) to increase tariff protection against foreign imports, and (ii) to alter the composition or degree of concentration of the domestic industry. Because of (ii), coordination of lobbying is a surrogate for cooperation in the second stage (which is often prohibited by anti-trust laws). Thus it is possible that even if firms are ex-ante identical in all respects, their optimal coordination of lobbying effort may call for asymmetric contributions. Non-symmetric outcomes in a more general framework for cooperative oligopolistic games have been treated by Long and Soubeyran (1999, 2000). Hillman et al. (2001) provides a specific illustration.

In what follows, we consider only the case where the optimum is symmetric. The domestic firms agree on coordinating their a_i to maximize their joint profit

$$\Pi = \sum_{i \in K} \pi_i .$$

Then

$$\frac{\partial \Pi}{\partial a_i} = \sum_{j \in K} \frac{\partial \pi_j}{\partial a_i}.$$

It can be shown that

$$\frac{\partial \pi_j}{\partial a_i} = \left[\frac{Es_j - 2}{E - n - 1}\right]\left[\theta'_j + k^* t'\right] q_j > 0.$$

It follows that the first order condition for joint maximization is

(20) $$\frac{\partial \Pi}{\partial a_i} = \left[(\theta'_i + k^* t')\frac{EH_K - 2s_K}{E - n - 1} - 2s_i\theta'_i\right] Z = 0,$$

where

$$H_K = \sum_{j \in K} s_j^2,$$

is the Herfindahl index of concentration of the domestic firms, and $s_K \equiv Q/Z$ the market share of the domestic firms.

It is interesting to ask the following question: does more heterogeneity among domestic firms lead to a higher tariff rate? The answer turns out to depend on the curvature of the demand curve. Recall that Lemma 3.1 says that if the demand curve is convex ($E > 0$), then a given reduction in import quota tends to have an equalizing effect on firms's sizes (i.e., the big firms will expand by less than the smaller firms.) Therefore the marginal gain in domestic industry's profit, caused by an increase in A, is relatively low. This means that the industry will not spend much on lobbying. This effect will be mitigated, however, if firms are ex-ante sufficiently different. Thus we would expect that if E is positive, then A will be greater, the greater is the heterogeneity among firms. Now the Herfindahl index H_K is a measure of heterogeneity: given the number of firms, this index is smallest when firms are identical. Our reasoning suggests that, if E is positive, one should expect a positive correlation between H_K and the size of the domestic industry's market share.

We now can state the following proposition:

Proposition 4.1. *If $E > 0$, then aggregate lobbying effort A will tend to be inversely related to the degree of domestic concentration, as measured by the Herfindahl index of concentration of domestic firms. If $E < 0$, then aggregate lobbying effort A will tend to be positively correlated to the degree of domestic concentration.*

Proof

From (20) and the definition of β_i, we get

(21) $$\beta_i = \frac{2s_i(E - n - 1)}{EH_K - 2s_K}.$$

Summing (21) over all $i \in K$, we obtain

$$t'(A) = \frac{1}{G}\left[\frac{2s_i(E - n - 1)}{EH_K - 2s_K} - 1\right],$$

where

$$G \equiv k\sum_{i\in K}\frac{1}{\theta_i'}.$$

This concludes the proof. □

Proposition 4.1 is stronger than its counterpart in Hillman et al. (2001), where nothing definite could be said for the case $E < 0$.

5. Concluding Remarks

This paper deals with a model of an asymmetric oligopoly where domestic firms allocate entrepreneurial time between lobbying for tariff protection and internal control (monitoring). Our results reinforce the conclusions of the paper by Hillman et al. (2001) which dealt with the case of lobbying for quota protection. It was shown in both models that the availability of lobbying opportunities may have differential effects on the profit of heterogenous domestic firms. In particular, under non-cooperative lobbying, the ranking of profits may well be reversed when lobbying becomes possible. This profitability reversal result may be attributed to free riding in a non-cooperative equilibrium. In the cooperative lobbying case, by definition there is no free riding, and the optimal allocation of lobbying effort reflects both the desire for a higher tariff and the motive of altering the cost structure of the domestic industry. Both models lend only limited support to the conventional wisdom that industries with greater concentration tend to enjoy more protection.

In this paper, it was taken as exogenous whether firms cooperate or not. It would seem desirable to develop a theory of endogenous coalition formation in the lobbying game. Such a theory would have a flavor similar to that of the theory of endogenous vertical integration[5].

5. See Gaudet and Long (1996) for a model of endogenous vertical integration.

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8 Merger Policies and Trade Liberalisation

Henrik Horn and James Levinsohn*

This paper is about interactions between trade policy and a narrow but important aspect of competition policy, namely merger policy. The notion that trade policy and competition policy might be inter-related is not new. From a purely intuitive viewpoint, it is natural to suspect that the two types of policies might interact. After all, the large literature on trade policy in imperfectly competitive markets relies on the same sorts of market structures that have led industrial organisation economists to consider possible roles for competition policy. The market imperfections that give rise to pure profits motivate the potentially welfare-enhancing role for government intervention in both the domestic (competition policy) and international (trade policy) contexts.

Recent developments in the policy arena have elevated concern about possible links between trade and competition policy. In particular, as international economic integration has progressed, policy makers have started to ponder the possible conflicts arising from nationally pursued competition policies in more unified goods markets. An idea that is underlying much of this discussion is the notion that international trade liberalisation, by limiting countries' abilities to promote their self-interest with beggar-thy-neighbour trade policies, will induce countries to use competition policies instead to pursue the same goals (with similar beggar-thy-neighbour consequences.)

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International organisations traditionally concerned with trade policies have also turned their attention to competition policies. For example, the members of the World Trade Organisation (WTO) noted the importance of giving more attention to competition policies in their first ministerial-level meeting in December 1996. Also, for more than a decade, the OECD has focused attention on the interaction between trade and competition policies. The European Union has gone even further, suggesting an international agreement in competition policies. The EU has also in practice sought to solve the problem of often conflicting competition policies in the context of a unified European market through supra-national competition policies.

A recent example of the alleged interplay between national competition policies and multilateral trade liberalisation is the Kodak-Fuji dispute concerning Japanese imports of consumer photographic film and paper. The United States accused Japan of (among other things) nullifying or impairing benefits accruing to the United States from the GATT by pursuing slack competition policies (widely interpreted.) However, a Panel Report adopted by the WTO Dispute Settlement Body rejected the United States claims on the grounds that they were not substantiated.

The appropriate design of competition policies has been discussed in a voluminous literature that almost exclusively disregards open-economy aspects of the issues. The role of any one of these policies, though, may change when one analyses an open, as opposed to closed, economy. In this paper, we choose to focus on links between merger policies and trade liberalisation. We put special emphasis on the role that international agreements such as the GATT play when merger policies are nationally chosen. As noted above, of particular concern is the possibility that liberalisation of international trade will induce countries to use competition policies increasingly to promote national interests at the expense of others. We examine the incentives for a welfare maximising government to make such a substitution. Interpreting merger policy as a choice of degree of industrial concentration, we investigate how the merger policy that is optimal from the point of view of an individual country is affected by restrictions on the use of tariffs and export subsidies.

We show that the intuition with which many informed economists approach the links between trade and merger policy may be misleading. This intuition is the following: trade liberalisation increases competition in the domestic market so liberalisation acts as a substitute for a stricter competition policy. Hence, as trade is liberalised, there is less of a need for competition policy, and rationally acting countries will therefore pursue slacker policies than before liberalisation. The main message of this paper is that while the first part of this logic—the pro-competitive effect of liberalisation—often would be correct, this reasoning does not provide the basis for determining whether trade liberalisation will lead to a more lax competition policy.

The paper focuses on structural aspects of merger (and industrial) policies, rather than on details of specific merger cases. Thus, it can perhaps be viewed as being concerned with the formulation of the framework in which the day-to-day decisions are made; that is, the writing of the Merger Guidelines, rather than the implementation of them.

Two general points emerge from our analysis. First, merger policies are indeed associated with international externalities in open economies. This suggests that there are potential gains from international policy coordination, even though the magnitude of these gains in practice is unclear. The second point is perhaps more surprising. We argue that one should not expect to find any particular relationship between trade policy and merger policy. We do indeed an unambiguous relationship in all the parametric models we analyse—a relationship which runs in the *opposite* direction to what is commonly suggested. However, considering this relationship in a slightly more general framework strongly suggests that it could be of any nature. Thus, we find no theoretical presumption that international trade liberalisation induces countries to pursue merger policies that have more of a beggar-thy-neighbour flavour. In our view, the burden of proof falls rather heavily on those who argue that trade liberalisation necessitates an international agreement on competition policy.

The remainder of the paper is organised as follows. In Section 1, we very briefly review the literature on trade and competition policy. Section 2 then presents our general framework. In Section 3, we ask how the presence of international trade impacts on a country's incentives to concentrate production. In this Section and those that follow, we begin our analysis using a more general representation of demand, which frequently enables us to decompose the influences that policy makers face. We are seldom able to derive specific results, however, since too much simply depends on the shape of demand functions. We therefore turn to an even more specific framework—with linear demand—and analyse the issue at hand in this special but familiar context.

In Section 4, we introduce trade policy in the form of export subsidies. We first analyse the home country's optimal merger policy when the home country imposes an export subsidy. We next examine the issue when it is the foreign country that imposes the export subsidy. Section 5 introduces a foreign country that also pursues a merger policy, and analyses how trade liberalisation impacts on the *equilibrium* degree of industry concentration. This is done in the context of four different model specifications. Section 6 returns to the question of whether trade liberalisation increases the desirability of supranational merger policies. Section 7 concludes. Finally, the analytics of the linear model are gathered in the Appendix.

1. The Literature

Links between trade and competition policy were analysed by Acquier and Caves (1979) who examined tradeoffs between domestic consumer welfare and monopoly profits from abroad. One of the first reviews of the strategic trade policy literature, Dixit (1984), investigates how domestic welfare, in an oligopolistic model of international trade, depends on the number of home firms, the number of foreign firms, and export subsidies. Dixit raises 'the commonly expressed view that the existence of foreign competition makes domestic anti-trust policy unnecessary, and may even make it desirable to encourage mergers of domestic firms, or prevention of excessive entry, so as to keep the home industry strong enough to withstand the competition', although he does not explicitly analyse how optimal trade and merger policies interact.[1] At about the same time, industrial organisation economists, who traditionally thought about mergers in a strictly domestic context, gave consideration to the role of international markets in analysing mergers. (See, for example, Ordover and Willig (1986).) From the outset of the literature on trade and imperfect competition, there has been a realisation that trade and merger policy may interact. The literatures on strategic trade policy and domestic merger policy seem to have then treated each other like relatives that, once introduced, were best ignored. Very few, if any, of the strategic trade policy papers that followed gave much consideration to the existence of domestic competition policy, and similarly most of the developments in the merger policy literature ignored the role of international competition or trade policy.

In the last few years, attention has again focussed on links between trade and competition policy. This rapidly expanding literature typically focuses on merger policy in the presence of international competition. These papers, which might be thought of as 'open-economy industrial organisation', typically analyse how implications of domestic merger policy change when the domestic country trades with other countries. In these papers, while trade matters, *trade policy* is usually either very much in the background or simply absent. A much smaller set of papers explicitly considers the impact of trade policy.

Examples of economics-oriented papers analysing merger policy in the presence of international trade (but not trade policy) are Barros and Cabral (1994), Head and Ries (1997), and Levinsohn (1996), while more law-oriented papers appear in Hawk (1994), and in the proceedings from the ABA's Antitrust Law Journal's symposium on The Role of Foreign Competition in the U.S. Merger Enforcement' (1996). These papers recognise

1. Another early example is Brander and Spencer (1984) who consider an oligopoly model in which the importing country sets a tariff and the exporting country responds by setting the number of firms in the exporting industry.

that the optimal design of merger policy may change drastically as one moves to an open-economy context. Another economics-oriented paper is Bliss (1996), in which the author argues generally against international harmonisation of competition policies and analyses the possible role of competition policies to promote exports in a Krugman cross-hauling model.

There is also a related literature in international regulation which investigates the issue of the delegation of regulatory powers from national authorities to an international body. This question has been addressed by Bhagwati (1991) in connection with the broadening of the international policy agenda as well as by Gatsios and Seabright (1990) and Neven (1992), in relation to regulatory reforms in the European Community. These authors have attempted to identify the policies which should be subject to international negotiations or assigned to higher levels of government. Policy spillovers are identified as the key issue in this discussion because they are at the source of prisoners' dilemma outcomes.

Another branch of the literature consists of papers which more explicitly examine links between trade policy and competition policy. Indeed, titles such as 'Competition and Trade Policy: Identifying the Issues After the Uruguay Round', (Lloyd and Sampson (1995)) 'Competition Policy and Trade Policy: Mediating the Interface', (Trebilcock (1996)) Competition, 'Competition Policy and the GATT' (Hoekman and Mavriodis (1994)) and 'Trade Policy and Competition Policy' (Motta and Onida (1997)) suggest that we are not the first to think about these links. Here, papers are aptly divided into more applied policy papers and more analytically formal papers. The papers listed immediately above fall into the former category. We now discuss in more detail examples of the latter which are most closely related to this paper.

Neven and Seabright (1997) formally show that trade liberalisation and competition policy might be substitutes in terms of their effects. For instance, in one of the several models in their paper, they show how liberalising trade might increase competition in the home market and hence might perform the same task as competition policy, with the latter interpreted as promoting competition.[2] Their focus is not on optimal policy responses by the government, but rather on the changes in firms' incentives to engage in anti-competitive practices. They write that 'static models ... confirm the widely held presumption that trade liberalisation has pro-competitive effects'. Neven and Seabright are careful, though, to point out that in more complicated, often repeated game frameworks, the insights from the static framework may not be robust. They conclude that 'Overall, our analysis suggests that unalloyed confidence that trade liberalisation will

2. With 'competition policy' we refer in this paper to the usage of anti-trust instruments, rather than policies that promote competition as such. Hence, the last qualification in the statement in the text.

address problems of uncompetitive market structure ... would be inappropriate. Nevertheless, it supports the *general presumption* that trade and domestic competition policies are substitutes, albeit imperfect ones.' (Our italics.)

Bond (1997) develops a political economy model of merger policy in which the government maximises a social welfare function to decide whether or not to allow various mergers. Bond argues that the sorts of mergers that would be allowed when competing states make the decision differ from those that would be allowed when a federal government makes the decision. The model is then used to analyse how merger policy differed in the era during which United States' states set competition policy and more recently when the federal government set the policy. Bond draws analogies between setting policy at the federal level and setting competition policy in the context of a customs union.

Rysman (2000) is more closely related to ours. Rysman uses a linear Cournot model in which a country first selects the number of firms in the industry, then sets the optimal trade policy, and firms then compete in a Nash fashion. Rysman's model only considers a scenario in which firms from the home and foreign countries compete in a third market. Rysman finds that the strategic benefits from choosing a large number of firms due to the commitment this confers are negated by the foreign subsidy in the second period. Since, by assumption, there is no consumer surplus to consider, Rysman finds that countries choose a monopoly and subsidise that monopoly. When subsidies are restricted, such as under the GATT, countries move toward greater competition.

Francois and Horn (2000) examine the setting of national competition policy in a two-country setting, emphasising the relationship of trade patterns to the goals of competition policy. They study in particular the relationship of national competition policies to terms-of-trade gains and losses, and the general equilibrium distributional effects of competition policy. However, in contrast to the present analysis, they do not focus on the role of trade liberalisation.

Our paper is most closely related to work done concurrently and independently by Richardson (1999). The approaches and issues addressed are quite similar. Like us, Richardson works with a model in which countries strategically set both merger policy and trade policy. We differ by placing the issues in a more general context, addressing the role of a broader range of trade policies (i.e. subsidies as well as tariffs), and considering merger technologies that give rise to both fixed cost savings and lower marginal costs. Richardson, though, examines issues relating to customs unions which we ignore.

2. The Model

The model is a two country partial equilibrium set-up. Merger policy takes the particular form of choosing the optimal level of industry concentration.[3] The number of identical firms in the home (foreign) country is given by $m(n)$. We assume that markets are segmented and that firms produce with constant marginal costs c and fixed costs f. In a later formulation, we will allow the constant marginal cost to depend on the degree of concentration, in order to capture the notion of ‘marginal cost synergies’. Firms compete in Cournot fashion. The markets are thus strategically separated in the sense that firms’ decisions concerning one market do not affect their incentives in the other market. On the demand side of the model, we consider the homogeneous products case. Introducing the next-simplest case of symmetrically differentiated products as in the CES utility representation significantly complicates the welfare analysis, both since entry will introduce variety effects, and since firms first order conditions become much more involved.[4]

As noted above, the intention is to focus on structural aspects of merger policy. The paper will not explicitly take into consideration firms’ incentives to merge. To do this would require a theory of endogenous merger formation, something that would substantially complicate the analysis.[5] One cannot generally assume that the government can achieve any level of concentration it desires simply by deciding on an upper degree of concentration, since firms may not want to merge to this extent. Nevertheless, we assume that our governments, in the long run, can set the desired degree of industrial concentration, and our merger policy hence also borrows features of industrial policy.[6] In our defence, note that our disregard of the short-run merger incentives has a direct counterpart in much of the industrial organisation and strategic trade policy literature: if firms do not have incentives to merge in these models (whatever the appropriate theory of merger formation is), they are likely to want to divest. However, for unexplained reasons this is typically not permitted in these models.

3. In our use of the term domestic industry concentration’ below, we refer to the number of domestic firms in the domestic market.

4. As noted below, much of the analysis requires second-order, or mixed, derivatives of a social welfare function. We investigated differentiated products in both the Cournot and Bertrand case. In each, we were unable to make much headway due to the complexity of the higher order derivatives.

5. Note that the traditional criterion for merger incentives—that the merging group’s profit after merger is larger than in the initial situation—in itself does not provide a theory of merger formation, since it is constrained to a comparison of two out of many possible configurations of merging firms. (See Horn and Persson (2001)).

6. As long as profits are positive, as they are in our parametric models below, the government can also influence entry.

Trade policy for the home (foreign) country is represented by the choice of a variable $r(s)$. We initially concentrate on the case of export subsidies (or export taxes if negative), but we will later consider specific tariffs. Let $\Pi^h(m, n, s)$ be the variable profits per firm in the home market, and let $\Pi^f(m, n, r)$ be the corresponding profits in the foreign markets net of the subsidy. The reduced form welfare level for the home country is given by $V(m, n, r, s)$, and consists of consumer surplus, $CS(m, n, s)$; industry variable profits from sales to the home market, $H(m, n, s) \equiv m\Pi^h(m, n, s)$; industry variable profits from export sales to the other country net the export subsidy, $E(m, n, r) \equiv m\Pi^f(m, n, r)$; and industry fixed costs, mf. In general, then,

$$V(m, n, r, s) = CS(m, n, s) + H(m, n, s) + E(m, n, r) - mf.$$

The model above is very, very simple. Somewhat surprisingly, even this model typically yields ambiguous answers to key questions. We believe this, in and of itself, is actually informative in that it warns us not to expect any simple relationships between trade and competition policies. Nonetheless, in an effort to derive more definitive results, we will sometimes impose more structure on the model. In these instances, we will assume that there is a linear industry demand, $p = a - bQ$, in each national market.

Before employing this model in any detail, it is useful to re-state why we are doing the analysis in the first place. As noted in the introduction, the policy concern that motivates this analysis is that as trade policy is liberalised, governments will have an increased incentive to act in a beggar-thy-neighbour fashion in setting their competition policy. If this is true, the role of internationally coordinated competition policy may be enhanced. The implicit assumption in this argument is that governments are acting rationally in their own (as opposed to global) self-interest and they do so before, as well as after, any trade liberalisation. For example, in our equilibrium framework, governments have an incentive to engage in trade policy. The same market structures that underlie this incentive also provide an incentive for the government to engage in competition policy. At the heart of the analysis is the *interaction* of these two sets of incentives. The question then becomes one of how this rational behaviour is impacted by trade liberalisation. Formally, this involves analysing how first-order conditions with respect to merger policy are affected by the trade policy regime. Note that this approach differs fundamentally from that of asking how the ‘need’ to pursue vigorous competition policies is affected by trade liberalisation. Our approach is, in this respect, the same as that of Richardson (1999), Bond (1997), and Rysman (2000).

We will consider cases where the trade policy is discretionarily determined by each country, and where it is constrained by an international trade agreement (the 'GATT'). Similarly, we will consider cases where merger policies are set at a national as well as at an international level. To understand this interaction between policies and between countries better, it is useful initially to highlight the channels through which trade by itself affects an individual country's incentives with regard to merger policy (which is modeled here as the country's optimal degree of concentration.) This is only an intermediate step, since the full analysis will have to take into consideration the interplay between the setting of trade and merger policies in the two economies.

3. Trade and the Incentives to Concentrate Production

In this Section, we use the framework developed above to begin to investigate links between international trade and a country's optimal degree of concentration while assuming there is no trade policy intervention.

When there is no international trade, the utility of the home country is determined by the number of domestic firms m and is given by $CS(m, 0, \cdot) + H(m, 0, \cdot) - mf$. Hence, with consumer surplus increasing in the number of firms ($C_m > 0$) and industry variable profits declining in the number of firms ($H_m < 0$), the optimal industrial concentration is in standard fashion such that the gain in consumer surplus from one more firm equals the sum of the resulting loss in industry profits and the additional fixed cost. Let m^a be the optimal degree of concentration in autarky.

There are two basic reasons why the optimal degree of concentration may differ in closed and open economies—trade enables home country firms to sell in foreign markets and it enables foreign firms to sell in the home country market. The home country's optimal degree of concentration is affected by trade through both these channels. Each is discussed in turn.

3.1. Foreign Consumers

Consider first how the presence of foreign consumers affects the optimal degree of concentration, assuming that there are no foreign firms, and that the home country does not use its trade policy. Home country welfare is now given by:

$$V(m, 0, 0, \cdot) = CS(m, 0, 0, \cdot) + H(m, 0, 0, \cdot) + E(m, 0, 0, \cdot) - mf.$$

Differentiating this expression w.r.t. m, and evaluating V_m at the autarky optimal level of industrial concentration yields:

$$V_m(m^a, 0, 0, \cdot) = E_m(m^a, 0, 0, \cdot).$$

Since $E(m, 0, 0) \equiv m\Pi^f(m, 0, 0)$, and industry profits typically decrease in the number of firms, $E_m(m, 0, 0)$ is in general negative. This is because there are no foreign firms and hence no foreign profits to shift. Domestic profits from the foreign market, then, are going to be maximised with collusion as any competition in the foreign market is destructive. With $V_m(m^a, 0, 0, \bullet) < 0$, adding a firm, relative to the autarky number of firms, reduces welfare, hence the optimal number of firms in the exporting free trade equilibrium will be smaller than the optimal number of firms in the autarkic equilibrium. Thus, *the presence of foreign consumers yields an incentive for the domestic country to increase the degree of concentration*.

3.2. Foreign Producers

International trade also implies competition from foreign firms, and the degree of this competition is influenced by the degree of foreign concentration. We begin by examining how foreign concentration affects the optimal degree of concentration among home firms, i.e., whether the two policies are strategic substitutes or complements. For the sake of clarity, we continue to assume that neither country uses trade policies. The impact on the home country's incentives is now captured by the relevant mixed derivative

$$V_{mn}(m, n, 0) = CS_{mn}(m, n, 0) + H_{mn}(m, n, 0) + E_{mn}(m, n, 0).$$

Given our assumption of a symmetric demand structure, the lack of trade barriers means that we can write welfare as

$$V(m, n, 0, 0) = CS(N) + m\Pi(N) - mf,$$

where $N = m + n$, and $\Pi(N)$ is total variable profits per firm resulting from home and foreign markets. The mixed derivative can hence be expressed as

$$V_{mn} = CS_{NN} + \Pi_N + m\Pi_{NN}. \tag{1}$$

This expression shows how the incentives for domestic concentration change with the introduction of another foreign firm.
To interpret (1), note that since output is homogeneous, we can rewrite the consumer surplus as

$$\begin{aligned} CS(m, n, s) &\equiv \tilde{C}S\ Q \\ &\equiv \int_0^Q P(\xi)d\xi - P(Q)Q, \end{aligned}$$

where $Q \equiv Q(m, n, s)$ is the total output volume sold in the home country market, and $P(Q)$ is the inverse demand function. We then have

$$\tilde{CS}_{QQ}\ Q = -P' - QP''.$$

Hence, a sufficient condition for $\tilde{CS}$ to be convex in total output is that $P'' \leq 0$.

Now return to (1). The first term shows how the benefit to consumers of another domestic firm changes with the introduction of another foreign firm. Expressing the consumer surplus as $\tilde{CS}[Q(N)]$, we have:

$$CS_{NN} = \tilde{CS}_{QQ} Q_N^2 + \tilde{CS}_Q Q_{NN}.$$

With general demands, the term Q_{NN} will depend on the third order derivatives of demand, and will thus be ambiguously signed. But, with linear demands, CS_{NN} is unambiguously negative: consumer surplus is convex in total output $(\tilde{CS}_{QQ} > 0)$, but the latter is concave in the number of firms ($Q_{NN} < 0$), and the latter effect dominates the former.

The second term in (1) represents the fall in profit per domestic firm with the introduction of another foreign firm to the market, and hence is negative. This effect tends to make foreign and domestic concentration strategic substitutes.

To interpret the third term in (1), think of $m\Pi_N$ as the industry-level profit destruction effect of entry of another domestic firm. The third term then gives how this industry profit destruction changes when a foreign firm enters. Without more structure, this term is also ambiguously signed. This is even true in the linear model. With industry demand given by $p = a - bQ$ and marginal costs given by c,

$$H_{mn} = E_{mn} = \frac{2(a-c)^2(2m-n-1)}{b(m+n+1)^4},$$

(still assuming the export subsidies are nil). This term can take on either sign, and will tend to be negative the lower is the degree of foreign concentration.[7]

The sign of V_{mn} is important in that it yields information about the strategic relationship between merger policies in the two countries, similar to the issue of whether outputs or prices of competing firms are strategic substitutes or complements. If $V_{mn} < 0$ (> 0), the optimal response on part of the home country to increased foreign concentration, is less (more) concen-

7. Details of the linear model are gathered in the Appendix.

tration. We cannot sign this derivative in general. However, it is note worthy that it is not sign-able even in the linear case:

$$V_{mn} = \frac{3(a-c)^2(2m-2n-1)}{b(m+n+1)^4}.$$

We conclude that the fundamental issue of whether more foreign competition yields incentives for more or less domestic competition cannot be determined unambiguously, and that restricting the analysis to the linear model does not change this ambiguity. This may appear somewhat surprising, considering the intuitively appealing notion that increased international competition should lessen the need for domestic competition, and thus for a restrictive merger policy. It is indeed correct in that international competition is a *substitute* for domestic competition, in the sense that it can perform the same role of disciplining firms serving the domestic market. However, the impact of international competition on incentives with regard to merger policy are determined by how increased foreign competition affects the *marginal* benefits and costs of domestic concentration. Whether foreign and domestic competition are *strategic* substitutes or complements is a much more subtle issue. From an analytic point of view, this is a simple point. But it is a crucial point if one is to understand why our results differ from those of the earlier literature, and it has not been appreciated in the policy discussion.

4. Export Subsidies and the Incentives to Concentrate Production

The previous Section looked at how international trade affects competition policy incentives assuming free trade. The main goal of this paper, though, is to consider the impact of trade liberalisation on the equilibrium degree of concentration. In this Section, we take a step towards that goal by introducing export subsidies. We first investigate how a country's merger policy interacts with its choice of export subsidy. We then investigate how the home country's merger policy interacts with the export subsidy of its trading partner.

4.1. Domestic Export Subsidies

Because of the strategic separability between the two markets, the optimal export subsidy depends only on conditions in the foreign market. The optimal subsidy is implied by the first order condition:

$$V_r(m,n,r,s) = 0 = m\prod_r^f(m,n,r),$$

hence its sign depends on whether home profits in the foreign market increase or decrease with the subsidy. In the special case where there are no foreign firms, the optimal subsidy would be negative. In this case, the negative subsidy (tax) works to deter destructive competition. More generally, the optimal subsidy would be positive with foreign firms in the foreign market in the Cournot case, as shown by Brander and Spencer (1985) and negative in the Bertrand case, as demonstrated by Eaton and Grossman (1986).

The direct impact of an exogenous change in the domestic export subsidy on the incentives with regard to the domestic degree of concentration, is given by

$$\begin{aligned} V_{mr} &= \frac{\partial^2}{\partial m \partial r}\left[m\Pi^f(m,n,r,s)\right] \\ &= \Pi_r^f(m,n,r) + m\Pi_{mr}^f(m,n,r), \end{aligned}$$

since a change in the subsidy has no impact on domestic consumer surplus or profits from the domestic market. In order to disentangle the various forces determining the sign of this expression, we will first assume the absence of foreign competition in the export market, so that the role of the export subsidy is to facilitate the extraction of foreign consumer surplus. We will then consider the case when it is used as a 'strategic trade policy' instrument, i.e., to shift foreign producer surplus.

When there is no foreign competition, there are two basic forces at work in determining the sign of V_{mr}. To see this, let $X(m, r)$ be the industry output sold in the foreign market: $X(m, r) \equiv mx(m, r)$ where $x(m, r)$ is the reduced form output per firm in the foreign market. Due to the linear cost structure, variable profits in the foreign market can then be written as:

$$\begin{aligned} m\Pi^f(m,0,r) &= P\left[X(m,r)\right]X(m,r) - cX(m,r) \\ &\equiv \Pi^M\left[X(m,r)\right]. \end{aligned}$$

Note that $\Pi^M(X)$ is simply the profit function that a monopolist would face if selling in the foreign market at constant marginal cost c. We assume that this profit is concave in the output volume. Also, let $r^*(m)$ be the optimal trade policy, given some arbitrary degree of domestic concentration m:

$$V_r(m, 0, r^*(m), \bullet) \equiv 0.$$

Hence,

$$\Pi_X^M\left(X\left(m,r^*(m)\right)\right)=0.$$

When there is no foreign competition, the optimal export subsidy induces the firms in the industry to jointly act as a monopolist in the foreign market. Since the oligopoly is over-producing compared to the optimal behaviour of the monopolist, the optimal trade policy is to tax the foreign sales of the oligopolists. This is welfare maximising since subsidy revenue is a pure transfer and any competition in the foreign market would just destroy profits.

Now return to the mixed derivative linking trade and merger policy in the case of no foreign firms:

$$V_{mr}=\Pi_{XX}^M X_m X_r+\Pi_X^m X_{rm}.$$

At the optimal trade policy, r^*, this derivative is given by:

$$V_{mr}\left(m,0,r^*(m)\right)=\Pi_{XX}^M X_m X_r,$$

since $\Pi_X^m=0.$ The first element of the product on the right-hand side is negative by the concavity of the profit function. The second element, X_m, gives the effect on industry output of the entry of an additional firm, and this will be positive. (Were this not the case, consumers would lose from the entry of an additional firm.) The third element, which equals mx_r, is again positive and gives the impact on industry output of an increase in the subsidy. Hence, $V_{mr}<0$.

It is reasonable to think of trade liberalisation as r moving toward zero. The above finding then implies that *in the absence of foreign competition, the optimal degree of domestic concentration increases with a small move toward home country trade liberalisation*. Intuitively, the negative mixed derivative V_{mr} directly reflects on the link between a country's optimal merger policy and its trade policy. Starting at the optimal export tax, a small reduction in this tax (an increase in r) will induce the home country to reduce the number of firms. This is simply a reflection of the fact noted above: When there are no export subsidies and there is no foreign competition, it is optimal for the domestic economy to be a monopolist in the foreign market. Adding domestic consumers into the picture introduces a trade-off and calls for a larger number of firms. The domestic export subsidy tends to ease this conflict between what is the optimal degree of concentration in the domestic and in the foreign markets. In fact, with two markets, the two policy tools m and r allow the home country to reach a first best with regard to capturing surplus in the foreign market.

Finally, in the case of the linear Cournot model we can also show that $V_{mr}(m, 0, r) < 0$ even if the export subsidy is not optimally set, as long as $r \geq r^*(m)$ (recall that $r^*(m) < 0$ in this case). This can be seen from the fact that for $n = 0$,

$$V_{mr} = -\frac{(a-c)(3m-1)+mr}{b(m+1)^3}.$$

Since this expression is negative at $r = r^*(m)$, it must be so *a fortiori* for larger values of r.

Next, we add foreign producers back into the calculations. Export subsidies (or taxes) play a role in addition to just restricting destructive competition in the foreign market. Now, export subsidies may serve to shift profits from the foreign to the domestic firms, as demonstrated by Brander and Spencer (1985). These subsidies, though, may also interact with the optimal degree of concentration—this is indeed the expressed fear behind some of the calls for international agreements on competition policies. It is difficult in general to draw any affirmative conclusions regarding the link between the two types of policies. Formally, the question boils down to whether V_{mr} is positive or negative for $n > 0$. The reasoning in the previous subsection is not directly applicable, since it relied on the absence of foreign firms. However, in the linear model, we have that $V_{mr} < 0$ also in the presence of foreign firms, as long as the export subsidy is at the optimal level

$$r^* = -\frac{(a-c)(m-n-1)}{2m(n+1)},$$

since in this case

$$V_{mr} = -\frac{(a-c)(n+1)}{b(m+n+1)^2} < 0.$$

But, when r is not optimal, the presence of foreign firms makes the sign of the mixed derivative unclear. For instance, at $r = 0$,

$$V_{mr} = -\frac{(a-c)(n+1)(3m-n-1)}{b(m+n+1)^3}.$$

This expression is positive for $n > 3m-1$. In such a case the introduction of a small positive export subsidy, which in itself would increase welfare since

$$V_r = -\frac{(a-c)m(m-n-1)}{b(m+n+1)^2} > 0$$

at $r = 0$, would give an incentive to the home country to reduce the degree of domestic concentration.

In sum, *there is no unambiguous relationship between the level of the domestic export subsidy and the optimal degree of concentration—not even in the linear case*.

4.2. Foreign Export Subsidies

We next consider export subsidies levied by the foreign government. The direct impact of the foreign subsidy on domestic welfare is

$$V_s = CS_s(m, n, s) + H_s(m, n, s).$$

In a standard model, the first term is positive, reflecting the gain to consumers from increased total supply to the market, and the second term is negative, since the subsidy yields a smaller market share for the domestic producers. The balance of these terms cannot be determined *a priori*: the negative profit shifting effect may outweigh the gain to consumers. This is true even in the linear model.[8]

Now turn to the implication of the foreign subsidy for the incentives with regard to the optimal degree of concentration:

$$V_{ms} = CS_{ms}(m, n, s) + H_{ms}(m, n, s).$$

Not surprisingly, this is also of ambiguous sign. The basic impact of the foreign subsidy is to increase the output of foreign firms, to reduce that of domestic firms, while in the aggregate yielding an output expansion. The term CS_{ms} measures the change in the sensitivity of consumer surplus to the number of domestic firms. With homogeneous outputs, it can be rewritten as

8. For instance, in the linear model $V_s = \{n/[b(m + n + 1)^2]\}[(a - c)(n - m) + ns(2m + 1)]$, a foreign export subsidy definitely benefits the domestic economy if $n \geq m$, while it will be detrimental if $n < [(a - c)\, m]/(a - c + 2sm + s)$. These equations are very similar to those derived in Dixit (1984). The key difference between Dixit's work and ours is that Dixit was concerned with the first derivatives (i.e. V_s) whereas we focus on the second mixed derivatives. Dixit's work, then, is an essential building block to ours.

$$CS_{ms} = \tilde{CS}_{QQ} Q_s Q_m + \tilde{CS}_Q Q_{sm}.$$

Again, both $\tilde{CS}_{QQ}$ and Q_{sm} are of ambiguous sign, with the latter involving third-order derivatives of the demand function. A similar ambiguity applies to the sign of H_{ms}. This basic lack of a clear impact of s on the incentives w.r.t. m is also evidenced by the fact that in the linear Cournot model,

$$sgn[V_{ms}] = sgn[(a - c)(m - 3n - 1) - 2ns\ (m - n)],$$

which clearly can take on either sign. We conclude that *the impact of the foreign export subsidy on the optimal degree of domestic concentration simply depends on the details of the situation even in the linear case*.

5. Multilateral Trade Liberalisation and the Equilibrium Degree of Concentration

Thus far we have examined the incentives the home country faces without considering the fact that the foreign country may also be strategically setting trade and merger policy. In order to consider the impact of multilateral trade liberalisation, however, one must take into consideration the fact that the foreign country will also change its policies in response to the trade liberalisation. To fix ideas, suppose one wishes to analyse the impact of the GATT, and that this is modelled as a move toward freer trade by both countries. In terms of the model, this amounts to reductions in both r and s, both of which will affect the home country's optimal degree of concentration. But this liberalisation will also affect the foreign country's chosen degree of concentration, and this will in turn affect the home country's decision problem with regard to the degree of concentration. Thus, several of the affects we considered one-by-one in the previous sections will now jointly impact the outcome.

We begin in Section 5.1 with export subsidies in the more general case. Here, we outline the forces that come into play and we provide a general modelling strategy. In order to obtain more determinate results, we then turn to variants of the linear demand model. Using the linear model we first examine, in Section 5.1.1, the case in which fixed costs give rise to economies of scale, but there are no marginal cost synergies. Since our focus is on the equilibrium degrees of concentration that result from trade liberalisation, we need to characterise the degree of concentration somehow. We do so in two ways—by counting the number of firms and in terms of the resulting Lerner index. We then investigate in Section 5.1.2 the case in which merger policy is more long run than trade policy. In Section 5.1.3, we consider the (still linear) case in which mergers convey marginal cost synergies, and we again compare the resulting equilibrium degrees of concentration. We conclude this Section by changing our focus from export subsidies to import tariffs (Section 5.2). We again characterise the resulting equilibrium degrees of concentration in terms of both the number of firms and in terms of Lerner indices.

5.1. Export Subsidies

We begin by assuming that countries simultaneously determine the degree of concentration and their export subsidies (if these are permitted by the trade regime).

In order to facilitate the analysis, we concentrate throughout on cases where the countries are identical, so as to allow symmetric equilibria with $r = s$ and $m = n$. There are four types of equilibria (in addition to autarky) that are of interest. In the 'discretionary' equilibrium, given by the pair (m^d, r^d), each country discretionarily chooses both its trade policy and the degree of concentration among domestic firms. This equilibrium is given by:

$$V_m(m, m, r, r) = 0,$$

$$V_r(m, m, r, r) = 0.$$

In the 'GATT' equilibrium $(m^g, 0)$, countries continue to choose concentration discretionarily, but have agreed not to utilise export subsidies:

$$V_m(m, m, 0, 0) = 0.$$

There are two cases where the degree of concentration is set by a supranational agency that maximises world welfare. A first case, which is obviously of less practical relevance (but is still of interest in that it yields information about the externalities involved in the merger policies) is where the countries retain the possibility to choose their export subsidies in a discretionary manner. The resulting degree of concentration and export subsidies are denoted (m^k, r^k), and are given by

$$V_m(m, m, r, r) + V_n(m, m, r, r) = 0,$$

$$V_r(m, m, r, r) = 0.$$

The other, and practically perhaps more interesting, case is where the 'GATT' is augmented by a supranational merger policy. We denote the resulting concentration level as m^S. Because of the assumed symmetry between the markets, it is given by:

$$V_m(m, m, 0, 0) + V_n(m, m, 0, 0) = 0.$$

Our interest is in comparing the degrees of concentration in the different policy regimes. An indication of the relative magnitude of m^d and m^g could be obtained by considering a marginal reduction in the subsidy from the discretionary level, assuming national merger policies:

$$\frac{dm}{dr} = -\frac{V_{mr} + V_{ms}}{V_{mm} + V_{mn}}.$$

However, note that the mixed derivatives that appear in the above equation are exactly the same as those we have already investigated, with the exception of V_{mn}, which has implicitly been assumed to be negative to ensure that one of the second-order conditions for the government's optimisation problem is fulfilled. As was seen above, most of these derivatives are of ambiguous sign. While in principle it is possible that the assumed symmetry between the countries might have helped to determine the direction in which concentration moves, we found that *even in the symmetric case one should not expect international trade liberalisation to have any particular effect on the equilibrium degree of concentration*. Instead, in order to get clear-cut results we turn now to models with linear demands to investigate these issues.

5.1.1. Fixed Cost Savings

In this subsection and those that follow, we work with a linear demand model. Before going further, we quickly review notation. As before, m denotes the number of home firms and n the number of foreign firms. Inverse demand is given by $p = a - bQ$. Fixed costs are denoted f and marginal costs are denoted c.

We begin by comparing the equilibria for the four cases considered above when fixed costs give rise to economies of scale, but where there are no marginal cost synergies. In the benchmark case of autarky, the equilibrium (and optimal) degree of concentration m^a is given by[9]

(2) $$(m + 1)^3 = h,$$

where $h \equiv (a - c)^2/(bf)$.[10]

Secondly, the 'pre-GATT' equilibrium degree of concentration, m^d, is characterised by the equation

(3) $$2(m + 1)(2m + 1) = h.$$

9. The derivations for the parametric models in the paper are done with the aide of the computer programs Derive-XM Ver. 3.0, and Scientific workplace 2.5. Further details about the calculations are provided in the Appendix.

10. Please see Section A.l.l in the Appendix for derivations of (2) to (6).

Thirdly, in the 'GATT' equilibrium, the degree of concentration, m^g is given by

(4) $$\frac{(2m+1)^3}{2(m+1)} = h.$$

The fourth case is where there is a supra-national merger policy that maximises world welfare, but where trade policies are decided upon unilaterally. The resulting degree of concentration, m^k, is characterised by

(5) $$4m(m + 1)^2 = h.$$

Finally, the equilibrium degree of concentration, m^s, pertaining to the case where the present GATT is extended to include a supra-national merger policy that maximises world welfare, is given by

(6) $$\frac{1}{2}(2m+1)^3 = h.$$

As can be seen, in all five cases the equilibrium degree of concentration is determined by the parameter h. Note also that in all cases under consideration, firms make non-negative profits.

There are at least two ways of characterising merger policy in the different equilibria—by a measure of concentration and by a measure of monopoly power such as a Lerner index. Because of the symmetry, a Herfindahl concentration ratio simply corresponds to the number of firms. We can then characterise the degree of concentration in the different equilibria as follows:

Proposition 1. *For values of h such that the equilibrium number of firms in allcases exceeds 1*, $m^k < m^s < \min(m^a, m^d) < \max(m^a, m^d) < m^g$.

Several points are noteworthy. First, while $m^a < m^d$ for low values of h, and conversely for h sufficiently large, it is always the case that $m^g > m^a$. Hence, the equilibrium degree of concentration is unambiguously *lower with free trade than in autarky*. That is, there are more firms in each economy with free trade than in autarky.

This result contrasts to those usually found in models where the number of firms is determined through zero-profit ('free entry and exit') restrictions. In the latter models, trade typically implies a 'rationalisation' in that it reduces the number of firms in each economy, even though the combined number is larger than in either economy in autarky. The same effect captured in these models—the lowered profitability because of the intensified competition—is also present here. Here, however, firms do not make zero profit in autarky, since the government restricts socially inefficient entry in order to exploit economies of scale. Hence, the intensified competition need not lead to a reduction in the number of firms.

Secondly, assuming countries pursue national merger policies, *trade liberalisation reduces the optimal degree of concentration compared to the situation where the countries discretionarily determine trade policies:* $m^g > m^d$. The 'GATT' is thus in this sense pro-competitive. Note, however, that the difference $m^g - m^d$ is never larger than 1/2. Thus, if the integer constraint is taken seriously, the difference between the two concentration levels could not be more than one firm. In the context of the model, the GATT has insignificant consequences for the optimal degree of concentration. We are undecided about exactly how to interpret this fact, but at the very least, the model does not suggest a strong impact of international trade liberalisation on nationally pursued merger policies.

Thirdly, the two equilibria involving a supranational merger policy feature significantly more concentration than the other equilibria. That is, *the basic distortion caused by nationally pursued merger policies is insufficient exploitation of economies of scale*. With nationally pursued merger policies, both countries strive to increase their market share by increasing the number of firms. The reason why a larger number of firms tends to increase the market share is exactly the same as the reason why the oligopoly as a whole produces more the larger the number of firms—it yields a commitment.

Our second measure of the restrictiveness of the merger policy is the Lerner index. Denoting this index by L, $L = (p - c)/p$, the value of the index is in the linear model in autarky

$$L^a = \frac{a-c}{a+m^a c}.$$

In the case of trade it is generally given by

$$L(m,r) = \frac{a-c-mr}{a+m(2c-r)},$$

so that

$$L\left(m^d,\ r^d\right) = \frac{a-c}{a+\left(2m^d+1\right)c}.$$

Hence,

Proposition 2. $L^d < L^g < L^s$.

Note, first, that for any particular m, $L(m, r^d) < L(m, 0)$, providing a tendency for GATT to be *anti*-competitive. But on the other hand, both indices are decreasing in the number of firms. Hence, to the extent that there are more firms with than without the GATT, it has a tendency to be *pro*-competitive. The latter of these two forces dominates the former when $2m^d + 1 > 2m^g$. This will indeed be the case since, as was noted above, $m^g - m^d < 1/2$. Hence, it follows that on balance trade liberalisation is *anti -competitive*, in the sense of being associated with a higher mark-up over true marginal costs: $L(m^g, 0) > L(m^d, r^d)$.

The intuition behind this result is simple. The export subsidies tend to increase production where, due to imperfect competition, there was too little production. When countries are then constrained not to use subsidies, they find it optimal to enforce a market structure with more firms, and this partially, but not fully, off-sets the negative impact of the trade liberalisation.

Secondly, we have seen that $m^s < m^g$. Hence, since the Lerner index falls in the number of firms in the absence of subsidies, we have that $L(m^s, 0) > L(m^g, 0)$. That is, absent export subsidies, with an supranational merger policy, the mark-ups are higher than with national policies. Again, the problem with nationally pursued competition policies is not that they are too lax, but rather that they are too restrictive.

Finally, observe that $L^s < L^a$ if and only if $2\, m^s > m^a$. This indeed holds, since

$$2m^s - m^a = \sqrt[3]{h}\left(\sqrt[3]{2} - 1\right) > 0.$$

Hence, as expected, the autarky equilibrium features higher mark-ups than the free trade equilibrium with supranational merger policies, hence reflecting the size differences between the two economies. It can also be seen that the mark-ups are higher in the autarky than in the discretionary equilibrium: $L^a > L^d$ if and only if $m^a < 2m^d + 1$. It can be shown that

$$2m^d - m^a = -1/2 + 1/2\sqrt{(1+4h)} - \sqrt[3]{h}.$$

This is positive for $h > 2 + \sqrt{5}$. Hence, in the range of h considered here, the discretionary equilibrium implies lower mark-ups than in autarky.

5.1.2. When Merger Policy is More Long-Run than Trade Policy

In the previous Section, trade and merger policy were set simultaneously. However, one might view merger policy to be of a more long-run nature (and hence changed less frequently) than the trade policy. In this subsection, we will briefly consider a variant of the model which seeks to capture this intuition.

Let the technology and demand be as in the previous section. However, assume now that in situations where countries unilaterally decide on export subsidies, this is done simultaneously in the two countries, but *after* they have simultaneously determined their respective degrees of industrial concentration.[11] The new element that appears now is that when determining their merger policies, countries have to take into account how the consequent decisions on subsidies will be affected. In the general case, this has the consequence of introducing derivatives of demand of an even higher order than above, and would clearly add to the ambiguity of the outcomes in the general case. However, with the linear parameterisation we can still solve for the various equilibria.

It is straightforward to show that when countries set both the export subsidies and the merger policies discretionarily, the equilibrium degree of concentration m^d is characterised by the expression.

$$\frac{4(m+1)^3}{m+2} = h.$$

In this case, the optimal concentration for one country is independent of that of the other country. Of course, both the 'GATT' equilibrium (with subsidies constrained to be zero, but with discretionary setting of merger policies) as well as the equilibrium with supranational merger policies (and no export subsidies), m^s, are the same as in the previous model.

We can then establish the following result:[12]

Proposition 3. *For values of h such that the number of firms is at least one in each equilibrium, it holds that* $m^s < m^d \leq m^g$.

In other words, the basic finding in the previous subsection—that, relative to the discretionary equilibrium, the degree of concentration would fall (or at least not increase) with the agreement on the GATT, and would increase with a supranational merger policy—is at least robust to one particular specification of the sequence of decisions.

5.1.3. Marginal Cost Synergies

The model above highlighted one aspect of strategic merger policies—

11. This timing is similar to that in Rysman (2000).

12. Strictly speaking, $m^d < m^g$ when treating m as a continuous variable. However, we conjecture that the difference between the two values never exceeds one.

the incentive for individual governments to capture foreign firms' market shares by promoting domestic entry. In that model, entry also benefited individual governments by increasing consumer welfare, but was restricted by its associated cost of less exploitation of economies of scale. However, mergers did not affect the competitive position of individual firms. That is, firms were no more efficient after merging. However, much of common thinking about mergers is that they do exactly this—indeed, this belief is what seems to motivate the promotion of 'national champions'. We will therefore in this subsection briefly consider a case where mergers lower marginal costs of the participating firms; that is, where mergers give rise to variable cost 'synergies', but where there are no fixed cost savings from mergers. Governments will again face a trade-off with regard to the merger policy, but the incentive to hold back entry will now stem from the cost an unconcentrated market structure has in terms of unexploited synergies.

The model is identical to the one in the previous subsection except for two differences. First, as mentioned above, there are no fixed costs: $f = 0$. More importantly, in order to capture the marginal cost synergies, we will use a simple formulation that is similar to the one employed by Perry and Porter (1985). To this end, let the marginal cost in a firm i be k/k_i^2, where k is a constant and k_i is the amount of capital employed in this firm. Let the total fixed amount of capital be $K = 1$. Since all domestic firms are symmetric, $k_i = K/m$, so that the marginal cost in each domestic firm is km^2. Intuitively, the government will have incentives to pursue a lax merger policy in order to achieve low marginal costs for domestic firms, partly for the sake of consumers (even though from their point of view the cost in terms of increased monopolisation matters) and partly in order to enhance the competitive position of domestic firms vis-a-vis their foreign counterparts.

How does the introduction of marginal cost synergies affect countries' incentives? We will consider three of the equilibria with trade again. First, in the case where both subsidies and and the degree of concentration are chosen unilaterally by each country, the equilibrium degree of concentration m^d is given by

$$m\left(12m^2 + 13m + 2\right) = \frac{a}{k}.$$

In the 'GAIT' equilibrium, with nationally determined industrial concentration, but with export subsidies set to zero, the corresponding value m^g solves

$$\frac{m^2}{m+1}\left(12m^2 + 15m + 5\right) = \frac{a}{k}.$$

Finally, in the absence of export subsidies, but with supranationally set industrial concentration, the equilibrium degree of concentration m^s is given by

$$m^2\left(8m^2+12m+5\right)=\frac{a}{k}.$$

A comparison of these three equations yields the following result:[13]

Proposition 4. *For values of a/k such that the number of firms in each equilibrium is at least one,* $m^s < m^d \leq m^g$.

Hence, the ranking of m^s, m^d, and m^g is exactly the same as in the two previous cases.

5.2. Tariffs

It might be argued that the consistency of the results above is due to the fact that in all cases, the trade policy was an export subsidy. We therefore now turn to investigating the interaction between tariffs and merger policies, first briefly applying a more general approach, and then turning to a linear Cournot model. We assume throughout this section that tariffs are the only trade policy at the disposal of the home and foreign countries.

In the presence of tariffs, the welfare function has to be modified to take into account the allocational effect of tariffs and the tariff revenue. With tariffs, welfare is now given by:

$$V(m, n, t_h, t_f) \equiv CS(m, n, t_h) + H(m, n, t_h) + E(m, n, t_f) - mf + t_h ny\,(m, n, t_h),$$

where $H(m, n, t_h) \equiv m\Pi^h(m, n, t_h)$, $E(m, n, t_f) \equiv m\Pi^h(m, n, t_f)$, and $y(m, n, t_h)$ is the sales of the representative foreign firm in the domestic market.

Consider the welfare maximising degree of concentration in the domestic economy for given concentration in the other country and for given tariffs. It is obtained by equating

$$V_m = CS_m + \left(\Pi^h + \Pi^f\right) - f + \left(m\Pi^h_m + \Pi^f_m\right) + tny_m,$$

with zero. The direct impact of trade liberalisation (interpreted as a restriction on the use of tariffs) on merger policy incentives, is given by the mixed derivative V_{mt_h}:

13. As above, $m^d < m^g$ when treating m as a continuous variable.

$$V_{mt_h} = CS_{mt} + \prod_t^h + m\prod_{mt}^h + n\left(y_m + ty_{mt}\right).$$

As was the case when we investigated the implications of an export subsidy for the optimal degree of concentration (V_{ms}), the sign of V_{mt} is ambiguous. A restriction on the use of tariffs might provide an incentive for governments to either relax or restrict industry concentration.
With a linear demand, and equal marginal costs c and fixed costs f,

$$sgn\left(V_{mt_h}\right) = -sgn\left[(a-c)(m-n) + t_h n(2m+1)\right].$$

This expression can clearly take on either sign. But, in the symmetric case, a reduction in a country's tariff level provides an incentive for the country to reduce domestic concentration.

Characterising merger policy by the degree of concentration: The autarky equilibrium number of firms m^a is, of course, the same as in the previous section, and is given by (2). Likewise, the equilibrium industrial concentration 'with GATT', i.e., with tariffs constrained to zero, and with national control of merger policies, is the solution m^g as given by (4), and the supranational competition authority would still choose m^s, as given by (6).

The difference between the case of tariffs and subsidies arises in the discretionary case. The equilibrium degree of industrial concentration with t_h and t_f unilaterally decided by the countries, is given by

$$\frac{(m+2)^2(2m+1)^3}{8m^2+12m+5} = h.$$

We can then show the following:

Proposition 5. $m^s < m^d < m^a < m^g$.

Note that the ranking of industrial concentration in this case of tariffs is identical to the ranking in the case of export subsidies!

Characterising merger policy by Lerner indices: The Lerner index with GATT (i.e., $t_h = t_f = 0$), is the same as in the case of export subsidies in Section 5.1. The Lerner index without GATT is now

$$L(m, t_h) = \frac{a-c+t_h m}{a+m(2c+t_h)}.$$

It can be shown, that for any particular value of m, the Lerner index is higher without GATT than with GATT. This only says that prices are higher with the tariffs. However, the number of firms will not be the same in the two equilibria. We have already seen that $m^g > m^d$. Therefore, since both the Lerner indices fall in the number of firms, we have the following:

Proposition 6. $L^g < L^d < L^s$.

To summarise, the general conclusions concerning the impact of international trade liberalisation on industrial concentration are almost the same in the case of tariffs as they are in the case of export subsidies. In particular, the removal of tariffs will induce countries to reduce industrial concentration, while from a global point of view it would be preferable that countries did just the opposite. The main difference between the tariffs and subsidies is that when tariffs are removed, the degree of monopoly power, as measured by a Lerner index, decreases whereas it increases in the case of export subsidies. The concern that GATT might induce countries to pursue less vigorous merger policies hence finds even less support in the case of tariffs than with export subsidies.

6. Trade Liberalisation and the Desirability of Supra-National Merger Policies

As noted at the beginning of the paper, some observers have suggested that trade liberalisation increases the desirability of, or need for, supranational merger policies. The implicit assumption is presumably that there are also gains to be had from supranational merger policies prior to trade liberalisation, but that these gains have increased as a result of the trade liberalisation. We will in this subsection briefly take a look at whether such a claim is warranted within the confines of the above model.

6.1. What Constitutes a 'Beggar-Thy-Neighbour' Merger Policy?

A basic conceptual problem with the above-mentioned claim is the lack of a precise meaning of the terms 'desirability' or 'need'. Implicit in the statement seems to be the presumption that trade liberalisation induces a country to change its merger policies in a direction that is detrimental to other countries. This raises the basic question of what direction this would take. What constitutes a beggar-thy-neighbour merger policy? Concentration among foreign firms will be detrimental to the domestic economy if:

$$V_n = CS_n + H_n + E_n > 0,$$

while it would be beneficial in the opposite case. The entry of a foreign firm will increase the total output, and will thus bring gains to consumers, but will bring losses for producers. The balance of these two effects is ambiguous, and will partly hinge on the relative importance of consumer and producer surplus. For instance, if profits are small initially, the positive effect of entry on consumer surplus may dominate. In this case, increased concentration abroad would amount to more of a beggar-thy-neighbour policy. On the other hand, if the domestic market is small relative to the foreign market, the opposite may prevail. We are thus led to the unsatisfactory conclusion that we cannot determine *a priori* whether concentration in one country is good or bad for other countries. Nor are we able to do so in the linear fixed cost model, even absent active trade policies. For instance, in the latter case

$$V_n = \frac{h^2}{(m+n+1)^3}(n-3m),$$

the sign of which is ambiguous in general.

6.2. The Claim in Four Different Versions

One possible interpretation of the above argument would then be to look at the situation from the point of view of an individual country, say the home country. Trade liberalisation could then be said to lead to more of a beggar-thy-neighbour merger policy if it induces the foreign country to change its merger policy in a direction that is unfavourable to the home country, given that the home country does not change *any* of its policies. Interpreting the liberalisation as a marginal reduction in the foreign trade policy instrument s, this situation would prevail if simultaneously

$$V_n^h < 0 \text{ and } V_{ns}^f < 0, \text{ or } V_n^h > 0 \text{ and } V_{ns}^f > 0, \text{ for } s > 0,$$

where superscripts h and f denote home and foreign welfare, respectively.

A second interpretation would be that trade liberalisation undertaken by *both* countries changed the foreign country's incentives with regard to merger policy in an unfavorable direction for the home country, for a given home country merger policy. Considering a symmetric situation with an equivalent small reduction in both r and s, this would correspond to the case where either

$$V_n^h < 0 \text{ and } V_{ns}^f + V_{nr}^f < 0, \text{ or } V_n^h > 0 \text{ and } V_{ns}^f + V_{nr}^f > 0, \text{ for } r, s > 0.$$

A third possible interpretation is that trade liberalisation fosters a beggar -thy-neighbour merger policy in the foreign country if the combined effect of the reductions in export subsidies and the induced change in the merger policies of the two countries result in a foreign degree of concentration which is less preferable than the pre-liberalisation concentration. Thus, comparing for instance the discretionary equilibrium and the 'GATT' equilibrium, trade liberalisation would be said to induce more of a beggar-thy-neighbour merger policy in the foreign country if

$$V^h(m^g, m^g, 0, 0) < V^h(m^g, m^d, 0, 0).$$

There are also other possible interpretations, but no single interpretation has a claim to general superiority. Instead, what constitutes the best measure depends on exactly what is being asked. However, if one wants to argue that the gains from supranational merger policies are larger after liberalization than before, then a more suitable approach would be to compare changes in welfare levels from supranational merger policies with and without trade (before and after) trade liberalisation. If

$$V(m^s, m^s, 0, 0) - V(m^g, m^g, 0, 0) > V(m^c, m^c, r^c, r^c) - V(m^d, m^d, r^d, r^d),$$

then the welfare gain from a supra-national merger policy is larger with than without trade liberalisation. Of course, this would be equivalent to establishing the claim that the gains from trade liberalisation are larger with supranational merger policies than with nationally pursued policies:

$$V(m^s, m^s, 0, 0) - V(m^c, m^c, r^c, r^c) > V(m^g, m^g, 0, 0) - V(m^d, m^d, r^d, r^d).$$

It is simply not obvious under what intuitively interpretable conditions the above inequalities might hold, and this is true for the linear model as well as the more general model. Hence, in even the linear model, the notion that the gains from supranational merger policies are larger after trade liberalization than before is not verifiable or refutable unless one resorts to numerical examples.

7. Concluding Discussion

At the outset of this paper, we noted that the intuition with which many informed economists approach the links between trade and merger policy is often not correct. While it is true that trade liberalisation is typically pro-competitive, this does not provide the basis for determining whether trade liberalisation will lead to a more lax competition policy. Instead, what is at stake are the consequences of trade liberalisation for the *marginal* incentives facing merger policy.

We have investigated the related notion that international trade liberalisation has the undesirable consequence of inducing countries to adjust their merger policies in a beggar-thy-neighbour direction. The analysis above, simple as it is, points to some potentially serious weaknesses in this argument. First, it is not clear whether a beggar-thy-neighbour policy involves more or less concentration among domestic firms, and this is true even in the linear case. More generally, the very notion of a beggar-thy-neighbour competition policy is somewhat amorphous. We suggest several plausible interpretations and their implications vary depending on what definition is adopted.

As we examined the impact of trade liberalisation on the equilibrium industry structure (i. e. competition policy) in a fairly general framework, we were not able to draw many unambiguous conclusions. Yet when we then moved to several specifications of the linear model, for example with and without synergies, and simultaneous and sequential setting of merger and trade policies, the results are remarkably similar across all the specifications. In particular, in all the parametric cases examined above, trade liberalisation results, in equilibrium, in a *stricter* standard for competition policy. Thus, even in very simple models, replacing intuition with a more analytic approach matters.

When we considered supra-national merger policy, we found that the problem is not that there are too few firms with mark-ups that are too high, but rather the contrary: countries foster too little concentration, and they do so in order to increase the market share in export markets. This proves costly since it implies an under-exploitation of economies of scale.

Nonetheless, the paper finds little support for the idea that, because of a strong trade policy-merger policy linkage, merger policies should be internationally regulated. Of course, a lack of a clear link between trade and merger policies does not preclude the possibility that there are substantial gains to be had from international agreements on merger policies. Indeed, this paper has shown how nationally pursued merger policies may be associated with externalities between countries.[14] The rationale for such an agreement would not stem from the inter-linkage between trade policy and merger policy, but rather from the fact that there are negative international externalities from nationally pursued merger policies, just like in the case

14. For example, note (for what it is worth) that in the symmetric linear Cournot model, the quantitative impact of a supranational merger policy seems to depend very little on whether trade is or is not liberalised. Note also that it has a much larger impact than trade liberalisation. These observations are at least consistent with the view that a supranational merger policy could be defended in its own right, regardless of whether or not there is an international trade agreement even though they certainly do not constitute a formal justification.

15. However, as argued by Bacchetta *et al*. (1998), such a theoretical argument is only a necessary, but not sufficient, reason for implementing such policies. It must also be shown that the externalities involved are empirically large enough to justify intervention and that there are no better legal alternatives than an international agreement.

of trade policies.[15]

Finally, the list of restrictive assumptions underlying the models is painfully long. Some are special in the sense of relying on specific functional forms and symmetry. But these are pretty obvious. Let us instead point to five more general weaknesses that need to be modified in subsequent work.

First, the notion of capturing merger policy by the choice of the degree of concentration seems to be a natural starting point, but not more than that. Instead, one needs to take into consideration firms' incentives to merge, and the impact of the merger policy on mergers. This requires a theory of endogenous merger determination.

Secondly, much of the policy debate has focused on the possibility that governments might treat firms differently depending on their nationality, whereas the analysis here has concerned the more general policy of choosing an industrial structure. It is not clear to us whether this focus in the debate reflects commentators' beliefs that the discriminatory aspects are empirically more important than the general aspects, or if it stems from the fact that discrimination violates much of the spirit of the GATT. In any event, it is clear that we need to study the incentives of governments to employ merger and competition policies in a discriminatory fashion.

Thirdly, the assumption that governments maximise social welfare is much neater than reality. A first problem is the fact that many governments seem to have other objectives. Here, one could easily modify the objective by weighting the components in the welfare function differently as done by, for example, Richardson (1999). A more serious problem, which this paper shares with most other papers in economics, is the assumption concerning the information at the disposal of the government. In actuality, it is very hard to evaluate welfare consequences of most mergers with any degree of precision. This lack of information makes the conduct of competition policy much more of a 'trial-and-error' process than is usually acknowledged. As a consequence, there are gains to be had from a world perspective of *not* harmonising competition laws, in order to learn the most efficient form of legislation.

Fourthly, in the tradition of the two sets of theories on which the paper builds, those of industrial organisation and strategic trade policy, the analysis has been done in partial equilibrium. However, an international agreement on merger policy, and more generally competition policy, will most likely not be sector specific, but apply to the whole tradeables sector. There are therefore reasons to believe that a general equilibrium approach might be more suitable.

Lastly, this paper does not consider the possibility of multinational firms as only purely domestic mergers are analysed. Relaxing this restriction would complicate the analysis, but would be an important advance since international mergers are an increasingly important policy concern.

Appendix

The following expressions pertain to the models in Subsections 5.1.1–5.1.3. Let the output of a Home country firm in its home market be x, let a foreign firm's sales be y, and let $c_h(c_f)$ be the home (foreign) country firm's marginal cost.

As in the text, we maintain the following assumptions. Markets are segmented, countries are identical, firms compete in a Cournot fashion, and firms face a linear industry demand curve given by $p = a - bQ$.
In equilibrium:

$$x = \frac{a-(n+1)c_h - n(c_f - s)}{b(m+n+1)},$$

$$y = \frac{a - mc_h - (m+1)(c_f - s)}{b(m+n+1)}.$$

Taking account of the symmetry between markets, the total profits of a home country firm, including subsidies, equal

$$\frac{\left[a-(n+1)c_h - n(c_f - s)\right]^2}{b(m+n+1)^2} + \frac{\left[a - nc_f - (n+1)(c_h - r)\right]^2}{b(m+n+1)^2} - f.$$

Consumer surplus (CS) is

$$\frac{\left[(m+n)a - mc_h - n(c_f - s)\right]^2}{2b(m+n+1)^2},$$

and the government outlays on export subsidies are

$$-m\frac{\left[a + nc_f - (n+1)(c_h - r)\right]^2}{b(m+n+1)} r.$$

Home country welfare ($V(\ )$ in the text) is then the sum of these expressions.

A.1. The Model in Subsection 5.1.1

In the model in subsection 5.1.1, $c_h = c_f \equiv c$.

A.1.1. Equilibria in the Different Policy Regimes

Note that by Proposition 1 (which is established below), m^k is the lowest among equilibrium concentrations under consideration. In order to ensure that ink $m^k \geq 1$, we restrict attention to cases where $h \geq 16 \equiv h_{\min}$. With $c_h = c_f \equiv c$, the equilibria are the following.

(i) The equilibrium degree of concentration in autarky is

$$f^a(m) \equiv (m+1)^3 = h.$$

It is clear that there is a unique solution to this equation for any h.

(ii) With discretionary setting of both trade and merger policies, the subsidies are given by

$$\text{(A1)} \qquad r^j = \frac{(a-c)}{2bm^j(m^j+1)}; \; j = d, k.$$

The equilibrium degree of concentration is given by

$$f^d(m) \equiv 2(m+1)(2m+1) = h.$$

$f^d(1) < h_{\min}$, f^d is continuous and monotonically increasing in m, and goes to infinity as m goes to infinity. Hence, a unique solution exists for any h.

(iii) With $r = s = 0$, and discretionary determination of merger policies:

$$f^g(m) \equiv \frac{(2m+1)^3}{2(m+1)} = h.$$

$f^g(1) < h_{\min}$, $f^g(m)$ increases monotonically in m

$$\frac{d}{dm} f^g(m) = \frac{1}{2}(2m+1)^2 \frac{4m+5}{(m+1)^2} > 0,$$

and

$$\lim_{m \to \infty} f^g(m) = \infty.$$

Hence, there exists a unique solution for any h.

(iv) With a supra-national merger policy, and discretionarily determined trade policies, the subsidies are again given by the expression above, and the equilibrium degree of concentration is given by:

$$f^k(m) \equiv 4m(m+1)^2 = h.$$

$f^k(1) < h_{\min}$, f^k is monotonic in m, and approaches infinity as m becomes very large. Hence, there is a unique solution for any h.

(v) Finally, with a supra-national merger policy and $r = s = 0$:

$$f^s(m) \equiv \frac{1}{2}(2m+1)^3 = h,$$

which also has a uniques solution for any h.

A.1.2. Non-Negativity Constraints

Consider first the constraint ensuring positive outputs: $a - c > max(ns, mr)$. By the symmetry of the equilibrium, and using the expression for the optimal r above, this corresponds to the requirement that

$$a - c > \frac{(a-c)}{2b(m^j+1)}; \quad j = d, k,$$

or $m^j > 1/2b - 1$; this condition is definitely fulfilled for $b > 1/4$.

Now turn to profits. There are three types of situations. First, profits are non-negative in autarky iff

$$\alpha^a(m) \equiv (m+1)^2 \leq h.$$

Secondly, with discretionary determination of export subsidies (includes the equilibria m^d and m^k) profits are non-negative iff

$$\alpha^d(m) \equiv \frac{4m^2(m+1)^2}{2m^2+2m+1} \leq h.$$

Thirdly, with merger policy set discretionarily, and with $r = s = 0$, profits are non-negative iff

$$\alpha^g(m) \equiv \frac{1}{2}(2m+1)^2 \leq h.$$

Clearly, since $m^g > m^s$, this also ensures that profits are positive in the case with supranational merger policies and the GATT.

Note that

$$\alpha^a(m) - \alpha^g(m) = -m^2 + \frac{1}{2} < 0,$$
$$\alpha^d(m) - \alpha^g(m) = -\frac{1}{2}\frac{6m^2 + 6m + 1}{2m^2 + 2m + 1} < 0.$$

Hence, if the constraint $\alpha^g(m) \leq h$ is fulfilled for all m, then the other constraints are also fulfilled. This is indeed the case, since

$$f^g(m) - a^g(m) = \frac{(2m+1)^3}{2(m+1)} - \frac{1}{2}(2m+1)^2$$
$$= \frac{1}{2}(2m+1)^2 \frac{m}{m+1} > 0.$$

Hence, profits are positive in all equilibria.

A.1.3. Proof of Proposition 1

In order to establish Proposition 1, we make pairwise comparisons of the equilibrium expressions:

$$f^d(m) - f^g(m) = \frac{1}{2}(2m+1)\frac{4m+3}{m+1} > 0,$$
$$f^a(m) - f^d(m) = (m+1)(m^2 - 2m - 1) >< 0,$$
$$f^k(m) - f^a(m) = (3m-1)(m+1)^2 > 0,$$
$$f^k(m) - f^s(m) = 2m^2 + m - \frac{1}{2} > 0.$$

It follows from the facts that: (i) $f^d(m) - f^g(m) > 0$; (ii) both functions are monotonically increasing in m; and (iii) there is a unique solution for any h, that for any h, $m^d < m^g$. The other claims in the Proposition follow analogously.

A.2. The Model in Subsection 5.1.2

We continue to have $c_h = c_f \equiv c$. The expressions for equilibrium quantities and the welfare function are thus the same as for the model in Subsection 5.1.1, and the equilibrium values m^g and m^s are also the same as in that model. The only new case to consider is the discretionary equilibrium. The optimal subsidies are still given by (Al). But, when optimising over the number of firms, the countries take into consideration the fact that the subsidies are determined as in (Al). As it turns out, the optimal number of home country firms m^d is independent of the number of foreign firms, and is given by

$$f^d(m) \equiv 4\frac{(m+1)^3}{m+2} = h.$$

This expression has a unique solution for any h, since $f^d(1) < h_{\min}$, f^d is continuous and monotonic in m, and $\lim_{m\to\infty} f^d(m) = \infty$. It is also straightforward to show that the second order condition for the optimisation w.r.t. m is always fulfilled.

A.2.1. Proof of Proposition 3

The Proposition follows from the above, and from the facts that

$$f^d(m) - f^g(m) = \frac{1}{2}\frac{4m^3 + 18m^2 + 19m + 6}{(m+2)(m+1)} > 0,$$
$$f^s(m) - f^d(m) = \frac{1}{2}\frac{8m^4 + 20m^3 + 6m^2 - 11m - 6}{m+2} > 0 \text{ for } m > 1.$$

A.3. The Model in Subsection 5.1.3

We now assume that $c_h = mk^2$ and that $c_f = nk^2$, and furthermore that $f = 0$. We are only concerned with situations where $a/k \geq 25$, in order for $m \geq 1$ in all three equilibria. The expressions for equilibrium quantities and the welfare function, are the same as for the model in Subsection 5.1, with $c_h = mk^2$ and $c_f = nk^2$.

(i) With discretionary determination of both trade and merger policies:

$$f^d(m) \equiv m(12m^2 + 13m + 2) = \frac{a}{k},$$

which clearly has a unique solution for any h. It can also be shown that the second order conditions are fulfilled locally in this equilibrium.

(ii) In the ‘GATT’ equilibrium:

$$f^g(m) \equiv \frac{m^2}{m+1}(12m^2 + 15m + 5) = \frac{a}{k}.$$

This has a unique solution for any a/k, since $f^g(1) < 25$,

$$\frac{d}{dm} f^g(m) = 2m \frac{18m^3 + 39m^2 + 25m + 5}{(m+1)^2} > 0,$$

and

$$\lim_{m \to \infty} f^g(m) = \infty.$$

Again, the second order conditions can be shown to be fulfilled locally in this equilibrium.

(iii) With supranational merger policy and no export subsidies:

$$f^s(m) \equiv m^2\left(8m^2 + 12m + 5\right) = \frac{a}{k},$$

which clearly has a uniques solution for any a/k. Again, the second order conditions are fulfilled locally in this equilibrium.

A.3.1. Proof of Proposition 4

The ranking of the merger policies follows from the fact that

$$f^d(m) - f^g(m) = 2m \frac{5m^2 + 5m + 1}{m+1} > 0,$$

$$f^s(m) - f^g(m) = 2m^3 \frac{4m^2 + 4m + 1}{m+1} > 0.$$

A.4. The Model in Subsection 5.2

We now turn to the case of specific tariffs t_h and t_f, and with identical marginal and fixed costs. In equilibrium home market quantities, consumer surplus, total profits of a home country firm, and government revenue, are:[16]

$$x = \frac{a - c + nt_h}{m + n + 1},$$

$$y = \frac{a - c - (m+1)t_h}{m + n + 1},$$

16. The parameter b is unity in this subsection.

$$CS(m, n, t_h) = \frac{\left[(m+n)(a-c) - nt_h\right]^2}{2(m+n+1)^2},$$

$$\tilde{\Pi}(m, n, t_h, t_f) = \frac{(a-c+nt_h)^2}{(m+n+1)^2} + \frac{\left[a-c-(n+1)t_f\right]^2}{(m+n+1)^2} - f,$$

and

$$G(m, n, r) = n\frac{a-c-(m+1)t_h}{m+n+1}t_h.$$

The only equilibria here that differ from the corresponding ones in the case of export subsidies are those with discretionary setting of trade policies, and among those, we only consider that with both merger and trade policy discretionarily set:

$$f^d(m) \equiv \frac{(m+2)^2(2m+1)^3}{8m^2+12m+5} = h.$$

The second order conditions supporting this equilibrium can be shown to be fulfilled. This equilibrium condition has a unique solution for any h, since $f^d(1) < h_{\min}$,

$$\frac{d}{dm}f^d(m) = 2(2m+1)^2(m+2)(m+1)\frac{24m^2+40m+23}{\left(8m^2+12m+5\right)^2} > 0,$$

and

$$\lim_{m\to\infty} f^d(m) = \infty.$$

A.4.1. Proof of Proposition 5

The Proposition follows from the findings above, combined with the facts that

$$f^d(m) - f^a(m) = \frac{8m^4+21m^3+14m^2+m-1}{8m^2+12m+5} > 0,$$

and

$$f^{s}(m) - f^{d}(m) = \frac{1}{2}(2m+1)^{3}\frac{6m^{2}+4m-3}{8m^{2}+12m+5} > 0.$$

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9 Why not Set Tariffs Uniformly Rather than Optimally

Tatsuo Hatta*

1. Introduction

The World Bank economists in the operation divisions have been recommending the adoption of a uniform tariff to the developing countries, while economists in the research divisions have been emphasizing that the revenue-constrained optimum tariff structure is non-uniform.[1]

This dichotomy of thought between practitioners and researchers as to the desirability of uniform tariff rates is similar to the dichotomy that exists between practitioners and researchers in tax policy regarding uniform commodity tax rates. Although the optimum tax rules have been the focus of research in public economics during the last quarter of century, the policy makers of the recent Japanese and U.S. tax reforms have taken for granted the desirability of uniform commodity tax rates for the efficiency purpose. Indeed, the Japanese reform substituted a uniform value added tax system for a highly divergent excise tax system, and the main slogan of the 1986 U.S. reform was "leveling the playing field."

The arguments of tax policy practitioners for a uniform commodity tax are well known: If different tax rates were imposed on a pair of substitutes, a consumer would be able to reduce the amount of tax payment by substituting the commodity with the lower tax rate for the commodity with the

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1. See Rajaram (1994) for a review of the World Bank's tariff recommendations. See Dahl, Devarajan, and van Wijnbergen (1994) and Mitra (1994) for researchers' view.

higher. These tax avoidance activities will cause distortions. Thus, a uniform commodity tax is most efficient. Musgrave's classic work (1959) is well known for taking this position.

Optimum tax theorists agree that the optimum commodity tax rates would be uniform if leisure were taxed at the same rate. They argue, however, that since leisure is untaxable in the real economy, a uniform commodity tax will inevitably distort the choice between leisure and commodities. In their view, therefore, commodity tax rates have to be adjusted so as to offset the leisure-commodity distortion as much as possible.

The revenue-constrained optimum commodity tax structure is clearly non-uniform. But there is also some truth in practitioners' hunch that divergences among commodity tax rates cause their own distortions. Thus, there must be a trade-off in making tax rates divergent. To make this trade-off explicit, Hatta (1986) and Hatta and Haltiwanger (1986) formalized practitioners' hunch within the framework of optimum tax theory. Using this formulation, they observed that the uniform commodity tax structure is likely to be a good approximation of the optimum structure in an economy where substitution among commodities is dominant. This observation integrates practitioners' intuition for uniform taxes into the framework of optimum tax theory. Since this observation gives a new justification for the uniform tax, it may be called the *neo-Musgravian perspective*. Empirical evidence by Fukushima and Hatta (1989) and Fukushima (1989) further support this perspective. It justifies the fact that most tax policy practitioners use uniform commodity taxation as their policy guideline.

The purpose of the present paper is to apply this observation to the revenue-constrained optimum tariff structure.

Unlike the optimum tax, however, the revenue-constrained optimum tariff is discussed in the models of fixed labor supply, where non-observability of leisure consumption is not an issue. Nevertheless, optimum tax theory is directly relevant to the revenue-constrained optimum tariff structure. Just as commodity taxes discourage the consumption of commodities (which is "imported" from the market) and encourage that of leisure (which is "exported" to the market as labor), import tariff is discourage the consumption of imported goods and encourage that of exported goods. Thus any import tariffs create distortions in the choice between the consumption of imported and exported goods. When import tariffs alone have to raise a given revenue, therefore, the optimum import tariff structure has to be non-uniform. In the simplest setting, the model of revenue-constrained optimum tariff rates under fixed labor supply becomes identical with that of optimum tax rates under flexible labor supply.

In view of the neo-Musgravian perspective regarding optimum commodity taxation, therefore, there is a possibility that a uniform tariff structure can be regarded as a good approximation to the optimum structure. We will examine the similarities and the differences between the optimum tax situation and the revenue-constrained optimum tariff situation.

Section 2 defines the issue of revenue-constrained optimum tariffs, while section 3 does the same for optimum taxation for a two good economy. In section 4, we derive a revenue-constrained optimum tariff formula for a three-good economy. In section 5, we first discuss the implications of this formula in the optimum tax context, and then apply them to the revenue-constrained tariff situation. Section 6 discusses the efficiency effects of tax and tariff reforms for the economy with four or more goods. In particular, we formally interpret the tax policy practitioners' hunch for recommending tax reforms toward uniformity. This interpretation is applied to the optimum tariff situation. A few concluding remarks are given in the final section.

2. Revenue-Constrained Optimum Tariff Rules: The Issue

Consider a small open economy where a fixed commodity bundle is supplied. In this economy, uniform excise taxes can attain the first best solution under the constraint of raising a given revenue. No combination of tariffs, however, can attain this first best solution. Revenue-constrained optimum tariff is thus become a non-trivial issue. In this section, we will illustrate this by a two-good model.

A. Optimality of Uniform Excise Taxes

Figure 1 depicts a small open economy which produces two goods, X and Y. Point Q is the production bundle. The slope of the bold line represents the relative prices of the two goods. Thus the bold line in this figure is the budget line that the consumers of this economy face in the absence of taxes. The indifference curves in the diagram represent the representative consumer's preferences. Consumption takes place at point F, which is the tax-free consumption bundle.

Let us now suppose that the government has to raise a revenue equal to the length AC measured in the Y unit. Suppose first that a lump-sum tax is levied to raise this revenue. Then his budget line will be the line CD, which starts at C and is parallel to the bold line. The consumption bundle will then move to point L.

Suppose that the government imposes an excise tax on commodity Y. The line BH in Figure 2 will then represent the consumer's budget line. It starts at point B, but cuts the vertical axis below A. Utility is then maximized at point E, and the government revenue equals the length of the line segment AC. In this diagram, therefore, the tax rate on commodity Y is so chosen that the resulting government revenue is exactly equal to the revenue raised by the lump sum tax in Figure 1.

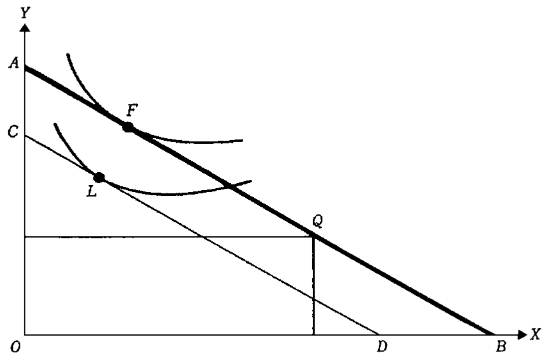

Figure 1

If excise taxes can be imposed both on commodities X and Y, the consumer's budget line will pass through a point to the left of B. By equating the tax rates on both commodities, the budget line can be made identical to the line segment CD in Figure 1. This combination of excise taxes amounts to a lump-sum tax. After all, a tax payer cannot reduce the amount of his tax obligation by changing the consumption mix. Thus, uniform excise tax rates on both commodities attain the optimum under the constraint of raising a given government revenue.

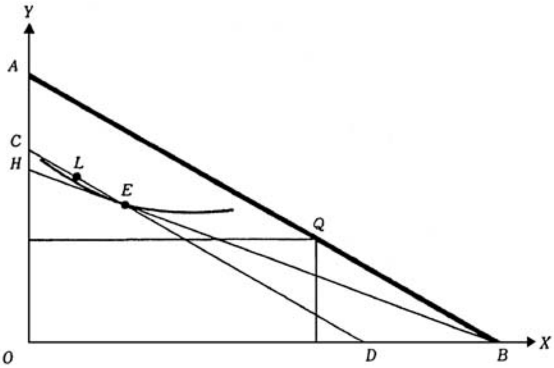

Figure 2

B. Suboptimality of Tariff Equilibrium

Let us now suppose that import tariffs rather than excise taxes are imposed on commodity Y as the only source of government revenue. The line *QK* in Figure 3 represents the budget line under an import tariff. The vertical distance between this line and the bold line measures the tariff revenue of the government at each point of the budget line. The tariff rate on *Y* corresponding to the budget line *QK* is so chosen that the government revenue under the optimized consumption bundle *M* is equal to *AC*. If *X* is a normal good, point *M* in Figure 3 is the only point on the line *CD* that is attainable by an import tariff.[2] Therefore, an import tariff equilibrium can not attain the first best.

Can a combination of import and export tariffs attain the first best? Just as an import tariff, an export tariff reduces the size of trade, increasing the domestic relative price of the imported commodity. Indeed, the line *QK* can also represent the consumer's budget line under an export tariff on *X*. By changing the tariff rates on exports and imports, the consumer's budget line pivots around the point *Q*. Thus no combination of tariffs, including the one that equalizes tariff rates on import and export goods, can make the budget line parallel to the bold line. In other words, no combination of import and export tariffs can attain the first best in the model of Figure 3.

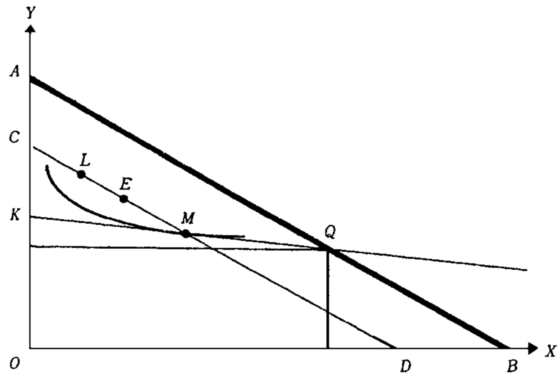

Figure 3

C. Revenue-Constrained Optimal Tariff Structure

The above discussion shows that if *X* is a normal good, point *M* in Figure 3 is the only point on the line *CD* that is attainable by a combination of tariff rates.[3] In the two commodity setting, therefore, there is no room

2. Note that point *M* corresponds to infinitely many combinations of import and export tariffs. In the following, therefore, we will normalize the tariff rates by assuming that one of the export tariff rates is always zero.

3. If *X* is an inferior good, a point other than *M* may be attainable on the line *CD* by a combination of tariff rates. See Hatta (1977a).

for choosing the equilibrium by adjusting tariff, and the concept of an optimal structure of tariff rates is meaningless.

The concept of an optimum tariff makes sense, however, in an economy with more than two commodities. To see this, generalize the economy described above to a three commodity economy where two commodities are imported and one commodity is exported. Then the equal revenue line *CD* of Figure 3 is generalized to an equal revenue plane. Again no combination of tariffs can attain the first best on this plane. This time, however, many different points on this plane are attainable by different combinations of tariff rates on the two imports, and choice of the optimal import tariff rates under a constrained revenue becomes a meaningful issue.[4]

3. Optimum Tax Rules: The Issue

The revenue-constrained tariff rules outlined above have a similar theoretical structure to the "optimal tax rules" studied in public economics. In the following, we will present those findings of this literature that are relevant to the "revenue-constrained tariff rules."

We have so far implicitly assumed that labor supply, and hence leisure demand, is fixed. In such an economy, imposing an equal ad valorem excise tax rate on all commodities would amount to a lump-sum tax. (Here and in the following, a good is called a commodity if it is not a leisure. Thus the phrase "all commodities" will not include leisure, while "all goods" consists of leisure and all commodities.)

In the optimal taxation literature, however, a critical role is played by the assumption that leisure consumption is endogenously determined. Of course, even under this assumption, an efficient resource allocation would be attained for the given revenue if an equal ad valorem excise tax rate could be imposed on all goods including leisure.

The problem is that leisure is untaxable in reality. A tax payer has a strong incentive to under-state his leisure consumption; by doing so he could reduce his claimed tax base for the leisure tax. Thus the tax office cannot gather precise information on the leisure consumption of each tax

4. Note that this topic of "revenue-constrained optimum tariff rule" is entirely different from the traditional topic of "optimum tariffs". The latter examines the situation where the country concerned is large, facing an upward-sloping supply curve of its imports. This literature usually assumes that the entire tariff revenue is returned to the consumers through a lump-sum tax. This means that any change in tariffs is accompanied by a revenue-offsetting change in a lump-sum tax. If the country were small, therefore, the optimum tariff rates in this situation would be zero. Non-zero rates become optimal only because the country considered in the traditional optimum tariff theory is large.

On the other hand, "the revenue-constrained optimum tariff rates" of a small country are non-zero because no lump-sum taxes are available by assumption.

payer, and hence cannot levy tax on leisure.

The tax office, however, can easily obtain data on the wage income of a tax payer from his employer. In the real economy, therefore, tax is imposed on wage income, rather than on leisure consumption. An important difference between the two taxes is that a tax on wage income encourages leisure consumption, while a tax on leisure consumption discourages it. Thus a tax on wage income could not neutralize the effect of a commodity tax upon leisure consumption. Optimality cannot be generally attained, therefore, by a simultaneous imposition of taxes on all commodities and wage at the same rate cannot generally attain the optimality.

To use the terminology of international trade, wage tax is imposed on the export of leisure, rather than on its consumption. This creates a similar situation as in Figure 3, where no combination of import and export tariffs can attain the efficient consumption bundle L. Figure 4 depicts this situation. The horizontal axis now represents the leisure consumption of this economy, while the vertical axis represents the consumption of the commodity. The initial endowment of leisure is OQ and that of the commodity is zero. Thus the point Q represents the consumers' initial endowment bundle. The wage rate in terms of units of the commodity is represented by the slope of the bold line.

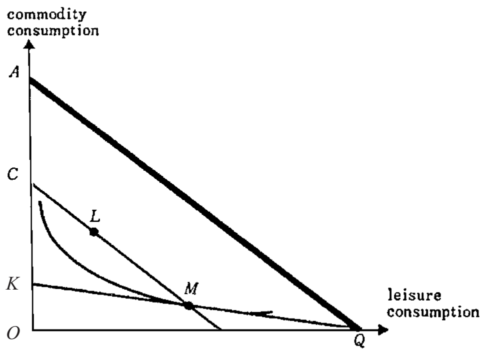

Figure 4

Suppose that the government has to raise a revenue equal to AC. The first best consumption bundle would then be L. But it is not possible to attain L by adjusting the commodity tax rate or the wage tax rate. Such an adjustment would pivot the consumer budget line around Q. In the figure, the given government revenue is attained by the budget line QK at the distorted consumption bundle M. In the model of Figure 4, therefore, the degree of freedom of feasible tax rates is again limited as in the model of Figure 3, and hence the issue of optimal tax rules does not arise.

If we consider an economy where two or more commodities are consumed along with leisure, a degree of freedom is added, and different combinations of commodity tax rates become compatible with a given revenue. Yet, the distortions that encourage over-consumption of leisure are inevitable under any combination of taxes on wage and commodities. (In particular, a simultaneous imposition of taxes on all commodities and wage at the same rate cannot generally attain the optimality.) It therefore becomes necessary to design the least cost combination of distortionary commodity taxes and the wage tax that raises a given revenue. Optimal tax theory characterizes the structure of such taxes.

The formal structure of the revenue-constrained optimum tariff rules is identical with that of optimum tax rules in a simple setting. In the following, we will first present an explicit solution of revenue-constrained optimum tariffs in a three commodity model. We will next give interpretations to this solution in terms of optimum tax rules. We will then examine the implications of these interpretations to the revenue-constrained optimum tariff rules.

4. A Revenue-Constrained Optimal Tariff Rule

In this section we will construct a simple three-commodity model of trade, and present an explicit solution of revenue-constrained optimum tariffs in that model.

A. The Model

Assume that a small open economy exports good 0, and imports goods 1 and 2. Denote the economy's output vector by $y' = (y^0, y^1, y^2)$, and its private consumption vector by $x' = (x^0, x^1, x^2)$. Define this economy's excess demand vector $z' = (z^0, z^1, z^2)$ by

$$z = x - y.$$

Note that z^0 is the excess demand for the export good, and hence it is the negative of the exported amount. Denote the vector of international prices of the three goods by $p' = (1, p^1, p^2)$. Then z, r, and p must satisfy

$$p'z + r = 0, \tag{1}$$

where r is the value of the public good.

Ad valorem export tariff t^0 and import tariffs t^1 and t^2 are imposed so that the domestic price vector $q' = (q^0, q^1, q^2)$ is given by

$$q^i = (t^i + 1)\, p^i, \quad i = 0, 1, 2. \tag{2}$$

The aggregate consumer faces the budget equation

$$q'z = 0. \tag{3}$$

(Since tariff revenues must finance the public good, $\sum_0^2 t^i p^i z^i = r$ must hold. This equation, however, is implied by (1), (2), and (3). So we will not explicitly consider this equation below.)

Without loss of generality we will assume[5]

$$t^0 = 0. \tag{4}$$

Assume that the aggregate consumer maximizes the value of his utility function $u = U(x)$ under the budget equation (3). We denote his compensated demand function for leisure and commodities by $x = x(q, u)$. Then we have

$$z = z(q, u), \tag{5}$$

where

$$z(q, u) \equiv x(q, u) - y.$$

By assumption we have

$$z^0(q, u) < 0,\ z^1(q, u) > 0, \text{ and } z^2(q, u) > 0. \tag{6}$$

Equations (1), (3), and (5) can be combined into the following equations:

$$q'z(q, u) = 0, \tag{7}$$

$$p'z(q, u) + r = 0. \tag{8}$$

When r and p are given, q can be chosen to maximize u in the system of these two equations, which contains variables q and u. In view of (2) and (4), the solution for q will yield the optimal tariff vector.[6]

B. The Rule

It is well known that in the three-good model of (2), (7), and (8), the

5. See Hatta (1993, p. 130).

6. We can also assume that y is not fixed. In that case, we have to redefine the function z as (17) below.

optimal t^1 and t^2 satisfy the following:

$$\frac{t^1}{t^2} = \frac{\eta_0^2 + \eta_1^2 + \eta_2^1}{\eta_0^1 + \eta_1^2 + \eta_2^1}, \tag{9}$$

where

$$\eta_j^i \equiv \frac{\partial z^i}{\partial q^j} \frac{q^j}{z^i}$$

This formula is due to Harberger (1958). Diamond and Mirrlees (1971, p. 263) and Auerbach (1985, p. 92) give its simple proofs. In the next section, we will give a detailed interpretation of this formula.

5. Implications of Optimal Tax Rules

The model of equations (7) and (8) is formally identical with the model of optimal taxation, and the optimal solution (9) can be interpreted in many different ways in the context of optimal taxation. Here we will give some of those interpretations that are most relevant to the revenue-constrained optimum tariff.

A. Optimal Tax Rules

A combination of wage and commodity taxes encourages leisure consumption and discourages commodity consumption, distorting the leisure-commodity consumption choice. A non-uniform commodity tax structure can mitigate this distortion ultimately created by the non-availability of leisure tax. Imposing a high tax rate on complements of leisure (*e.g.,* yachts and concerts) and subsidizing substitutes for leisure (*e.g.,* dish washers and microwave ovens) would reduce leisure consumption,[7] serving to counteract this distortion.

This type of non-uniformity among the commodity tax rates will reduce the distortion in the leisure-commodity consumption choice. But it will create new distortions in the choice among commodities. In making commodity tax rates non-uniform, therefore, a policy maker faces a trade off between distortion in the leisure-commodity consumption choice and distortions among commodities. The optimal tax structure is the one that strikes the balance in this trade off. Formula (9) can be interpreted as formally expressing this perspective.

7. Note that the word “leisure” here is used in the sense of non-working hours.

1. The Corlett and Hague Rule

First, this formula proves that optimum taxation requires that the higher tax rate be imposed on the commodity with the higher wage elasticity of compensated demand. In particular, the formula implies that a higher tax rate should be imposed on complements of leisure than on substitutes for leisure. We may call this implication the Corlett and Hague Optimum Tax Rule, after its founders Corlett and Hague (1953). This ranking of tax rates counteracts the distortions created by the non-availability of the leisure tax.

In the extreme case where cross elasticities among commodities, *i.e.*, η_2^1 and η_1^2, are zero, equation (9) boils down to

$$\frac{t^1}{t^2} = \frac{1/\eta_0^1}{1/\eta_0^2}. \tag{10}$$

Thus the tax rate of a commodity is inversely proportional to the wage elasticity of demand for that commodity.

2. Substitutability Rule

Second, equation (9) implies that given the values of η_0^1 and η_0^2, the more strongly substitutable the two commodities are, the closer the optimal commodity tax structure is to uniformity. As we remarked earlier, the non-uniformity of the commodity tax rates may reduce the distortion in the leisure-consumption choice, but will create new distortions in the choice among the commodities. In particular, when cross elasticities among commodities are high, a non-uniform commodity tax structure creates strong distortionary effects in the choice among the commodities. The optimum tax structure then tends to be close to uniform. In other words, high cross elasticities among commodities create a strong power that pulls the optimal commodity tax rates toward uniformity.

3. The Inverse Elasticity Rule

When cross elasticities among commodities are zero,

$$\eta_0^i = -\eta_i^i, \tag{11}$$

holds.[8] Thus equation (l0) may be rewritten as

$$\frac{t^1}{t^2} = \frac{1/\eta_1^1}{1/\eta_2^2}. \tag{12}$$

8. This follows directly from $\eta_0^i + \eta_1^i + \eta_2^i = 0$ and $\eta_2^1 = \eta_1^2 = 0$.

In words, the commodity tax rate is inversely proportional to the own demand elasticity of that commodity. This is called the Inverse Elasticity Rule and is attributed to Ramsey (1927).[9] This Rule implies that a low tax rate should be imposed on a commodity with a high demand elasticity.

Equation (12) is well known, and is often cited as evidence for a widely divergent optimal commodity tax structure. But that is misleading. In the real economy, substitutability among commodities dominates, which pulls the optimal commodity tax rates toward uniformity. The Inverse Elasticity Rule is valid only when this pulling power is non-existent.

4. Wage Elasticity vs Own Elasticity

It is often believed that the Inverse Elasticity Rule holds because taxing the commodity with a high own demand elasticity is distortionary, regardless of its cross substitutability with the other commodity.

This reasoning, however, is not correct. In fact, the commodity with the higher own demand elasticity can have the higher optimum tax rate. To see this, note that when η_2^1 and η_1^2 are not zero, (9) can be rewritten as

$$\text{(13)} \qquad \frac{t^1}{t^2} = \frac{-(\eta_1^1 + \eta_2^2) - \eta_0^1}{-(\eta_1^1 + \eta_2^2) - \eta_0^2} .$$

This expresses the tax ratio solely in terms of the own elasticities and wage elasticities of the two commodities, revealing that the wage elasticity, and not the own elasticity, of each commodity plays a decisive role in the ranking of the two tax rates. In particular, this equation shows that the commodity with the higher own demand elasticity must have the higher optimum tax rate, if the wage elasticity of this commodity is the higher of the two. This is in contrast to the qualitative implication of the Inverse Elasticity Rule regarding the ranking of the two tax rates.

Indeed, the Inverse Elasticity Rule holds because its assumption of zero cross elasticities among commodities implicitly ranks the wage elasticities of the two commodities in accordance with their own elasticities. Under this assumption, equation (11) implies that the commodity with the higher demand elasticity is necessarily the stronger substitute for leisure from (11). From (13), therefore, this commodity must have the lower optimum tax rate, which yields the Inverse Elasticity Rule.

Both the Inverse Elasticity Rule and (10) are obtained under the assumption of zero cross substitutability among commodities. Even when this assumption is dropped, however, the qualitative implication of (10) is robust; the ranking of the wage elasticities alone determines the ranking of the op-

9. Ramsey himself, however, derived this formula for uncompensated elasticities.

timal tax rates whether or not commodities are substitutable. On the contrary, once this assumption is dropped, the qualitative implication of the Inverse Elasticity Rule breaks down.

In the real world, moreover, a commodity with a high demand elasticity is usually a strong substitute for another commodity. But the Inverse Elasticity Rule only considers the situation where a highly demand elastic commodity has no substitutes among commodities. It is not easy to come up with an example of such a commodity. The Inverse Elasticity Rule, therefore, is not as practical as it first looks.

B. Revenue-Constrained Optimum Tariff Rules

Let us now apply the optimal tax rules to the three-commodity open economy model of Section 4. Formula (9) has three implications:

First, the higher tariff rate should be imposed on the good that is more substitutable for leisure than the other. Second, the more substitutable the two imports are, the better the uniform tariff structure approximates the optimal tax rate structure.

Third, the own elasticities of demand are not as important as generally believed in ranking tariff rates. The crucial parameters in determining the ranking of tax rates are the wage elasticities of demand for the commodities.

6. Implications of Tax Reform Rules

A. Revenue-Constrained Tax Reform Rules

Let us consider the optimum tax rules for the case where there are three or more commodities.[10] In this case, a simple, explicit expression of optimal tax rates no longer exists, unlike (11) in the model of two commodities and leisure. Optimal tax rules then are obtained from the optimality conditions that implicitly contain tax rates as variables. Many of them give insightful characterizations of optimal tax rates,[11] but do not give guidance as to in which direction the tax structure should be reformed, unless we know the exact point estimates of demand elasticities of all goods.

Theory of revenue-constrained tax reform, on the other hand, gives explicit criteria that tells whether or not a particular tax reform improves efficiency without requiring exact point estimates of demand elasticities of all goods. They require only the signs and the relative magnitudes of demand elasticities of a selected number of goods.

10. Then the number of goods, which include leisure, is four or more.
11. Sandmo (1976) and Hatta (1993), for example.

1. Grouping of Commodities

A new element that appears in the case of three or more commodities is the different degrees of substitutability among different commodity pairs. If different tax rates are imposed on a pair of strong substitutes, such as chicken and fish, a consumer will be able to avoid a substantial amount of tax payment by substituting the commodity with the lower rate for the other, regardless of the tax rates of the commodities outside of this pair. An economist's intuition would tell that a revenue-neutral reduction of the tax rate differential of this pair leaving all other tax rates intact would improve efficiency. This argument is the usual justification for broad-based taxes.

Indeed, Hatta and Haltiwanger (1986) established an empirically testable criteria of strong substitutability of a commodity pair under which squeezing their tax rates improves efficiency, when all other tax rates are kept constant.

2. The Corlett and Hague Term and the Practitioner's Hunch Term

Revenue-neutral commodity tax reform rules can be derived for a commodity pair that may not be strongly substitutable. For that purpose, we first analyze a formula that shows whether or nor a particular revenue-neutral tax reform improves efficiency.

Throughout the rest of this section we assume that:

the tax rates of goods 1 and n are both revenue-increasing.

This means that raising the tax rate of commodity 1 (commodity n) keeping all other tax rates constant increases the revenue.

Hatta (1986) showed that under this assumption, efficiency is improved by an increase in t^1 accompanied by a revenue-neutralizing decrease in t^n if and only if N^{1n} is positive, where

$$N^{1n} \equiv \frac{(\tau^n \eta_0^n - \tau^1 \eta_0^1)}{t^0 + 1} + \left[\frac{\sum_1^n (t^n - t^i) p^i z_i^n}{z^n (t^n + 1)} + \frac{\sum_1^n (t^i - t^1) p^i z_i^1}{z^1 (t^1 + 1)} \right], \tag{14}$$

$$r^i \equiv (t^i - t^0) / (t^i + 1), \quad \text{and} \quad z_i^j = \partial z_j / \partial q^i.$$

The first term of the RHS of equation (14) may be called the *Corlett and Hague term*. Corlett and Hague (1953) considered the situation where the initial commodity tax rates are equal. Then the second term in (14) vanishes, and the first term alone dictates the direction of the welfare effect. Besides, $\tau^1 = \tau^n$ holds in this situation, and hence the sign of the first term is solely dependent upon the sign of $\eta_0^n - \eta_0^1$. Thus the aforementioned result by Corlett and Hague follows from the sign of this term. This justifies the naming of the term.

On the other hand, the second term in (14) is positive if the following conditions are satisfied:[12]

(a) The 1st commodity is imposed the lowest tax rate among all commodities, and is substitutable for all other commodities.

(b) The n-th commodity is imposed the highest tax rate, and is substitutable for all other commodities.

In other words, the second term in (14) is made positive by increasing the lowest commodity tax rate and reducing the highest commodity tax rate so as to keep the revenue constant, when the commodities with the extreme tax rates are substitutable for all other commodities. Equation (14) makes it clear, therefore, that the second term pulls the extreme commodity tax rates toward uniformity when commodities are substitutable. We will call this term the *practitioners' hunch term*, since practitioners of tax policy usually recommend equalization of tax rates so as to reduce distortions among commodities, without paying much attention to wage elasticities.

3. The Integrated Effect of a Tax Reform[13]

It is readily seen that the Corlett and Hague term is non-negative if and only if[14]

(15) $$\tau^n \eta_0^n - \tau^1 \eta_0^1 \geq 0.$$

The discussion above makes it clear that if (15) holds in addition to (a) and (b) above, then efficiency is improved by an increase in t^1 accompanied by a simultaneous reduction in t^n so as to maintain the initial revenue level.

Since $\tau^n > \tau^1$ under (a) and (b), inequality (15) is automatically satisfied if the n-th good is more or equally substitutable for leisure than the first good is, *i.e.*,

(16) $$\eta_0^n \geq \eta_0^1.$$

Thus the revenue-constrained squeezing of extreme commodity tax rates improves efficiency when (a), (b), and (16) are satisfied. This may be

12. Condition (a) implies that $t^1 < t^i$ and $x_i^1 > 0$ for $i = 2,..., n$, while condition (b) implies that $t^i < t^n$ and $x_i^n > 0$ for $i = 1,..., n-1$.

13. The discussion here follows Hatta (1986).

14. Under a wage taxation, $t^0 < 0$ (See Hatta (1993, p. 127)). $t^0 + 1$ must be positive since the wage tax rate would be 100% or more, otherwise.

viewed as a generalization of the Corlett and Hague result to the situation where the initial commodity tax structure is not uniform.

Upon scrutiny, however, the relative magnitude of the wage elasticities of substitution between the first and the n-th good does not play a critical role as a condition for welfare improving tax reform. To begin with, inequality (15) is satisfied even if (16) is violated, especially if t^n is much greater than t^1. In any case, whether or not the economy satisfies (15) can be verified empirically. Besides, (15) is only a part of a set of sufficient conditions for efficiency improvement, and hence, even if it is violated, the squeezing of the tax rates can improve efficiency under conditions (a) and (b). These observations imply that unless commodity 1 is strongly complementary with leisure or commodity n is strongly substitutable for leisure, the sign of the practitioner's hunch term can easily dominate the sign of the Corlett and Hague term.

As the extreme tax rates are squeezed, either the highest tax rate will become equal to the second highest or the lowest will become equal to the second lowest, sooner or later. Suppose that the former takes place first. Then a joint reduction of the two highest tax rates will improve efficiency if the commodities with these rates are substitutable for all other commodities, and if a condition similar to (15) is not flagrantly violated. Tax reform can proceed in this manner and more and more commodities will share each of the extreme tax rates. As the reform progresses, the wage elasticity of the group of the commodities that share the highest tax rate will become similar to the wage elasticity of the group of the commodities that share the lowest tax rate, and a generalized version of condition (15) becomes unlikely to be violated. Thus we can expect that in an economy where substitutability dominates, tax reforms toward uniformity are likely to improve efficiency monotonically, unless tax rates are already close to uniform.

Fukushima and Hatta (1989) discusses various modifications to the tax reform schemes toward uniformity when some of the efficiency improvement conditions are violated.

4. Strategy of Tax Reform

The discussion above suggests a three-step implementation of optimal tax rules to an arbitrarily divergent initial tax system.

First, bundle together closely substitutable commodities, and make the tax rates within each bundle uniform, while leaving the tax rates across different bundles different. Each bundle may be called a *composite commodity*.

Second, equate the tax rates across composite commodities, thus making commodity tax rates uniform. Here we apply the extreme tax rate squeezing rule, treating each composite commodity as if it were a commodity. Since composite commodities are likely to be substitutable for each other, the sufficient conditions for efficiency improvement are likely to be satisfied at each successive squeezing of the extreme tax rates.

Third, fine tune the tax rates of composite commodities by applying the Corlett and Hague rule to commodity pairs that flagrantly violates (15).

A large efficiency gain will be obtained by the second step, if a uniform tax is a good approximation of the optimal tax. This prognosis, however, is in direct conflict with the celebrated empirical estimation by Atkinson and Stiglitz (1972), which showed rather divergent optimal tax rates.

It turns out, however, that their estimate of the divergent optimal tax rates is due to their assumption of extremely high elasticity of labor supply. If the elasticity of labor supply were high, wage elasticities of commodities can be widely divergent, and the Corlett and Hague term can be negative at some stage in the second step of the reform above. Under such an assumption, therefore, Atkinson and Stiglitz's result of divergent optimal tax rates is consistent with our theoretical analysis.

Fukushima and Hatta (1989) have established, however, that when this elasticity is changed to realistic values in the Atkinson-Stiglitz model, the optimal tax rates become much closer to uniformity. It shows that if the compensated wage elasticity of labor supply is 0.5 or less, the efficiency cost of adopting a uniform tax structure rather than the optimal one is less than 5% of the government revenue in all three regions considered by Atkinson and Stiglitz.[15] Thus large efficiency gains will be obtained by the first and the second steps of our tax reform strategy, and the gains obtained from the last stage will be relatively small.

B. Revenue-Constrained Tariff Reform

The tax reform rules discussed above can also be directly applied to the revenue-constrained tariff reform situation.

First, bundle together closely substitutable importables, and make the tariff rates within each bundle uniform, while leaving the tariff rates across different bundles different. Second, equate the tariff rates across the bundles, thus making all the tariff rates uniform. Third, fine-tune the tariff rate of each commodity by applying the Corlett and Hague rule to the commodity pairs that flagrantly violates (15). Again we can expect that a close approximation of the optimal tariff structure is at the end of the second step if imports are substitutable among themselves.

Some modifications are needed, however, in applying the optimal tax rules and reform rules to the tariff situation.

First, assuming that there is only one export good is obviously unrealistic. The export in the model of Section 4 should be interpreted as a compound of export goods.

15. In contrast, this efficiency cost would be 36.52% in Sweden if its wage elasticity were 2.03 as implicitly assumed by Atkinson and Stiglitz.

Second, substitutable rather than fixed supply of outputs is essential in the trade model. This can be brought into the analysis by redefining the function z as

$$z(q, u) \equiv x(q, u) - y(q), \tag{17}$$

where $y(q)$ is the supply function of the producers. In this interpretation, substitution terms in tariff rules discussed above should be interpreted as

$$z_j^i \equiv x_j^i - y_j^i ,$$

where the subscript shows the variable with which the given function is differentiated.

Third, under the presence of production subsidies and consumption taxes, the prices that the producers face become different from those that the consumers face. Then modifications are needed in the formal analysis itself.

Fourth, the existence of non-traded goods brings in a new element. But extension of the existing theory to this case does not seem particularly difficult. The revenue-constrained tax reform formula given in (14) was obtained in Hatta (1986) as a straightforward modification of the revenue-unconstrained version of the tax reform formula of Hatta (1977a). On the other hand, revenue-unconstrained versions of the tariff reform formulae for the economy with *non-traded* goods are already derived in Hatta (1977b) and Fukushima (1979). Thus a revenue-constrained tariff reform formulae for an economy with non-traded goods should be similarly obtained by a straightforward modification of the revenue-unconstrained versions.

Fifth, determining the tariff rates on the imported intermediate inputs is an entirely new element in the problem of revenue-constrained optimum tariff.[16]

7. Concluding Remarks

The reason why the optimum tax theory and the revenue-constrained tariff theory have similar formal structures is that both models have untaxable goods. Consumption of leisure is untaxable in the taxation model, while the consumption of the exportable commodity is untaxable in the tariff model.

Note, however, that if consumption taxes can be levied on the exportables along with import tariffs, the first best can be attained by equating tariff rates and consumption tax rates. To see this, consider again the econ-

16. See Panagariya (1994), Chambers (1994), and Mitra (1994).

omy depicted in Figure 2. Suppose that an import tariff on commodity Y is combined with a consumption tax on commodity X with an equal rate. Then the consumers' budget line will coincide with the line CD, making this combination equivalent to a lump sum tax. Point L will be the resulting consumption bundle.

The non-availability of the leisure taxation in the taxation model is a natural assumption; it is based on the intrinsic nature of leisure. On the other hand, the reason for the non-availability of consumption taxes on exportables is ad hoc, reflecting a particular political situation or development stage of an economy. In many situations, consumption taxes are feasible as policy instruments. Then the policy should aim at uniform rates of tariffs and consumption taxes on commodities other than imported commodities.

What we showed in this paper is that, even during a period when such consumption taxes are not available, a uniform tariff structure can be a good approximation of the optimum when importables are substitutes among themselves.

In the present paper, we note the formal similarity between the revenue-constrained optimum tariff and the optimum commodity tax structures. This enabled us to exploit the neo-Musgravian perspective for taxes in characterizing the revenue-constrained optimum tariffs. More theoretical and empirical research are needed in order to clarify how closely the uniform tariff approximates the revenue-constrained optimum tariff structure. The neo-Musgravian perspective sheds light on the directions of this research.

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10 Local Content Requirements and International Market Share Rivalry

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1. Introduction

Foreign firms locate themselves in a host country for a number of reasons. It could be for lower labour costs in the host country. For example, many Japanese firms make foreign direct investments (henceforth to be referred to as FDI) in many Asian countries as labour costs there are a fraction of that in Japan. Typically, in such cases the commodities produced in the host country are exported in their entirety to a third country (called the consuming country). FDI also takes place in order to have access to a market which is otherwise not penetrable. The host country does not lose out if there are no domestic firms there, and in fact it encourages FDI in order to reduce the level of unemployment. However, foreign firms often import inputs from their home countries and therefore the host country does not benefit fully from having the foreign firms. In order to reap the full benefit of having FDI, host countries tend to impose local content requirements on foreign firms.[1] However, if there are more than one host countries who compete in the oligopolistic market in a third country, the host countries

1. Local content regulations, which require that a foreign firm uses a certain minimum amount of domestically produced inputs in producing its final output, are commonplace internationally and have been increasing in popularity in developed and developing countries alike (see UNIDO, 1986). The automobile industries, for example, in many countries are subject to these regulations (see Herander and Thomas (1986)). There are numerous other examples of these regulations in other industries, the oil refining industry in the United States of America being one of them (see Krugman and Obstfeld (1994, pp.212-4)). The WTO is very much cognisant of the fact that local content requirement is used pervasively to restrict the international mobility of capital and has incorporated in the WTO Treaty the elimination of it as its long term objective.

may want to use local content requirements strategically in order for the foreign firms located on their soil to gain a higher share of the market and thus create more employment. This is particularly so when the host countries do not have effective access to instruments such as export subsidies to raise their market share, as they often fall foul of WTO regulations.

Given the prevalence of local content agreements, it is surprising that the existing literature has ignored this as a possible instrument for the host country. Since the work of Grossman (1981), a small theoretical literature on content protection has developed (see Davidson et al., 1985; Krishna and Itoh, 1988; Richardson, 1991, 1993; Lopez-de-Silanes et al., 1996; Lahiri and Ono, 1998a).[2] However, in none of these papers, with the exception of Lahiri and Ono (1998a, 2003), local content is considered as a policy instrument. Moreover, final goods are taken to be competitive in Grossman (1981), Krishna and Itoh (1988) and Richardson (1991, 1993), and in the case where the final goods are imperfectly competitive (Davidson et al., 1985; Lopez-de-Silanes et al., 1996), only one foreign firm is considered. In Lahiri and Ono (1998a), the final goods are produced under imperfect competition, and the number of foreign firms is endogenous. However, the good there is non-tradeable. Lahiri and Ono (2003) consider export oriented FDI and local content requirements, but foreign firms are located only in one country. Therefore, they do not consider the strategic use of local content requirement as an instrument to gain market share.

The theoretical literature on foreign direct investment is very large (see, for example, Brander and Spencer, 1987; Dixit, 1984; Ethier, 1986; Helpman, 1984; Hillman and Ursprung, 1993; Hortsman and Markusen, 1992; Katrak, 1977; Lahiri and Ono, 1998a, 1998b, & 2003; Motta, 1992; Ono, 1990; Smith, 1987).[3] However, most of the literature analyse the problem from the viewpoint of foreign firms.

In this paper we consider a model in which foreign firms locate themselves in two host countries and export their produce in their entirety to a third country, the consuming country. These firms compete in the consuming country in an oligopolistic market there.[4] We assume the existence of

2. There is also a related literature on rules of origin. See, for example, Krishna and Krueger (1995) and Falvey and Reed (1998).

3. Foreign investment is, broadly speaking, of two types: (i) FDI where a firm locates its plant in a foreign country along with necessary managerial resources, and (ii) portfolio investment where a firm simply owns a part of the capital stock of a foreign firm. In the latter type, which is prevalent in the literature of tax competition, foreign investment is equivalent to international mobility of the factor of production capital (see Ruffin (1984) for a survey of the theoretical literature on international factor movements).

4. It may be helpful to think of the two host countries as China and Malaysia, the third country as the USA, and the oligopolistic good to be VCR or digital camera.

unemployment in both host countries. The two host country governments choose local content requirements to maximise welfare. We consider two cases. In the first case, there is one foreign firm in each host country. In this case, a local content restriction would not affect the number of firms, but it would influence the output decisions of the firms. In the second case, the number of foreign firms in one of the countries is endogenous. In both cases we try to characterise both cooperative and non-cooperative levels of optimal local content requirements in the two host countries. We also examine if the two countries can benefit from a coordinated policy reform.

The basic economic model for the case of fixed number of foreign firms is spelt out in details in the following section. Section 3 then carries out a formal analysis for the basic model. The case of free entry and exit of foreign firms is analysed in section 4. Finally, some concluding remarks are made in section 5.

2. The Benchmark Model

In our model there are two exporting (host) countries (labelled as country 1 and country 2) and one consuming (importing) country. There are two foreign firms (one located in each exporting country) competing for the oligopolistic market of a homogeneous good in the consuming country.[5] The two foreign firms can originate from two different countries or from one country. In section 3 we should consider the case of free entry and exit of foreign firms in one of the two exporting countries. We assume the existence of unemployment in the two exporting countries. The inverse demand function for oligopolistic good is given by

$$p = \alpha - \beta D, \tag{1}$$

where p is price and D is the total demand for the good, which is equal to the sum of output produced by the two firms, i.e.

$$D = x_1 + x_2, \tag{2}$$

where x_i ($i = 1, 2$) is the output of a foreign firm in country i. The profits of a foreign firm located in country i, π_i, ($i = 1, 2$), is given by

5. This benchmark model is an extension of the international market share rivalry model of Brander and Spencer (1985). There are three main differences between the present model and that of Brander and Spencer (1985). First, the firms are foreign owned in our model whereas they are domestic in their model. Second, we consider the existence of unemployment, the Brander-Spencer model is a full employment one. Finally, the policy instruments considered are different: they use export subsidies and we consider local content requirement.

(3) $$\pi_i = (p - c_i)\, x_i, \quad i = 1, 2,$$

where the marginal costs of the foreign firms located in country 1 and 2, denoted respectively by c_1 and c_2, are taken to be constants, and therefore they are also the average variable costs. As an extreme assumption, we take that each foreign firm would prefer to use inputs from its home country as it is cheaper to do so, but it faces a stipulation that at least a δ_i, (i = 1, 2), proportion of total inputs has to be bought in the host country in which the foreign firm is located. Let $b_i\,(\hat{b}_i)$ be the unit input cost in country i if all the inputs are bought in the host (home) economy. With the aforesaid stipulation on local contents, the marginal costs for the foreign firms in country 1 and 2 are given by

(4) $$c_i = \hat{b}_i\left(1-\delta_i\right)+\delta_i b_i, \quad i=1,\ 2,$$

where $b_i > \hat{b}_i$, $(i = 1, 2)$.

The firms are assumed to behave in a Cournot-Nash fashion. Hence, profit maximisation yields

(5) $$\beta x_i = p - c_i, \quad i = 1, 2.$$

Given the policy decisions of the governments, the equilibrium output of a foreign firm can be found from (5) as

(6) $$x_i = \frac{\alpha - 2c_i + c_j}{3\beta}, \quad i, j = 1,\ 2 \quad i \neq j.$$

As stated before, we assume that there is unemployment in countries 1 and 2. Following Brander and Spencer (1987), factor input costs are taken to be the income of the factors which would remain unemployed in the absence of the production of the oligopolistic good. With this and assuming that the entire profits of the foreign firms are repatriated, the welfare level in country i, (i = 1, 2), denoted by W_i is given by

(7) $$W^i = x_i b_i \delta_i, \quad i = 1,\ 2.$$

This completes the description of the model structure, and we now turn to analysis.

Substituting (4) in (6), and totally differentiating the result we obtain

(8) $$dx_i = -\frac{2(b_i - \hat{b}_i)}{3\beta} d\delta_i + \frac{(b_j - \hat{b}_j)}{3\beta} d\delta_j \quad i, j = 1,\ 2 \quad i \neq j.$$

The intuition is straightforward. Each foreign firm will decrease (increase) its production if it faces a higher (lower) local content requirement or if the local content required from the rival firm is reduced (raised). This is because a more severe local content restriction for a firm gives its rival a competitive advantage.

Totally differentiating the welfare functions we get

$$3\beta dW^1 = A_1 d\delta_1 + A_2 d\delta_2, \tag{9}$$

$$3\beta dW^2 = A_3 d\delta_1 + A_4 d\delta_2, \tag{10}$$

where

$$A_1 = \left[3\beta x_1 b_1 - 2b_1\delta_1(b_1 - \hat{b}_1)\right],$$
$$A_2 = b_1\delta_1(b_2 - \hat{b}_2),$$
$$A_3 = b_2\delta_2(b_1 - \hat{b}_1),$$
$$A_4 = \left[3\beta x_2 b_2 - 2b_2\delta_2(b_2 - \hat{b}_2)\right].$$

A more severe local content on a firm has two opposing effects on its host's welfare, and one positive effect on the other country. First, for a given level of output, it raises employment and this is good for the host. Second, it gives the firm in the other country a competitive advantage raising employment in the other country and lowering that at home. This is why A_1 and A_4 are ambiguous, and A_2 and A_3 are unambiguously positive.

3. The Determination of Local Content Restriction

In this section, we first consider the case where the governments behave in a non-cooperative fashion. We find the non-cooperative Nash levels of local content restrictions, δ_1^N and δ_2^N, by setting A_1 and A_4 equal to zero,[6]

$$\delta_1^N = \frac{3\beta x_1}{2(b_1 - \hat{b}_1)} > 0, \tag{11}$$

$$\delta_2^N = \frac{3\beta x_2}{2(b_2 - \hat{b}_2)} > 0. \tag{12}$$

6. Both welfare functions are concave in the local content parameters as $3\beta W^1_{\delta_1\delta_1} = -4b_1(b_1 - \hat{b}_1) < 0$ and $3\beta W^2_{\delta_2\delta_2} = -4b_2(b_2 - \hat{b}_2) < 0$.

We now turn to comparing the levels of restrictions in the two countries under a number of scenarios. First of all, it can be verified that when b_1=b_2 and $\hat{b}_1 = \hat{b}_2$, the non-cooperative optimal levels of the local content requirements would be the same in the two countries. Next, we assume that the two foreign firms face the same unit input costs at home, (i.e., $\hat{b}_1 = \hat{b}_2 = \hat{b}$ (say)). By using the explicit solutions of (11) and (12) we obtain

$$\left(\delta_1^N - \delta_2^N\right)\Big|_{\hat{b}_1=\hat{b}_2=\hat{b}} = -\frac{1}{3}\frac{(\alpha-\hat{b})(b_1-b_2)}{(b_1-\hat{b})(b_2-\hat{b})}.$$

It follows from the above that when $\hat{b}_1 = \hat{b}_2$,

$$\left(\delta_1^N - \delta_2^N\right)\Big|_{\hat{b}_1=\hat{b}_2} \gtreqless 0 \iff b_2 \gtreqless b_1.$$

That is, when the unit input costs in the home countries are identical, the relative magnitude of non-cooperative optimal levels of local content restrictions in the two host (exporting) countries depends on the relative size of the input costs in the host countries. In particular, country 1 applies a higher (lower) local content requirement if the unit input cost in that country is lower (higher) than that in country 2. This result can be explained intuitively as follows. Suppose that the local content restriction level in country 2 is the same as the optimal level in country 1 and $b_1 > b_2$. Clearly, country 2 has a higher market share, and therefore a higher output base to raise employment by raising the restriction level. This is why the optimal local content restriction is higher in country 2. This result is formally stated as

Proposition 1. *When the unit input costs in the home countries of the two firms are identical, a host country, in a Nash equilibrium, applies a higher (lower) local content requirement if the unit input cost in that country is lower (higher) than that in the other host country.*

Finally, suppose that the unit input costs in the two host countries are identical ($b_1 = b_2$) whereas $(\hat{b}_1 \neq \hat{b}_2)$. From the explicit solutions we get

$$\left(\delta_1^N - \delta_2^N\right)\Bigg|_{b_1=b_2=b} = \frac{\left[5\alpha - 9b + 2(\hat{b}_1+\hat{b}_2)\right]}{15(b-\hat{b}_1)(b-\hat{b}_2)}(\hat{b}_1-\hat{b}_2).$$

In this case, no clear cut result emerges. However, if the size of the demand for the oligopolistic good is sufficiently large, i.e. if $\alpha >> 0$ and $b_1 = b_2$, we find

$$\delta_1^N \gtreqless \delta_2^N \quad \Leftrightarrow \quad \hat{b}_1 \gtreqless \hat{b}_2 .$$

The result is different from the previous case because an increase in δ_1, at the margin, increases marginal cost in country 1 by *more* than that in country 2 when $b_1 > b_2$ and $\hat{b}_1 = \hat{b}_2$, but increases marginal cost in country 1 by *less* than that in country 2 when $\hat{b}_1 > \hat{b}_2$ and $b_1 = b_2$.

Proposition 2. *When the unit input costs in the two host countries are identical and* $\alpha >> 0$, *a foreign firm, in a Nash equilibrium, is subjected to a higher (lower) local content requirement if the unit input cost in its home country is higher (lower) than that in the other home country.*

Having compared the two Nash values of the local content parameters, we now examine the cooperative equilibrium. In order to find the cooperative equilibrium, we define total welfare by adding (9) and (10);

(13) $$3\beta\, dW = \left(A_1 + A_3\right)d\delta_1 + \left(A_2 + A_4\right)d\delta_2 .$$

For total welfare to be concave in δ_1 and δ_2, we must have

$$\begin{aligned}
3\beta W_{\delta_1\delta_1} &= -4b_1(b_1 - \hat{b}_1) < 0,\\
3\beta W_{\delta_2\delta_2} &= -4b_2(b_2 - \hat{b}_2) < 0,\\
9\beta^2\left[W_{\delta_1\delta_1}W_{\delta_2\delta_2} - W_{\delta_1\delta_2}^2\right] &= 16b_1b_2(b_1 - \hat{b}_1)(b_2 - \hat{b}_2)\\
&\quad -\left[b_1(b_2 - \hat{b}_2) + b_2(b_1 - \hat{b}_1)\right]^2 > 0.
\end{aligned}$$

Setting the coefficients of $d\delta_1$ and $d\delta_2$ equal to zero, and solving simultaneously for δ_1 and δ_2, we find the cooperative solutions as

(14) $$\delta_1^C = \beta\frac{\left[2b_1x_1(b_2 - \hat{b}_2) + b_2x_2(b_1 - \hat{b}_1)\right]}{b_1(b_2 - \hat{b}_2)(b_1 - \hat{b}_1)} > 0,$$

(15)
$$\delta_2^C = \beta \frac{\left[b_1 x_1 (b_2 - \hat{b}_2) + 2 b_2 x_2 (b_1 - \hat{b}_1)\right]}{b_2 (b_2 - \hat{b}_2)(b_1 - \hat{b}_1)} > 0.$$

As before we compare the levels of restrictions in the two countries. When the input costs bought in the two home countries are identical, (i.e., $\hat{b}_1 = \hat{b}_2 = \hat{b}$), by using the explicit solutions for (14) and (15) we obtain

$$\left(\delta_1^C - \delta_2^C\right)\Big|_{\hat{b}_1 = \hat{b}_2 = \hat{b}} = -\frac{(\alpha - \hat{b})\left[6 b_1 b_2 - \hat{b}\left(b_1 + b_2\right)\right]}{\theta_1}\left(b_1 - b_2\right),$$

where $\theta_1 = 16 b_1 b_2 (b_1 - \hat{b})(b_2 - \hat{b}) - \left[b_1 (b_2 - \hat{b}) + b_2 (b_1 - \hat{b})\right]^2 > 0$ from the concavity condition, and the numerator of the first term on the right hand side of the above equation is positive since $b_i > \hat{b}$, $i = 1, 2$. Therefore, when $\hat{b}_1 = \hat{b}_2$,

$$\left(\delta_1^C - \delta_2^C\right)\Big|_{\hat{b}_1 = \hat{b}_2} \gtreqless 0 \quad \Leftrightarrow \quad b_2 \gtreqless b_1.$$

That is, with $\hat{b}_1 = \hat{b}_2$ and the the governments cooperate, a country applies a higher (lower) local content requirement if the unit input cost in that country is lower (higher) than that in the other country, a similar result to the non-cooperative case. Formally,

Proposition 3. *When the unit input costs in the home countries of the two firms are identical, a host country, in a cooperative equilibrium, applies a higher (lower) local content requirement if the unit input cost in that country is lower (higher) than that in the other host country.*

When the unit input costs in the two host countries are identical ($b_1 = b_2 = b$), from the explicit solutions we get

$$\left(\delta_1^C - \delta_2^C\right)\Big|_{b_1 = b_2 = b} = \frac{\left[2(2\alpha - 3b) + (\hat{b}_1 + \hat{b}_2)\right]}{\theta_1}(\hat{b}_1 - \hat{b}_2),$$

where $\theta_1 = 16 b^2 (b - \hat{b}_1)(b - \hat{b}_2) - \left[b^2\left[(b - \hat{b}_1) + (b - \hat{b}_2)\right]\right]^2 > 0$ from the concavity condition. As in the non-cooperative case, for significantly large α and $b_1 = b_2$,

$$\delta_1^C \gtreqless \delta_2^C \quad \Leftrightarrow \quad \hat{b}_1 \gtreqless \hat{b}_2.$$

Once again, the qualitative result here is exactly the same as in the corresponding case in the non-cooperative equilibrium.

Proposition 4. *When the unit input costs in the two host countries are identical and $\alpha >> 0$, a foreign firm, in a cooperative equilibrium, is subjected to a higher (lower) local content requirement if the unit input cost in its home country is higher (lower) than that in the other home country.*

3.1. Reform from a Non-Cooperative Equilibrium

In this subsection we examine the effects on welfare in both countries of a small increase in the local content requirements when the initial levels are set at the non-cooperative level. This can be seen as a multilateral effort to coordinate local content restriction policies. Substituting (11) in (9), and (12) in (10), we obtain

$$dW^1\Big|_{\delta_1=\delta_1^N} = \frac{b_1 x_1 (b_2 - \hat{b}_2)}{2(b_1 - \hat{b}_1)} d\delta_2 > 0, \tag{16}$$

$$dW^2\Big|_{\delta_2=\delta_2^N} = \frac{b_2 x_2 (b_1 - \hat{b}_1)}{2(b_2 - \hat{b}_2)} d\delta_1 > 0. \tag{17}$$

Equations (16) and (17) suggest that starting from the non-cooperative equilibrium, a multilateral increase in the levels of local content requirements is strictly Pareto-improving.[7] The intuition is straightforward. As we have noted before, the international externalities associated with a stricter local content restriction are positive. Since we start from the non-cooperative equilibrium, due to envelope property, the own effects of the reform are absent and it is only the positive externalities that determine the outcome.

Proposition 5. *Starting from the non-cooperative equilibrium, when the number of foreign firms is exogenous, a multilateral increase in the levels*

7. By strict Pareto improvement, we mean that the welfare levels in the two host countries are higher: we do not take into account the consuming country's welfare.

of local content requirements is strictly Pareto-improving.

By using the above results, one can also compare the relative magnitudes of optimal local content requirements for the two countries under the cooperative and non-cooperative equilibria. From (10) and (13), we find

$$3\beta \frac{\partial W}{\partial \delta_1}\bigg|_{\delta_1=\delta_1^N} = A_2 > 0,$$

$$3\beta \frac{\partial W}{\partial \delta_2}\bigg|_{\delta_2=\delta_2^N} = A_3 > 0.$$

From the concavity of the global welfare it then follows that $\delta_i^C > \delta_i^N$, $i = 1, 2$. It is the competition for FDI which keeps the non-cooperative levels of the local content restrictions at a level that is lower than the co-operative levels. Formally,

Proposition 6. *When the number of foreign firms is exogenous, all host governments apply a more severe local content restrictions under a cooperative solution than under a non-cooperative solution.*

4. Free Entry and Exit of Foreign Firms

In the preceding section we assumed that the number of foreign firms in the two host countries are exogenously given. In this section, we relax this assumption and assume that there are now n identical foreign firms from the rest of the world operate in country 1.[8] It is assumed that country 1 is small in the market for FDI. Hence, the foreign firms will move into (out of) country 1 if the profits they make in country 1 are larger (smaller) than the reservation profit, $\bar{\pi}$, that they can make in the rest of the world. Therefore, in the FDI equilibrium we must have

$$\pi_1 = \bar{\pi}. \tag{18}$$

The total demand for the good is now given by

$$D = nx_1 + x_2. \tag{19}$$

8. Unfortunately, it is not possible to endogenise the numbers of firms in both countries as then one group of firms—the ones with higher marginal costs—will be forced out of the market. One way out could be to relax the assumption that the goods produced by the two groups of firms are homogeneous as was done in Lahiri and Ono (1998b).

The closed form solutions to many of the key variables in the model can be solved sequentially as:

(20) $$n = \frac{\alpha - 2c_1 + c_2}{\sqrt{\pi}\sqrt{\beta}} - 2,$$

(21) $$x_1 = \frac{\alpha - 2c_1 + c_2}{\beta(2+n)} = \frac{\sqrt{\pi}}{\sqrt{\beta}},$$

(22) $$x_2 = \frac{\sqrt{\pi}\sqrt{\beta} + c_1 - c_2}{\beta}.$$

Substituting (4) into (20) to (22) and totally differentiating the results we obtain

(23) $$dn = -\frac{2(b_1 - \hat{b}_1)}{\sqrt{\pi}\sqrt{\beta}} d\delta_1 + \frac{(b_2 - \hat{b}_2)}{\sqrt{\pi}\sqrt{\beta}} d\delta_2,$$

(24) $$dx_1 = 0,$$

(25) $$dx_2 = \frac{(b_1 - \hat{b}_1)}{\beta} d\delta_1 - \frac{(b_2 - \hat{b}_2)}{\beta} d\delta_2.$$

Equation (23) states that since there is free entry and exit of FDI in country 1, an increase in the level of local contents in country 2, or a decrease in the level of local contents in country 1, will encourage more foreign firms to enter country 1. The foreign firm in country 2 will increase (decrease) production if it is allowed to use less (more) local contents or if the level of local contents for the firms in country 1 is raised (reduced) (equation (25)). This is because an increase in $\delta_1(\delta_2)$ gives the firm in country 2 a competitive advantage (disadvantage) over the firm in country 1. Because of free entry and exit and the linearity of demand, the output of a foreign firm in country 1 does not change with the policy instruments.

Adjusting the welfare equation (7) for country 1 (by multiplying it by n) and then totally differentiating W^1 and W^2, we get

(26) $$\beta\, dW^1 = A_5 d\delta_1 + A_6 d\delta_2,$$

(27) $$\beta\, dW^2 = A_7 d\delta_1 + A_8 d\delta_2,$$

where

$$A_5 = b_1\left[\beta x_1 n - 2\left(b_1 - \hat{b}_1\right)\delta_1\right],$$
$$A_6 = b_1\left(b_2 - \hat{b}_2\right)\delta_1,$$
$$A_7 = b_2\left(b_1 - \hat{b}_1\right)\delta_2,$$
$$A_8 = b_2\left[\beta x_2 - \left(b_2 - \hat{b}_2\right)\delta_2\right].$$

Setting A_5 and A_8 equal to zero, we obtain the non-cooperative optimal levels of the two policy instruments as[9]

(28) $$\hat{\delta}_1^N = \frac{\beta n x_1}{2(b_1 - \hat{b}_1)} > 0,$$

(29) $$\hat{\delta}_2^N = \frac{\beta x_2}{2(b_2 - \hat{b}_2)} > 0.$$

Having found the non-cooperative levels for the free entry case, we now compare the levels of local content restrictions by substituting the explicit solutions of the variables in the expression and considering special cases.

It is to be recalled in the last section, i.e. when there is only one firm in each country and $b_1 = b_2$ and $\hat{b}_1 = \hat{b}_2$, the optimal non-cooperative level of the local content requirements were the same in the two countries. In the present case however that is not true. From (28) and (29), we find that when $b_1 = b_2$ and $\hat{b}_1 = \hat{b}_2$,

$$\hat{\delta}_1^N \gtreqless \hat{\delta}_2^N \quad \Leftrightarrow \quad \left.\frac{x_2}{D}\right|_{\delta_1 = \delta_2 = 0} \lesseqgtr \frac{1}{3}.$$

That is, country 2 imposes higher (lower) local content restrictions if the market share of the foreign firm located in that country is more (less) than one-third. An increase in the local content restriction in country 2 lower its market share and increases the profitability of the firms in country 1, leading to an inflow of new firms in country 1. This lowers the market share

9. Both welfare functions are concave in the local content parameters as $\beta W^1_{\delta_1\delta_1} = -4b_1(b_1 - \hat{b}_1) < 0$ and $\beta W^2_{\delta_2\delta_2} = -2b_2(b_2 - \hat{b}_2) < 0$.

of country 2 even more. This second round effect via changes in the number of firms was absent before, and this explains why the result is qualitatively different in the presence of free entry and exit than under fixed number of firms.

When $\hat{b}_1 = \hat{b}_2 = \hat{b}$, we obtain

$$(30) \qquad (\hat{\delta}_1^N - \hat{\delta}_2^N)_{\hat{b}_1=\hat{b}_2=\hat{b}} = (b_2 - b_1)(\alpha - \hat{b} - 2\sqrt{\overline{\pi}}\sqrt{\beta}) + (b_2 - \hat{b})(\alpha - \hat{b} - \sqrt{\overline{\pi}}\sqrt{\beta}) - 4(b_1 - \hat{b})\sqrt{\overline{\pi}}\sqrt{\beta}$$

where $(\alpha - \hat{b} - 2\sqrt{\overline{\pi}}\sqrt{\beta}) = \beta x_1 n\big|_{\delta_1=\delta_2=0} > 0.$

It follows from (30) that $\hat{\delta}_1^N > \hat{\delta}_2^N$ if $b_2 > b_1$ and $\overline{\pi} \simeq 0,$ and that $\hat{\delta}_1^N < \hat{\delta}_2^N$ if $b_2 < b_1$ and $\overline{\pi} >> 0.$ Therefore in contrast to the no entry case, the relative size of local content requirements in the free entry case not only depends on the size of relative unit input costs in the two countries but also on the number of foreign firms entering country 1. The above results are summarised formally in the following proposition.

Proposition 7. *When there is free entry and exit of foreign firms in country 1 and just one foreign firm in country 2, the following are true:*

(i) *when* $b_1 = b_2$ *and* $\hat{b}_1 = \hat{b}_2$, $\hat{\delta}_1^N \gtreqless \hat{\delta}_2^N \quad \Leftrightarrow \quad \dfrac{x_2}{D}\Big|_{\delta_1=\delta_2=0} \lesseqgtr \dfrac{1}{3},$

(ii) $\hat{\delta}_1^N > \hat{\delta}_2^N$ *if* $b_2 > b_1$ *and* $\overline{\pi} \simeq 0,$ *and*

(iii) $\hat{\delta}_1^N > \hat{\delta}_2^N$ *if* $b_2 < b_1$ *and* $\overline{\pi} >> 0.$

Before proceeding to the case where the governments cooperate, we compare the non-cooperative restriction levels in the no entry case with that in the free entry and exit case. Subtracting (28) from (11), and (29) from (12), and using the explicit solutions we find the following

$$\delta_1^N - \hat{\delta}_1^N = \frac{5\alpha + 45\sqrt{\pi}\sqrt{\beta} - 4\hat{b}_1 - \hat{b}_2}{105\left(b_1 - \hat{b}_1\right)} > 0,$$

$$\delta_2^N - \hat{\delta}_2^N = \frac{10\alpha - 15\sqrt{\pi}\sqrt{\beta} - 8\hat{b}_1 - 2\hat{b}_2}{105\left(b_1 - \hat{b}_1\right)} > 0,$$

since the denominators are positive and it can easily be shown, by using $\alpha - 2\hat{b}_1 + \hat{b}_2 - 2\sqrt{\pi}\sqrt{\beta} = \beta x_1 n\big|_{\delta_1=\delta_2=0} > 0$, that the numerators are also positive. This result shows that when there is free entry and exit in one of the countries, both countries impose less severe restrictions than in the case where the number of firms are exogenous in both countries. This can be explained intuitively as follows. Country 1 has to be more cautious about raising the local content restriction in the presence of free entry and exit because a higher restriction would lead to the exit of some of the firms (which is not possible in the absence of free entry and exit), reducing employment. If country 2 increases the restriction, as mentioned above, it lowers the market share of the firm in country 1 and increases the profitability of the firms in country 1, leading to an inflow of more firms into the market in the presence of free entry and exit. This lowers the market share of the firm in country 2 even more. Therefore, the levels of optimal local content restrictions are lower in both countries when there is free entry and exit in country 1 than when the number of firms in country 1 is fixed.

Proposition 8. *In a non-cooperative equilibrium, the host governments apply less severe local content restrictions when there is free entry and exit of foreign firms in one of the countries than in the case where the number of firms are exogenous in both countries.*

We now turn to the cooperative equilibrium. Total welfare is given by adding (26) and (27)

$$\beta\, dW = \left(A_5 + A_7\right)d\delta_1 + \left(A_6 + A_8\right)d\delta_2 \tag{31}$$

Setting the coefficients of $d\delta_1$ and $d\delta_2$ equal to zero, and solving simultaneously for δ_1 and δ_2, we find the optimal cooperative local content restriction levels as[10]

(32) $$\hat{\delta}_1^C = \beta \frac{\left[b_1 x_1 n(b_2 - \hat{b}_2) + b_2 x_2 (b_1 - \hat{b}_1)\right]}{b_1 (b_2 - \hat{b}_2)(b_1 - \hat{b}_1)} > 0,$$

(33) $$\hat{\delta}_2^C = \beta \frac{\left[b_1 x_1 n(b_2 - \hat{b}_2) + 2 b_2 x_2 (b_1 - \hat{b}_1)\right]}{b_2 (b_2 - \hat{b}_2)(b_1 - \hat{b}_1)} > 0.$$

When $\hat{b}_1 = \hat{b}_2$, subtracting (33) from (32), we obtain

$$(\hat{\delta}_1^C - \hat{\delta}_2^C)\Big|_{\hat{b}_1 = \hat{b}_2 = \hat{b}} = \beta \frac{b_1 x_1 n(b_2 - \hat{b})\left(b_2 - b_1\right) + b_2 x_2 (b_1 - \hat{b})\left(b_2 - 2b_1\right)}{b_1 b_2 (b_1 - \hat{b}_1)(b_2 - \hat{b}_2)}.$$

It follows from the above equation that $\hat{\delta}_1^C > \hat{\delta}_2^C$ if $b_2 > 2b_1$, and $\hat{\delta}_1^C < \hat{\delta}_2^C$ if $b_2 \le b_1$.

Proposition 9. *When there is free entry and exit of foreign firms in country 1 and just one foreign firm in country 2 and* $\hat{b}_1 = \hat{b}_2$, *the following are true:*

(i) $\hat{\delta}_1^C > \hat{\delta}_2^C$ *if* $b_2 \ge 2b_1$, *and*

(ii) $\hat{\delta}_1^C > \hat{\delta}_2^C$ *if* $b_2 \le b_1$.

10. For the total welfare function to be concave in the policy parameters we need

$$\beta W^1_{\delta_1\delta_1} = -4b_1(b_1 - \hat{b}_1) < 0,$$
$$\beta W^2_{\delta_2\delta_2} = -2b_2(b_2 - \hat{b}_2) < 0,$$
$$\beta^2\left[W_{\delta_1\delta_1} W_{\delta_2\delta_2} - W^2_{\delta_1\delta_2}\right] = 6b_1b_2(b_1 - \hat{b}_1)(b_2 - \hat{b}_2) - \left[b_1^2(b_2 - \hat{b}_2)^2 + b_2^2(b_1 - \hat{b}_1)^2\right] > 0.$$

The condition is satisfied if $6b_1b_2(b_1 - \hat{b}_1)(b_2 - \hat{b}_2) > b_1^2(b_2 - \hat{b}_2)^2 + b_2^2(b_1 - \hat{b}_1)^2$.

On the other hand, when $b_1 = b_2$, we obtain

$$\left(\hat{\delta}_1^C - \hat{\delta}_2^C\right)_{b_1=b_2=b} = -\frac{\beta x_2}{(b-\hat{b}_2)} < 0.$$

When the unit input costs in the two home countries are the same, in the presence of free entry and exit in country 1, country 2 applies more severe local content restrictions than country 1.

Proposition 10. *When there is free entry and exit of foreign firms in country 1 and just one foreign firm in country 2 and $b_1 = b_2$, country 2 applies more severe local content restrictions than country 1.*

Finally, since A_6 and A_7 are both positive (see (26) and (27)), as in the previous section, the following two propositions can be proved easily

Proposition 11. *Starting from the non-cooperative equilibrium, when there is free entry of FDI in one of the host countries, a multilateral increase in the levels of local content requirements is strictly Pareto-improving.*

Proposition 12. *When there is free entry of FDI in one of the host countries, the host governments apply more severe local content restrictions under the cooperative solution than that under the non-cooperative solution.*

5. Conclusion

Foreign direct investment (FDI) has been an important tool in the integration of the world economy. There has been a phenomenal increase in the level of FDI over the last two decades. The countries which have succeeded in achieving high growth rates of national income, tend to be the countries which have been able to attract a large amount of FDI.

Because of international agreements, there are now limited number of instruments that a host country government can employ, to encourage or discourage foreign firms, and to make the best use of them. One such instrument is to specify that at least a certain fraction of inputs should be bought in the local market. This restriction on the input use is called the local content requirement. This instrument is now widely used, and in this paper we examine how this instrument can be used strategically by countries.

We develop a model of FDI in which foreign firms locate themselves in two host countries and export their entire produce to another country, called the consuming country. The commodity is produced under an oligopolistic condition. We assume the existence of unemployment in both host countries. We consider two cases depending on whether or not there is free entry and exit of foreign firms in one of the host countries. We find that the non-cooperative levels of local contents are higher than the cooperative ones for both countries whether or not there is free entry and exit of foreign firms. The optimal levels of local content requirements are also compared across countries and between the cases of no entry and free entry of foreign firms. It is shown that the relative unit cost structure plays an important role in determining the relative level of local content requirements. Free entry and exit of foreign firms in one of the countries reduce the levels of local content restrictions in both countries.

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11 Balance of Payment Adjustment under Capital Mobility

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1. Introduction

The size of international capital and exchange transactions have increased enormously in recent years as a result of financial deregulation and rapid progress in information and communication technologies. Apparently, the world has entered the era of perfect capital mobility and flexible exchange rates first envisaged by financial theorists such as Mundell (1960) and Fleming (1959) a long time ago. With the globalization of financial transactions the national rates of interest have tended to converge or at least to co-move in the same directions and exchange rates have fluctuated wildly in the short run and considerably even in the medium or long runs. The purpose of this paper is to reconsider the roles which interest rates and exchange rates (or money supplies) play in the *long-run* adjustment of international imbalances under perfect capital mobility.[1]

There are already a bulky literature on the determinants of exchange rates under international capital mobility. Since exchange rates are relative prices of different currencies, the theory of exchange rates can be estab-

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1. In 70s exchange rates seemed to be affected by the behavior of accumulated current account imbalances between countries. Their relationships have become less evident in 80s but revived dramatically in 90s as exemplified by recent currency crises in Latin America and Asia. In 70s there were apparently no definite correlation between exchange rates and international interest rate difierentials but 80s and 90s have witnessed their close co-movements. It is not completely clear, however, what roles their movements play in the world of globalized financial markets.

lished only if the concept of money is clearly stipulated. The popular asset market approach to exchange rate determination is based on the Keynsian view of money as a store of value. It is powerful in explaining short-run exchange rate fluctuations due to speculative bubbles, but appears to be less relevant to the long run trend of exchange rates. In this paper, we adopt the orthodox view of money as an indispensable means of payment. This view, coupled with the hypotheses of purchasing power parity and interest rate parity, seems to provide a useful explanation of the long-run behaviors of exchange rates and interest rates. This line of studies may be traced back to the partial equilibrium analysis of exchange rates by Robinson (1959) and Metzler (1961), later extended and elaborated by Tsiang (1959) and Sohmen (1961) to cover forward exchange contracts. More recently, the general equilibrium models in this spirit are also developed by Lucas (1982), Helpman and Razin (1982) and Svensson (1985).[2]

The plan of the paper is as follows. In Section 2, we explain the basic structure of the model. In Section 3, we describe the equilibrium conditions of the model. There are potentially a number of interpretations of the general equilibrium under capital mobility, but we consider two representative cases. The first interpretation regards the rate of interest as a major factor of adjustment in the international capital and exchange market. Section 4 is devoted to the analysis of this version. In this case, the current account imbalances are automatically adjusted through time, but the country with the higher rate of time preference tends to accumulate external debt indefinitely until it starves under the pressure of interest payment. The exchange rate plays no role staying stationary throughout the process of adjustment. The second interpretation assigns a crucial role of international adjustment to the exchange rate, or to the money supply of the key-currency country. Section 5 is allotted for the discussion of this case. Here, foreign exchange market becomes potentially unstable in the short run and the adjustment of international imbalances may not be achieved in the absence of correct monetary policy or appropriate interest rate target.

2. Production and Consumption

We consider a monetary model of two countries, home and foreign. There is only one homogeneous good produced in fixed quantity in each country. Each country has its own currency. It is indispensable as a means of payment for purchasing the good produced in that country. There are bonds designated in the home and foreign currencies serving as a store of value. The bonds and currencies are traded in perfectly competitive inter-

2. See Obstfeld and Rogoff (1996) for a brief survey of the more recent literature based on this view of money formalized as the cash-in-advance models of money demand.

national markets under the regime of flexible exchange rates. In this section, we describe the structure of the model and subjective equilibrium of its agents.

Let us begin by explaining the home country's structure. We assume the existence of discrete time periods ($t = 1, 2, ...$). At the beginning of each period, the representative consumer is assumed to receive payment in home money, M_t, (wages, dividends and monetary transfer from the government) and engage in financial transactions. All markets open and operate simultaneously for bonds and foreign exchanges. The consumer's consumption in period t, C_t, is constrained by

$$(1) \qquad p_tC_t = M_t - (1 + i_{t-1})B_{Ht-1} - (1 + i^*_{t-1})e_tB_{Ft-1} + B_{Ht} + e_tB_{Ft},$$

where p_t denotes the home country's price of the good in period t, B_{Hs} and B_{Fs} its external debts in period s in the form of bonds denominated in the home and foreign currencies, i_s and i^*_s the home and foreign nominal interest rates in period $s(s = t - 1, t)$ and e_t the exchange rate, or the price of the foreign currency in terms of the home currency. We adopt here and henceforth the convention that the subscript ($s = t, t - 1, t + 1$) to a variable signifies the period it belongs to. Equation (1) means that the home country's consumption and repayment of external debts made in period $t - 1$ are financed by the representative consumer's money income (wages, dividends and government transfer) and new borrowings made in period t.

For simplicity, the home and foreign representative consumers are assumed to form the same static expectations with regard to exogenous variables in all future periods. To be precise, they expect that the home country's price and real income levels in period $t + 1$, p_{t+1} and M_{t+1}/p_{t+1}, will repeat themselves in all future periods. Similarly, the exchange rate is expected to be e_{t+1} and the home and foreign interest rates are expected to be i_{t+1} and i^*_{t+1} in period $t + 1$ and thereafter indefinitely.[3] To ease our analysis and exposition, they are further assumed to keep their consumption and external assets at the same levels in all future periods.[4] Under this assumption, the home consumer's repayment of the debt made in period t must be equal to its repayment of debt in made in period $t + 1$, i.e.,

$$(2) \qquad (1+i_t)B_{Ht} + (1+i^*_t)e_{t+1}B_{Ft} = (1+i_{t+1})B_{Ht+1} + (1+i^*_{t+1})e_{t+1}B_{Ft+1}.$$

3. This assumption may be arbitrary but does not necessarily imply that consumers are totally irrational. Even if they attempt to behave rationally, their rationality is necessarily bounded when they lack information about the structure of economy to predict future course of events rationally.

4. This assumption means that consumers do not difierentiate consumptions in all future peiords.

This ensures that the real values of planned consumption and external assets are kept at constant levels in period $t + 1$ and afterwards.

We also assume that the uncovered interest parity condition is satisfied in the competitive international capital markets. Under the present assumption of static expectations, it may be expressed as[5]

$$(1+i_t)e_t = (1+i_t^*)e_{t+1}, \tag{3}$$

$$i_{t+1} = i_{t+1}^*. \tag{4}$$

Let us denote by $\tilde{C}_{t+1}$ the home country's planned consumption in period $t + 1$ and distinguish it from its actual consumption, C_{t+1}, in period $t + 1$. In view of (2)-(4), it is constrained by

$$p_{t+1}\tilde{C}_{t+1} = M_{t+1} - \frac{(1+i_t)i_{t+1}}{1+i_{t+1}}(B_{Ht} + e_t B_{Ft}). \tag{5}$$

From (1), (3) and (5), we get the integrated budget constraint

$$C_t + \frac{1}{r_t}\tilde{C}_{t+1} = \frac{M_t}{p_t} + \frac{M_{t+1}}{r_t p_{t+1}} - (1+i_{t-1})\frac{B_{Ht-1}}{p_t} - (1+i_{t-1}^*)\frac{e_t B_{Ft-1}}{p_t}, \tag{6}$$

where r_t is the real effective rate of interest defined by[6]

$$r_t = \frac{p_t(1+i_t)i_{t+1}}{p_{t+1}(1+i_{t+1})}. \tag{7}$$

Equation (6) shows that the home country's present value of planned consumption is equal to the present value of its outputs and external assets.

The home country's consumer is assumed to maximize a utility function of the Cobb-Douglas form:

$$u = C_t^{\rho}\tilde{C}_{t+1}^{1-\rho}, \tag{8}$$

5. Formally, (4) is to be written $(1 + i_{t+1})e_{t+1} = (1+i_{t+1}^*)e_{t+2}$ just as (3), but it is simplified here by the assumption that $e_{t+1} = e_{t+2}$.

6. Note that the real efiective rate of interest, r_t, may difier from the nominal rate of interest, it, on account of expected changes not only in the price level but also in the nominal rate of interest in the future. In the special case where $p_t = p_{t+1}$, r_t becomes the weighted average of i_t and i_{t+1}.

subject to the constraint (7). Thus we may write the home country's consumption function in period t as

$$(9) \qquad C_t = \rho\left[\frac{M_t}{p_t} + \frac{M_{t+1}}{r_t p_{t+1}} - (1+i_{t-1})\frac{B_{Ht-1}}{p_t} - (1+i^*_{t-1})\frac{e_t B_{Ft-1}}{p_t}\right].$$

Note that it is proportional to the present value of the home country's wealth by a constant factor ρ.

In a similar fashion, we obtain the foreign country's consumption function in period t. It may be written

$$(10) \qquad C^*_t = \rho^*\left[\frac{M^*_t}{p^*_t} + \frac{M^*_{t+1}}{r^*_t p^*_{t+1}} - (1+i_{t-1})\frac{B^*_{Ht-1}}{e_t p^*_t} - (1+i^*_{t-1})\frac{B^*_{Ft-1}}{p^*_t}\right],$$

where we indicate foreign variables by asterisks. The foreign real effective interest rate, r^*_t, is defined by

$$(11) \qquad r^*_t = \frac{p^*_t(1+i^*_t)i^*_{t+1}}{p^*_{t+1}(1+i^*_{t+1})}.$$

In light of (3), (4), (7), and (8), the home and foreign real effective interest rates are related to each other, i.e.,

$$(12) \qquad r^*_t = \lambda_t r_t,$$

where

$$(13) \qquad \lambda_t = \frac{p_{t+1}}{p_t}\frac{p^*_t}{p^*_{t+1}}\frac{e_t}{e_{t+1}},$$

on the assumption that the home and foreign consumers have the same expectations with regard to the exchange rate. We may rewrite (10) as

$$(14) \qquad C^*_t = \rho^*\left[\frac{M^*_t}{p^*_t} + \frac{M^*_{t+1}}{r^*_t p^*_{t+1}} + (1+i_{t-1})\frac{B_{Ht-1}}{e_t p^*_t} + (1+i^*_{t-1})\frac{B_{Ft-1}}{p^*_t}\right],$$

since $B_{Ht-1} + B^*_{Ht-1} = 0$ and $B_{Ft-1} + B^*_{Ft-1} = 0$ as a result of international capital transactions in period $t-1$.

The home and foreign countries are assumed to produce one and the same good. The familiar purchasing power parity condition

$$p_s = e_s p_s^* \quad (s = t,\ t + 1), \tag{15}$$

states that the home and foreign price levels are equalized via the exchange rate in each period as a result of international price arbitrage. In what follows, we shall confine ourselves to the case where this condition is satisfied.[7] Thus we have $r_t = r_t^*$ in view of (12) and (13). In words, the home and foreign real effective interest rates are equalized under the purchasing power parity condition.

From the definition of real effective interest rates, (12) may also be written

$$e_t = \frac{1+i_t^*}{1+i_t} \frac{i_{t+1}^*}{1+i_{t+1}^*} \frac{1+i_{t+1}}{i_{t+1}} e_{t+1}. \tag{16}$$

This equation reveals that the current exchange rate is closely associated with the expected exchange rate, current and expected interest rates in the home and foreign countries. When the foreign current expected interest rates are higher than the home current and expected rates of interest, the expected exchange rate is bound to be lower than the current rate. Given the current and expected interest rates, the current exchange rate moves directly in proportion to the expected rate. Given the expected exchange rate, the current rate rises immediately in response to a rise in the foreign current and expected interest rate relative to the home current and expected interest rates. These results seem to fit in with recent experiences in international financial markets.

The representative consumer in each country is assumed to prepare money at the beginning of period t in order to pay for its consumption in the same period as described by (9) and (14). For simplicity, each country's output is supposed to be at the full employment level and correctly anticipated by firm and consumers. We simplify the world by assuming away capital investment and depreciation.

3. General Equilibrium

The major concern of the present paper is to clarify the determinants of the exchange rate and the dynamics of current account adjustment in a two-country monetary model of international trade and finance where each country's currency is used only for transaction purposes. In this section, we introduce money as a medium of exchange and formulate the monetary equilibrium of the model. We first consider the general equilibrium of the

7. Real exchange rates deviate from purchasing power parity in the short run, but a number of recent studies have shown that they tend toward it in the long run. See Rogoff (1996) for a survey of empirical literature on purchasing parity.

world in which international capital movements are prohibited by some reason or another (e.g. by government decree) and then formulate that of the world under perfect capital mobility. The analysis of the model under alternative assumptions will be postponed to the next two sections.

3.1. The World without International Capital Movements

In the absence of any risks with regard to the repayment of loans, no one will be induced to hold a country's currency for the store-of-value purposes as long as the rate of nominal interest denominated in the currency becomes positive. We assume that this is indeed the case. Capital transactions are assumed to be free inside the country. In the absence of international lending or borrowing, however, the consumer in each country uses money only for purchasing her country's product. To put it differently, the equilibrium condition in the domestic capital market implies

$$p_t C_t = M_t. \tag{17}$$

The present model becomes extremely simple in the absence of capital mobility. Since there is no international lending or borrowing, we can simplify (6) by setting $B_{Ht-1} = B_{Ft-1} = 0$. The home consumer's budget constraint then reduces to

$$C_t + \frac{1}{r_t}\tilde{C}_{t+1} = \frac{M_t}{p_t} + \frac{1}{r_t p_t} M_{t+1}. \tag{18}$$

We may write the home country's consumption function as

$$C_t = \rho\left(\frac{M_t}{p_t} + \frac{1}{r_t p_{t+1}} M_{t+1}\right). \tag{19}$$

In the world without international capital movements, the domestic commodity market must be equilibrated in every period so that

$$C_t = Y_t, \tag{20}$$

where Y_t denotes the output of the national product in period t. Combined with (17), this implies the quantity-of-money equation

$$p_t Y_t = M_t. \tag{21}$$

Let us also assume that a similar relationship is expected to hold in period $t + 1$, or

(22) $$p_{t+1} Y_{t+1} = M_{t+1},$$

where Y_{t+1} denotes the expected output in period $t + 1$. Substituting (19), (21) and (22) into (20), we get

(23) $$r_t = \frac{\rho}{1-\rho}\frac{Y_{t+1}}{Y_t}.$$

In equilibrium the home country's real effective interest rate is thus equal to the product of the consumer's time preference rate $\rho/(1 - \rho)$ and the expected growth factor Y_{t+1}/Y_t. In the stationary state where the growth factor is unity, the real effective interest rate is exactly equal to the time preference rate. The equilibrium in the domestic capital market implies the home country's current account equilibrium.

We can stipulate similar relationships for the foreign country as well. Thus

(24) $$r_t^* = \frac{\rho^*}{1-\rho^*}\frac{Y_{t+1}^*}{Y_t^*},$$

(25) $$p_t^* Y_t^* = M_t^*.$$

In general there is no reason to expect that the home and foreign real effective interest rates coincides with each other. The home and foreign price levels are also determined independently of each other. We can express the exchange rate as

(26) $$e_t = \frac{Y_t^*}{Y_t}\frac{M_t}{M_t^*},$$

by virtue of purchasing power parity condition, (15).

3.2. The World with Perfect Capital Mobility

Let us turn to the case where international capital movements are completely free. The equilibrium condition in international capital market is written

(27) $$B_{Ht} + B_{Ht}^* = 0,$$

(28) $$B_{Ft} + B_{Ft}^* = 0.$$

Using (1) and its counterpart for the foreign country and recalling that $B_{Ht-1} + B_{Ht-1}^* = 0$ and $B_{Ft-1} + B_{Ft-1}^* = 0$, we can rewrite (27) and (28) as

(29) $$p_t C_t + e_t p^*_t C^*_t = M_t + e_t M^*_t,$$

which means that the home and foreign supply of money in period t must be used for the purchase of world product in the same period. The equilibrium condition in the world commodity market, together with purchasing power parity (15), implies

(30) $$C_t + e_t p^*_t C^*_t = Y_t + e_t p^*_t Y^*_t.$$

We assume that the national currency of each country is used as an indispensable means of payment in purchasing the good produced in that country. Also suppose that the consumers in each country prefer to buy domestically produced good as long as it is available. The monetary equilibrium condition for the home currency is then given by

(31) $$min(p_t C_t, p_t Y_t) + max\left[e_t p_t (C^*_t - Y^*_t),\ 0\right] = M_t,$$

and the corresponding condition for the foreign currency by

(32) $$min(p^*_t C^*_t, p^*_t Y^*_t) + max\left[\frac{p_t}{e_t}(C_t - Y_t),\ 0\right] = M^*_t.$$

Provided that the world capital market is in equilibrium, we have $C_t > Y_t$ or $C_t < Y_t$ according as $C^*_t < Y^*_t$ or $C_t > Y_t$ as is clear from (29). For definiteness, let us suppose for the moment that $C_t \geq Y_t$ and $C^*_t \leq Y^*_t$ in the neighborhood of equilibrium. This means that the home country runs a deficit, and the foreign country a corresponding surplus, in its trade account. In this case, (31) becomes

(33) $$p_t Y_t = M_t,$$

which, combined with (29), (30) and (31), yields

(34) $$p^*_t Y^*_t = M^*_t.$$

It should be clear that these quantity equations also obtain when $C_t \leq Y_t$ and $C^*_t \geq Y^*_t$ in the neighborhood of equilibrium. Substituting (9) and (14) into (30), we get

(35) $$(\lambda_t \rho p_t Y_{t+1} + \rho^* e_t p^*_t Y^*_{t+1}) \frac{1}{r^*_t} - \left[(1-\rho) p_t Y_t + (1-\rho^* e_t p^*_t Y^*_t)\right]$$
$$= (\rho - \rho^*)\left[(1+i_{t-1}) B_{Ht-1} + (1+i^*_{t-1}) e_t B_{Ft-1}\right].$$

Quantity equations (33) and (34), together with the equilibrium condition for the world commodity market (35), ensures monetary equilibrium in both countries.

Under the assumption of uncovered interest parity, (3) and (4), asset holders become indifferent as to the choice of bonds denominated in the home currency and those denominated in the foreign currency. Thus the composition of their portfolio becomes indeterminate in every period. To avoid arbitrariness, we henceforth assume that international credit is held in the form of bonds denominated in the foreign currency, or

$$B_{Ht} = B_{Ht-1} = 0. \tag{36}$$

This may be interpreted to mean that the foreign currency serves as the key currency in international lending and borrowing.[8]

In what follows, let us concentrate on the system of equations (15), (33), (34) and (35) describing the general equilibrium of international economies. Given ρ, ρ^*, λ_t, i_{t-1}, i^*_{t-1}, Y_t, Y_{t+1}, Y^*_t, Y^*_{t+1}, B_{Ft-1} and B_{Ht-1}, these four equations contain six "unknowns," r^*_t, e_t, p_t, p^*_t, M_t and M^*_t. We obtain alternative interpretations of the system depending on which variables we choose as ultimate unknowns. We shall consider two basic interpretations of the system pertaining to the regime of flexible exchange rates in the next two sections.

4. Adjustment by Interest Rate

The orthodox interpretation of the model of international economies under capital mobility set out in the preceding section is that the world capital market is cleared by the adjustment of interest rate in every period.

4.1. Short-Run Equilibrium

In this subsection we consider the short-run international equilibrium in which the interest rate is adjusted to clear the world capital market with money supply exogenously given in each country. In this case, there are four endogenous variables, p_t, p^*_t, e_t, and r^*_t, to be determined by four equations (15), (33), (34) and (35). The values of p_t, p^*_t, and e_t are determined in the same fashion as in the world without international capital movements considered in the preceding section. For instance, substituting

8. Recall the assumption that a country's product can be purchased only by its currency. In light of this it may seem natural that the country with a deficit in her current account issues bonds denominated in the currency of the country with a corresponding surplus. As noted in the text, however, the choice of denominating currency is immaterial as long as one can freely trade currencies in the foreign exchange market.

(33) and (34) into (15), we obtain the expression of the exchange rate:

$$e_t = \frac{M_t}{M_t^*}\frac{Y_t^*}{Y_t}, \tag{37}$$

which is identical to (26). Thus international capital mobility exerts no influence whatsoever on the determination of national price levels and the exchange rates under the present interpretation of the system.

It is the rate of interest which plays a major role in the equilibration of international capital market in the present system. The substitution of (33) and (34) into (35), together with (15) and (36), yields[9]

$$r_t^* = \frac{\rho Y_{t+1} + \rho^* Y_{t+1}^*}{(1-\rho)Y_t + (1-\rho^*)Y_t^* + (1+i_{t-1}^*)(\rho-\rho^*)B_{Ft-1}/p_t^*}. \tag{38}$$

The denominator of the left-hand side of this equation may be assumed to be positive. Note that $\lambda_t = 1$ and $r_t = r_t^*$ by virtue of (15). In the special case in which the home and foreign consumers' rates of time preference are identical, or $\rho = \rho^*$, (38) simplifies to

$$r_t^* = \frac{\rho}{1-\rho}\frac{Y_{t+1} + Y_{t+1}^*}{Y_t + Y_t^*}. \tag{39}$$

This is the weighted average of the home and foreign interest rates in the world without international capital movements.

More interesting is the case where the home and foreign consumers have different time preference rates. In this case, the term, $(\rho-\rho^*)B_{Ft-1}/p_{t-1}^*$, plays a role to determine the equilibrium rate of interest. In view of (38), an increase in $(\rho-\rho^*)B_{Ft-1}/p_t^*$, lowers (resp. raises) the real effective rate of interest in period t if $(\rho-\rho^*)B_{Ft-1}$ is positive (resp. negative). For concreteness, suppose that $(\rho-\rho^*)B_{Ft-1}/p_t^* > 0$. If $\rho > \rho^*$ and $B_{Ft-1} > 0$, an increase in B_{Ft-1}/p_t^*, then means an increase in the real indebtedness of the home country whose rate of time preference is higher than that of the foreign country, or an international transfer of real wealth from the former to the latter. This in turn suppresses the world's propensity to consume thereby lowering the equilibrium rate of intrerest. If $\rho < \rho^*$ and $B_{Ft-1} < 0$, a decrease in B_{Ft-1}/p_t^*, or an increase in its absolute value means an increase in the real indebtedness of the foreign country whose rate of time preference is higher than that of the home country, or an international transfer of real wealth from the former to the the latter. Thus we obtain the same conclu-

9. With the purchasing power parity condition prevailing in every period, we have $\lambda_t = 1$, or $r_t = r_t^*$. (See (13) and (15))

sion. Genarally, we have

Proposition 1. (International indebteness and interest rate): *An increase in the real indebtedness of a country with higher (resp. lower) rate of time preference than that of its trading partner lowers (resp. raises) the equilibrium real interest rate.*

There are some noteworthy implications of this proposition. First, recall that an increase in the money supply of the foreign country raises the foreign price level and decreases the real indebtedness of the foreign country in the same period (seibniorege effects). Thus Proposition 1 implies that the money supply of the key-currency country is generally not neutral to the real structure of the international economy. In contrast, an increase in the home country's money supply merely gives rise to a proportionate rise in the home price level and the nominal exchange rate leaving all the real variables unaffected. Second, note that a deficit in a country's current account will, *ceteris paribus*, increase its real external debt thereby affecting the world interst rate over time. For instance, a deficit in the home country's current account is bound to lower (resp. raise) the world equilibrium interest rate in the course of time if its rate of time prefence is higher (resp. lower) than that of the foreign country. Third, an increase in the rate of interest in a period increases the real indebtedness of the home country and lowers (resp. raises) the rate of interest in the next priod if the home residents have a higher (resp. lower) rate of time preference than the foreigners.

4.2. Current Account and Interest Rate Dynamics

The general equilibrium of the system considered in the foregoing analysis is temporary in nature. As noted above, each country's external indebtedness changes through time to affect the equilibrium of the system as long as its current account is out of balance. At this point, let us consider the dynamic adjustment process of current account imbalances. To simplify matters, we assume here that all exogenous variables are stationary, or $M_t = M$, $M_t^* = M^*$, $Y_t = Y_{t+1} = Y$, $Y_t^* = Y_{t+1}^* = Y^*$ and $r_t = r_t^* = i_t$.

With these simplifying assumptions, we may write the inter-periodical change in the home country's net external debt as

$$(40) \qquad B_{Ft} - B_{Ft-1} = p^*(C_t - Y_t) + i_{t-1}B_{Ft-1} = p^*(Y_t^* - C_t^*) + i_{t-1}B_{Ft-1}.$$

The first term of the right-hand side signifies the home country's deficit in trade account, and the second its deficit in service account. The substitution of (9) and (14) into (40) yields

$$B_{Ft}-B_{Ft-1}=\left[1-\rho(1+\frac{1}{i_t})\right](-p^{*}Y+i_{t-1}B_{Ft-1})$$

(41)
$$=\left[1-\rho^{*}(1+\frac{1}{i_t})\right](p^{*}Y^{*}+i_{t-1}B_{Ft-1}).$$

If $\rho=\rho^{*}$, (38) reduces to

(42)
$$i_t=\frac{\rho}{1-\rho}=\frac{\rho^{*}}{1-\rho^{*}},$$

in the present setting. Therefore, we have $B_{Ft}=B_{Ft-1}$ in view of (41). In words, the interest rate is equalized to the common rate of time preference and the current account is balanced every period.

Generally, (38) and (41) yield

(43)
$$i_t=\frac{(1-\rho)^{*}\rho p^{*}Y+(1-\rho)\rho^{*}p^{*}Y^{*}}{(\rho-\rho^{*})B_{Ft}+(1-\rho)(1-\rho^{*})p^{*}(Y+Y^{*})}.$$

Note that the rate of interest is negatively (resp. positively) correlated with the current value of the home country's net external debt if $\rho>\rho^{*}$(resp. $\rho<\rho^{*}$). Thus the dynamics of interest rate is directly related to the dynamics of home net external debt. Substituting (43) into (41) and rearranging terms, we get

$$B_{Ft}-B_{Ft-1}=\frac{(\rho-\rho^{*})\left[(1-\rho)p^{*}Y^{*}-\rho B_{Ft-1}\right]I_t}{(1-\rho^{*})\rho p^{*}Y+(1-\rho)\rho^{*}p^{*}Y^{*}}$$

(44)
$$=\frac{(\rho^{*}-\rho)\left[(1-\rho^{*})p^{*}Y+\rho^{*}B_{Ft-1}\right]I_t^{*}}{(1-\rho^{*})\rho p^{*}Y+(1-\rho)\rho^{*}p^{*}Y^{*}},$$

where I_t and I_t^{*} represent the home and foreign national incomes measured in the unit of the foreign currency in period t, i.e.,

(45)
$$I_t=p^{*}Y-i_{t-1}B_{Ft-1},$$

(46)
$$I_t^{*}=p^{*}Y^{*}+i_{t-1}B_{Ft-1}.$$

This is a first-order non-linear difference equation in B_F. The stationary state solutions of (44) are given by

(47) $$\overline{B}_F = \frac{(1-\rho^*)p^*Y}{\rho^*},$$

(48) $$\underline{B}_F = -\frac{(1-\rho)p^*Y}{\rho^*}$$

provided that $\rho \neq \rho^*$.

Figure 1 illustrates the dynamic adjustment process of the current account balance for the case $\rho > \rho^*$. The curve BB is the graph of (43). It has a positive intercept on the vertical axis and cuts the 45 degree line through the origin at two points, E and F, signifying the stationary state solutions of (44). Of these stationary equilibria, E is stable, but F is unstable. Starting from any initial value between $\overline{B}_F$ and $\underline{A}BF$, the home country's net external debt monotonically increases and converges to $\overline{B}_F$ as time tends to infinity. The polygonal line with arrows exemplifies a possible adjustment path along which the current account imbalance decreases through time. From (43), it should be clear that the rate of interest decreases monotonically and converges to the corresponding stationary value.

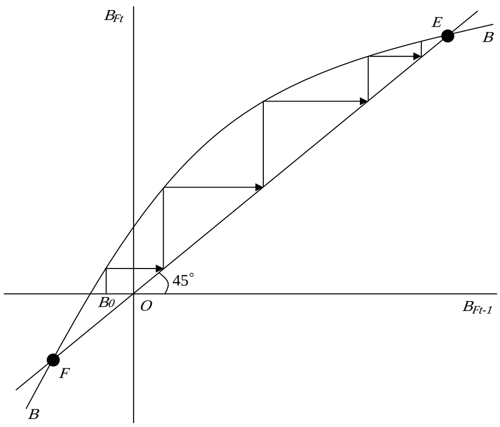

Figure 1. External Debt under Interest Adjustment

At the stable stationary equilibrium, the home country becomes a net debtor, and the foreign country a net creditor due to the assumption $\rho > \rho^*$ meaning that the home consumer's time preference is stronger than the foeigner's. The inspection of (41) reveals

(49) $$i_t = \frac{\rho^*}{1-\rho^*} < \frac{\rho}{1-\rho},$$

in the stationary state. Thus the rate of interest is equalized to the foreign consumer's time preference rate in the long run. These results are reversed in the case $\rho < \rho^*$. Now, $\underline{B}_F$ is the stable stationary value of the foreign country's net external debt. The home country becomes a net creditor, and the foreign country a net debtor in the long run. The rate of interest converges to the home consumer's time preference rate as time tends to infinity. I have established

Proposition 2. (Stability of Interest Rate Dynamics): *The current account imbalances are automatically adjusted through time and the country with weaker time preference than the rest of the world is bound to be a net creditor setting the international interest rate in line with its time preference rate in the long run.*

It should be noted here that the net debtor has to pay out the sum of interest amounting to the entire value of its output in the stationary state with no purchasing power left for its consumption. This point can be readily confirmed by substituting (47) (or (48)) into (45) (or (46)) with $i_{t-1} = (1-\rho)/\rho$ and $B_{Ft-1} = \overline{B}_F$ (or $i_{t-1} = (1-\rho^*)/\rho^*$ and $B_{Ft-1} = \underline{B}_F$). This result may be referred to as the "tragedy of a cicada" in analogy to the well known story of a cicada and ants in the Fables of Aesop.

Proposition 3. (Tradgedy of a Cicada): *In the long-run stationary state the country with lower time preference consumes everything produced in the world leaving nothing for the country with stronger time preferece.*[10]

5. Adjustment by Money Supply

In the foregoing section we assumed that the rate of interest plays a key role in the equilibration of the world capital market. This interpretation of the basic model leads to the orthodox conclusion that international current account disequilibrium tends to be dissolved over time through the international transfer of wealth from the country with deficit to the country with surplus. It also implies that the country with stronger time preference than the rest of the world tends to accumulate external debt and impoverished to the point of starvation in the long run. It is, however, possible to view the world market as the place where the home currency is exchanged for the foreign currency and regard the exchange rate or, more basically, the key currency country's money supply, as the key adjusting factor for the market. This view turns out to be relevant to the situation in which the

10. The myopic behavior, or the bounded rationality of the consumer is not responsible for this seemingly absurd result. For instance, a similar result obtains in the general equilibrium model of international trade with perfectly informed rational consumers discussed by Helpman and Razin (1982).

home and foreign time preference differ from each other and the monetary authority adjusts money supply so as to keep the world real interest rate at a certain target level. The tragedy of a cicada may be avoided in such a situation by the appropriate monetary policy of the key-currency country.

5.1. Short-Run Equilibrium

In the model of the preceding section, the exchange rate is determined by the purchasing power parity condition (15) and quantity equations (33) and (34) in the same fashion as in the case where there are no international capital transactions. Thus international capital mobility exerts no influence on its equilibrium value. Moreover, given the home and foreign money supplies, exchange rate is kept constant throughout the current account adjustment process described above. This conclusion is apparently at variance with recent experiences in the foreign exchange markets. In reality, the exchange rate appears to get more volatile both in the short run and in the long run when less restrictions are imposed on international capital transactions. This observation suggests that money supplies, together with the exchange rate, play some role in international adjustment. In the present section, we therefore consider an alternative interpretation of our system, i.e., according to which the key currency country's money supply is adjusted to clear the international money market.

We assume that the foreign country, or the key currency country, adjusts its money supply so as to fix the rate of interest at a certain predetermined level and the home country keeps its money supply at a given level. In this regime, we have four endogenous variables, e_t, p_t, p_t^*, and M_t^*, to be determined by four equations (15), (33), (34) and (35) given the values of all other variables. To be more precise, p_t is trivially determined by (33). Given r_t^* and p_t, (34) may be solved for e_t to give

(50) $$\frac{e_t}{p_t} = \frac{\left[\rho Y_{t+1} + \rho^* Y_{t+1}^*\right] / r_t^* - \left[(1-\rho)Y_t + (1-\rho^*)Y_t^*\right]}{(1+i_{t-1}^*)(\rho-\rho^*)B_{Ft-1}},$$

provided that $(\rho - \rho^*)\, B_{Ft-1} \neq 0$. Given p_t and e_t, (15) and (34) determine p_t^* and M_t^*. In view of the purchasing power parity condition (15), the present regime is viable only if the foreign country, or the key currency country, adjusts its money supply, or its price level in conformity with (50).

The present regime is viable only if the home and foreign consumers have different time preferences, or $\rho \neq \rho^*$ with some international indebtedness in the preceding period, or $B_{Ft-1} \neq 0$. Otherwise, the present regime would become meaningless. Furthermore, the target range of interest rate is restricted if the equilibrium exchange rate is to be positive. To be more precice, let us define the critical rate of interest as

$$(51) \qquad \tilde{r}^* = \frac{\rho Y_{t+1} + \rho^* Y^*_{t+1}}{(1-\rho)Y_1 + (1-\rho^*)Y^*_t},$$

which is the weighted average of the home and foreign equilibrium rates of interest in the world without capital mobility. (See (23) and (24) above). The target rate of interest must be set above (resp. below) this critical level if $(\rho - \rho^*)\, B_{Ft-1} < 0$ (resp. > 0), or

$$(52) \qquad r^* \lessgtr \tilde{r}^* \quad \text{according as} \quad (\rho - \rho^*)B_{Ft-1} \gtrless 0.$$

This short-run equilibrium is potentially unstable under the usual Walrasian adjustment process if the exchange rate is regarded as the adjusting factor in money market. To see this point, suppose that the home country runs a deficit and the foreign country a corresponding surplus in the trade account. From equations (9), (14), (34) and (35), the excess demand for the foreign currency may be written,

$$p_t C_t + e_t p^*_t C^*_t - p_t Y_t - e_t p^*_t C^*_t = \frac{p_t}{r^*_t}(\rho Y_{t+1} + \rho^* Y^*_{t+1})$$

$$(53) \qquad -\left[(1-\rho)p_t Y_t + (1-\rho^*)p_t Y^*_t\right] - (1+i^*_{t-1})(\rho - \rho^*)B_{Ft-1}e_t.$$

If $(\rho - \rho^*)\, B_{Ft-1} < 0$, a rise in e_t, or a fall in the external value of the foreign currency will increase the excess demand for the foreign currency ensuring the local stability of the foreign exchange market. In contrast, if $(\rho - \rho^*)\, B_{Ft-1} > 0$, the equilibrium becomes unstable.[11] This outcome may not be relevant, however, to the present regime in which the foreign government is supposed to adjust its money supply so as to achieve the target interest rate.[12]

Let us consider the determinants of exchange rate under the present regime. The exchange rate is here dependent on diverse factors: the target rate of interest, the current output levels, the expected future output levels, the home and foregn rates of time preference, the home country's money supply and the home country's net external debt. Comparing (50) with (36), it should be clear that *the exchange rate is likely to be more volatile under*

11. If the home country runs a surplus and the foreign country a corresponding deficit in the trade account, the left-hand side of (53) divided by e_t may be interpreted as the excess demand for the home currency, and the equilibrium is also apparently stable if and only if $(\rho - \rho^*)B_{Ft-1} < 0$.

12. In fact, it may be equally plausible here to regard the exchange rate as the adjusting factor in achieving the purchasing power parity condition, (15), and the foreign money supply as the adjusting factor in achieving money market equilibrium, (32).

adjustment by money supply than under adjustment by interest rate because of its dependency on additional factors such as international indebtedness and future (expected) output levels.

Some of comparative statical results depends on whether the short-run equilibrium is stable in the sense mentioned above, i.e., whether the sign of $(\rho - \rho^*)B_{Ft-1}$ is negative or positive. For instance, a rise in the foreign target rate of interest leads to a depreciation of the home currency and a fall in the foreign price level and money supply if $(\rho - \rho^*)B_{Ft-1} < 0$ but would lead to opposite results if $(\rho - \rho^*)B_{Ft-1} > 0$. Similarly, an increase in the expected future output (expected income growth) will bring about an appreciation of the home currency if and only if $(\rho - \rho^*)B_{Ft-1} < 0$. In contrast, an increase in the home money supply will result in a proportionate rise in the home price level and a corresponding depreciation of the home currency irrespective of the sign of $(\rho - \rho^*)B_{Ft-1}$.

The dynamic effects of current account imbalance on the equilibrium exchange rate differs depending on whether the home country is currently a net borrower or a net lender in the world capital market. Suppose that the home country runs a deficit in its current account in period $t - 2$. It would increase its net indebtedness in period $t + 1$. Alternatively put, it would increase the absolute value of B_{t-1} if $B_{t-1} > 0$, but decrease the absolute value of B_{t-1} if $B_{t-1} < 0$. In view of (50), we obtain

Proposition 4. (Current Account Imbalances and Exchange Rate): *If a country runs a deficit in its current account, it will undergo an depreciation (resp. appreciation) of its currency over time if it is a net lender (resp. borrower) in the world capital market.*

5.2. Current Account and Money Supply Dynamics

At this point, let us investigate the adjustment process of the current account under the present setup. For simplicity, all the exogenous variables are assumed to be stationary through time, or that $Y_t = Y_{t+1} = Y$, $Y_t^* = Y_{t+1}^* = Y^*$, $M_{t-1} = M_t = M$ and so on. The foreign money supply and the foreign price level are endogenously determined, but the foreigners assumed to have static expectations with respect to the price level so that $r_t = r_t^* = i^*$.

With these assumptions, we can express the inter-periodical change in the foreign net external debt as

$$B_{Ft} - B_{Ft-1} = \left[1 - \rho^*(1 + \frac{1}{i^*})\right](-p_t^* Y + i^* B_{Ft-1}) \tag{54}$$
$$= \left[1 - \rho(1 + \frac{1}{i^*})\right](p_t^* Y^* + i^* B_{t-1}).$$

From (15) and (50),

$$p_t^* = \frac{(\rho-\rho^*)(1+i^*)i^* B_{Ft-1}}{\left[\rho-(1-\rho)i^*\right]Y+\left[\rho^*-(1-\rho^*)i^*\right]Y^*}. \tag{55}$$

Substituting (55) into (54), we get

$$B_{Ft} = (1-\frac{\left[\rho-(1-\rho)i^*\right]\left[\rho^*-(1-\rho^*)i^*\right](Y+Y^*)}{\left[\rho-(1-\rho)i^*\right]Y+\left[\rho^*-(1-\rho^*)i^*\right]Y^*})\, B_{Ft-1}. \tag{56}$$

The monetary authority of the key-currecy country can convert any initial state into a stationaty state of this adjustment process by setting the target rate of interest at a unique level depending on the sign of $(\rho-\rho^*)B_{F0}$. In view of (52), it is given by

$$i^* = max\left[\frac{\rho}{1-\rho},\ \frac{\rho^*}{1-\rho^*}\right], \tag{57}$$

when $(\rho-\rho^*)\ B_{F0} < 0$, and by

$$i^* = min\left[\frac{\rho}{1-\rho},\ \frac{\rho^*}{1-\rho^*}\right], \tag{58}$$

when $(\rho-\rho^*)B_{F0} > 0$.

Starting from any initial state, the monetary authority can reduce international indebtedness indefinitely through time by appropriately choosing the target rate of interest. Here again, the range of the appropriate target interest rates depend on the sign of $(\rho-\rho^*)B_{F0}$.

First, suppose that $(\rho-\rho^*)B_{F0} < 0$. In view of (50), (51), (52) and (55), B_{Ft} then decreases monotonically over time and converges to zero if and only if

$$max\left[\frac{\rho}{1-\rho},\frac{\rho^*}{1-\rho^*}\right] > i^* > \tilde{r}^*. \tag{59}$$

This condition also ensures that the exchange rate and foreign price level remain positive throughout the process. If the current account imbalances are to be adjusted through time, the target interest rate must be set at a level not lower than the rate of time preference of either country.

Turn to the case where $(\rho - \rho^*)B_{F0} > 0$. In light of (50), (51), (52) and (55), the range of appropriate target interest rates relevant to this case is

(60) $$i^* < min\left[\frac{\rho}{1-\rho}, \frac{\rho^*}{1-\rho^*}\right].$$

The automatic adjustment of current account imbalances is possible only if the target interest rate is set at a level intermediate between the minimum of the two country's rates of time preference and lower than the critical level which ensures the existence of meaningful equilibrium.

In summary, we can state

Proposition 5. (International Adjustmentby Money Supply): *International current account imbalances may be adjusted to avoid the tragedy of a cicada if the key-currency country set the target rate of interest appropriately and adjusts its money supply comformably so as to equilibrate money market continuously.*

Figure 2 illustrates the stable adjustment process for the case where $B_{F0} > 0$ and the target interest rate is chosen from the relevant appropriate range. The home country's current account remains always in surplus so that the home external debt, together with its current account surplus, decreases monotonically through time and converges to zero as time tends to infinity. The home currency appreciates against the foreign currency and the foreign price level and money supply rise throughout the process of adjustment.

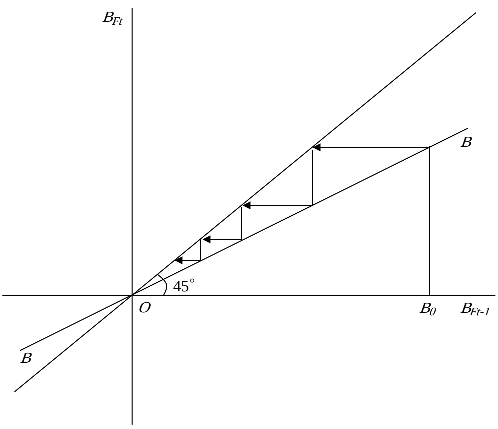

Figure 2. External Debt under Money Supply Adjustment

6. Summary and Conclusion

In this paper we have analyzed the long-run adjustment of current account imbalances of two countries under the regime of flexible exchange rate with perfect international capital mobility. Our analysis of international adjustment is based on the view of money circulating from producers to consumers and then from consumers to producers serving on the way only as a means of payment. Specifically, we have considered two possible factors in international adjustment, i.e., the interest rate and the key-curency country's money supply (or exchange rate) in the context of a simple cash-in-advance model of international trade payments.

In the case of adjustment by interest rate, the exchange rate is determined by the money supplies and real national incomes of the two countries independently of international indebtedness and national time preferences. The current account imbalances are basically adjustable through international specie-flow mechanism in this case. The country with time preference stronger than elsewhere tends to run a surplus in its current account, while the rest of the world tends to accumulate net external debt until it uses up all the non-interest income in interest payment. The case of adjustment by money supply gives rise to drastically different performances of the system. The equilibrium value of exchange rate becomes sensitive to changes in international indebtedness and national time preferences. The current account imbalances may be adjusted over time only if the target interest rate is set at an appropriate level depending on the key-currency country's initial state of external indebtedness and time preference relative to the rest of the world.

Let us briefly mention some qualifications of the present model. First, it is assumed that the home and foreign countries produce one and the same commodity. This assumption hinders us from considering the determination of the real exchange rate and its implications for international adjustment. It is, however, not difficult to extend the analysis of the temporary equilibrium to the case where there are two or more commodities. Such an extension is interesting in its own right, but would not affect the major conclusions of the present study substantially. Second, national currencies are supposed to function entirely as a means of payment, and not as a store of value, in the present model. This assumption serves to focus our attention on the important aspect of money, but it may be unrealistic in the uncertain world where money is used as store of value to hedge exchange and country risks. The asset market approach to exchange rate determination emphasizes this function of money. It should be considered, however, as a complement (rather than a substitute) to the formulation adopted here.

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12 Technology, Geography, and Trade

Jonathan Eaton and Samuel Kortum*

1. Introduction

Theories of international trade have not come to grips with a number of basic facts: (i) trade diminishes dramatically with distance; (ii) prices vary across locations, with greater differences between places farther apart; (iii) factor rewards are far from equal across countries; (iv) countries' relative productivities vary substantially across industries. The first pair of facts indicate that geography plays an important role in economic activity. The second pair suggest that countries are working with different technologies. Various studies have confronted these features individually, but have not provided a simple framework that captures all of them.

We develop and quantify a Ricardian model of international trade (one based on differences in technology) that incorporates a role for geography.[1] The model captures the competing forces of comparative advantage promoting trade and of geographic barriers (both natural and artificial) inhibiting it. These geographic barriers reflect such myriad impediments as transport costs, tariffs and quotas, delay, and problems with negotiating a deal from afar.

The model yields simple expressions relating bilateral trade volumes, first, to deviations from purchasing power parity and, second, to technology and geographic barriers.[2] From these two relationships we can estimate the parameters needed to solve the world trading equilibrium of the model and to examine how it changes in response to various policies.

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1. Grossman and Helpman (1995) survey the literature on technology and trade while Krugman (1991) provides an introduction to geography and trade.

2. Engel and Rogers (1996) and Crucini, Telmer. and Zachariadis (2001) explore the geographic determinants of deviations from the law of one price.

Our point of departure is the Dornbusch, Fischer, and Samuelson (1977) two-country Ricardian model with a continuum of goods. We employ a probabilistic formulation of technological heterogeneity under which the model extends naturally to a world with many countries separated by geographic barriers. This formulation leads to a tractable and flexible framework for incorporating geographical features into general equilibrium analysis.

An additional feature of our model is that it can recognize, in a simple way, the preponderance of trade in intermediate products. Trade in intermediates has important implications for the sensitivity of trade to factor costs and to geographic barriers. Furthermore, because of intermediates, location, through its effect on input cost, plays an important role in determining specialization.[3]

Table 1. Trade, Labor, and Income Data

Country	Imports % of Mfg. Spending	Imports from Sample as % of All Imports	Mfg. Wage (U.S.=1)	Human-Capital Adj. Mfg. Wage (U.S.=1)	Human-Capital Adj. Mfg. Labor (U.S.=1)	Mfg. Labor's % Share of GDP
Australia	23.8	75.8	0.61	0.75	0.050	8.6
Austria	40.4	84.2	0.70	0.87	0.036	13.4
Belgium	74.8	86.7	0.92	1.08	0.035	13.2
Canada	37.3	89.6	0.88	0.99	0.087	10.5
Denmark	50.8	85.2	0.80	1.10	0.020	11.5
Finland	31.3	82.2	1.02	1.10	0.022	12.5
France	29.6	82.3	0.92	1.07	0.205	12.6
Germany	25.0	77.3	0.97	1.08	0.421	20.6
Greece	42.9	80.8	0.40	0.50	0.015	6.1
Italy	21.3	76.8	0.74	0.88	0.225	12.4
Japan	6.4	50.0	0.78	0.91	0.686	14.4
Netherlands	66.9	83.0	0.91	1.06	0.043	11.0
New Zealand	36.3	80.9	0.48	0.57	0.011	9.6
Norway	43.6	85.2	0.99	1.18	0.012	8.7
Portugal	41.6	84.9	0.23	0.32	0.033	10.7
Spain	24.5	82.0	0.56	0.65	0.128	11.6
Sweden	37.3	86.3	0.96	1.11	0.043	14.2
United Kingdom	31.3	79.1	0.73	0.91	0.232	14.7
United States	14.5	62.0	1.00	1.00	1.000	12.4

Note: All data except GDP are for the manufacturing sector in 1990. Spending on manufactures is gross manufacturing production less exports of manufactures plus imports of manufactures. Imports from the other 18 excludes imports of manufactures from outside our sample of countries. To adjust the manufacturing wage and manufacturing employment for human capital. we multiply the wage in country i by $e^{-0.06H_i}$, and employment in country i by $e^{0.06H_i}$, where H_i, is average years of schooling is country i as measured by Kyriacou (1991). See the Appendix for a complete description of all data sources.

3. Hummels, Rapoport, and Yi (1998) document the importance of trade in intermediates. Yi (2003) discusses how trade in intermediates, which implies that a good might cross borders several times during its production, can reconcile the large rise in world trade with relatively modest tariff reductions. Krugman and Venables (1995) also provide a model in which, because of trade in intermediates, geography influences the location of industry.

We estimate the model using bilateral trade in manufactures for a cross-section of 19 OECD countries in 1990.[4] The parameters correspond to: (i) each country's state of technology, governing absolute advantage, (ii) the heterogeneity of technology, which governs comparative advantage, and (iii) geographic barriers. We pursue several strategies to estimate these parameters using different structural equations delivered by the model and data on trade flows, prices, geography, and wages.

Our parameter estimates allow us to quantify the general equilibrium of our model in order to explore numerically a number of counterfactual situations:

(i) We explore the gains from trade in manufactures. Not surprisingly, all countries benefit from freer world trade, with small countries gaining more than big ones. The cost of a move to autarky in manufactures is modest relative to the gains from a move to a "zero gravity" world with no geographic barriers.

(ii) We examine how technology and geography determine patterns of specialization. As geographic barriers fall from their autarky level, manufacturing shifts toward larger countries where intermediate inputs tend to be cheaper. But at some point further declines reverse this pattern as smaller countries can also buy intermediates cheaply. A decline in geographic barriers from their current level tends to work against the largest countries and favor the smallest.

(iii) We calculate the role of trade in spreading the benefits of new technology. An improvement in a country's state of technology raises welfare almost everywhere. But the magnitude of the gains abroad approach those at home only in countries enjoying proximity to the source and the flexibility to downsize manufacturing.

(iv) We analyze the consequences of tariff reductions. Nearly every country benefits from a multilateral move to freer trade, but the United States suffers if it drops its tariffs unilaterally. Depending on internal labor mobility, European regional integration has the potential to harm participants through trade diversion or to harm nonparticipants nearby through worsened terms of trade.

With a handful of exceptions, the Ricardian model has not previously served as the basis for the empirical analysis of trade flows, probably because its standard formulation glosses over so many first-order features of the data (e.g., multiple countries and goods, trade in intermediates, and geographic barriers).[5] More active empirical fronts have been: (i) the grav-

4. We think that our model best describes trade in manufactures among industrial countries. For most of these countries trade in manufactures represents over 75 percent of total merchandise trade. (The exceptions are Australian exports and Japanese imports.) Moreover, the countries in our sample trade mostly with each other, as shown in the second column of Table 1.

5. What has been done typically compares the export performance of only a pair of countries. MacDougall (1951, 1952) is the classic reference. Deardorff (1984) and Leamer and Levinsohn (1995) discuss it and the subsequent literature. Choudhri and Schembri (2002) make a recent contribution.

ity modeling of bilateral trade flows, (ii) computable general equilibrium (CGE) models of the international economy, and (iii) factor endowments or Heckscher-Ohlin-Vanek (HOV) explanations of trade.

Our theory implies that bilateral trade volumes adhere to a structure resembling a gravity equation, which relates trade flows to distance and to the product of the source and destination countries' GDPs. Given the success of the gravity model in explaining the data, this feature of our model is an empirical plus.[6] But to perform counterfactuals we must scratch beneath the surface of the gravity equation to uncover the structural parameters governing the roles of technology and geography in trade.[7]

In common with CGE models we analyze trade flows within a general equilibrium framework, so we can conduct policy experiments. Our specification is more Spartan than a typical CGE model, however. For one thing, CGE models usually treat each country's goods as unique, entering preferences separately as in Armington (1969).[8] In contrast, we take the Ricardian approach of defining the set of commodities independent of country, with specialization governed by comparative advantage.

Our approach has less in common with the empirical work emanating from the HOV model, which has focussed on the relationship between factor endowments and patterns of specialization. This work has tended to ignore locational questions (by treating trade as costless), technology (by assuming that it is common to the world), and bilateral trade volumes (since the model makes no prediction about them).[9] While we make the Ricardian assumption that labor is the only internationally immobile factor, in princi-

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6. Deardorff (1984) reviews the earlier gravity literature. For recent applications see Wei (1996), Jensen (2000), Rauch (1999), Helpman (1987), Hummels and Levinsohn (1995), and Evenett and Keller (2002).

7. We are certainly not the first to give the gravity equation a structural interpretation. Previous theoretical justifications posit that every country specializes in a unique set of goods, either by making the Armington assumption (as in Anderson (1979), and Anderson and van Wincoop (2003) or by assuming monopolistic competition with firms in different countries choosing to produce differentiated products (as in Helpman (1987), Bergstrand (1989), Redding and Venables (2001)). An implication is that each source should export a specific good everywhere. Haveman and Hummels (2002) report evidence to the contrary. In our model more than one country may produce the same good, with individual countries supplying different parts of the world.

8. Hertel (1997) is a recent state-of-the-art example.

9. Leamer (1984) epitomizes this approach, although Leamer and Levinsohn (1995) admit its failure to deal with the obvious role of geographic barriers. The literature has begun to incorporate roles for technology, introducing factor-augmenting technological differences, as in Trefler (1993, 1995) and industry-specific technological differences, as in Harrigan (1996). Trefler (1995) recognizes geography by incorporating a home-bias in preferences. Davis and Weinstein (2001) strive to incorporate more general geographic features.

ple one could bridge the two approaches by incorporating additional immobile factors.

To focus immediately on the most novel features of the model and how they relate to the data we present our analysis in a somewhat nonstandard order. Section 2, which follows, sets out our model of trade, conditioning on input costs around the world. It delivers relationships connecting bilateral trade flows to prices as well as to geographic barriers, technology, and input costs. We explore empirically the trade-price relationship in Section 3. In Section 4 we complete the theory, closing the model to determine input costs. With the full model in hand, Section 5 follows several approaches to estimating its parameters. Section 6 uses the quantified model to explore the counterfactual scenarios listed above. Section 7 concludes. (The Appendix reports data details.)

2. A Model of Technology, Prices, and Trade Flows

We build on the Dornbusch, Fischer, Samuelson (1977) model of Ricardian trade with a continuum of goods. As in Ricardo, countries have differential access to technology, so that efficiency varies across commodities and countries. We denote country i's efficiency in producing good $j \in [0, 1]$ as $z_i(j)$.

Also as in Ricardo, we treat the cost of a bundle of inputs as the same across commodities within a country (because within a country inputs are mobile across activities and because activities do not differ in their input shares). We denote input cost in country i as c_i. With constant returns to scale, the cost of producing a unit of good j in country i is then $c_i/z_i(j)$.

Later we break c_i into the cost of labor and of intermediate inputs, model how they are determined, and assign a numeraire. For now it suffices to take as given the entire vector of costs across countries.

We introduce geographic barriers by making Samuelson's standard and convenient "iceberg" assumption, that delivering a unit from country i to country n requires producing d_{ni} units in i.[10] We set $d_{ii} = 1$ for all i. Positive geographic barriers mean $d_{ni} > 1$ for $n \neq i$. We assume that cross-border arbitrage forces effective geographic barriers to obey the triangle inequality: For any three countries i, k, and n, $d_{ni} \leq d_{nk}\, d_{ki}$.

Taking these barriers into account, delivering a unit of good j produced in country i to country n costs:

$$p_{ni}(j) = \left(\frac{c_i}{z_i(j)}\right) d_{ni}, \tag{1}$$

10. Krugman (1995) extols the virtues of this assumption. Most relevant here is that country i's *relative* cost of supplying any two goods does not depend on the destination.

the unit production cost multiplied by the geographic barrier.

We assume perfect competition, so that $p_{ni}(j)$ is what buyers in country n would pay if they chose to buy good j from country i. But shopping around the world for the best deal, the price they actually pay for good j will be $p_n(j)$, the lowest across all sources i:

$$p_n(j) = min\{p_{ni}(j);\ i = 1,..., N\}, \tag{2}$$

where N is the number of countries.[11]

Facing these prices, buyers (who could be final consumers or firms buying intermediate inputs) purchase individual goods in amounts $Q(j)$ to maximize a CES objective:

$$U = \left[\int_0^1 Q(j)^{(\sigma-1)/\sigma} dj\right]^{\sigma/(\sigma-1)}, \tag{3}$$

where the elasticity of substitution is $\sigma > 0$. This maximization is subject to a budget constraint that aggregates, across buyers in country n, to X_n, country n's total spending.

Dornbusch, Fischer, and Samuelson work out the two-country case, but their approach does not generalize to more countries.[12] Extending the model beyond this case is not only of theoretical interest, it is essential to any empirical analysis of bilateral trade flows.

2.1. Technology

We pursue a probabilistic representation of technologies that can relate trade flows to underlying parameters for an arbitrary number of countries across our continuum of goods. We assume that country i's efficiency in

11. Bernard, Eaton, Jensen, and Kortum (2003) extend the analysis to allow for imperfect competition to explain why exporting plants have higher productivity, as documented in Bernard and Jensen (1999). With Bertrand competition each destination is still served by the low-cost provider, but it charges the cost of the *second*-cheapest potential provider. The implications for the aggregate relationships we examine below are not affected.

12. For two countries 1 and 2 they order commodities j according to the countries' relative efficiencies $z_1(j)/z_2(j)$. Relative wages (determined by demand and labor supplies) then determine the breakpoint in this "chain of comparative advantage." With more than two countries there is no such natural ordering of commodities. Wilson (1980) shows how to conduct local comparative static exercises for the N-country case by asserting that $z_i(j)$ is a continuous function of j. Closer to our probabilistic formulation, although with a finite number of goods and no geographic barriers, is Petri (1980). Neither paper relates trade flows or prices to underlying parameters of technology or geographic barriers, as we do here.

producing good j is the realization of a random variable Z_i (drawn independently for each j) from its country-specific probability distribution $F_i(z) = \Pr[Z_i \leq z]$. We follow the convention that, by the law of large numbers, $F_i(z)$ is also the fraction of goods for which country i's efficiency is below z.

From expression (1) the cost of purchasing a particular good from country i in country n is the realization of the random variable $P_{ni} = c_i d_{ni}/Z_i$, and from (2) the lowest price is the realization of $P_n = \min\{P_{ni};\ i = 1,..., N\}$. The likelihood that country i supplies a particular good to country n is the probability π_{ni} that i's price turns out to be the lowest.

The probability theory of extremes provides a form for $F_i(z)$ that yields a simple expression for π_{ni} and for the resulting distribution of prices. We assume that country i's efficiency distribution is Fréchet (also called the Type II extreme value distribution):

$$F_i(z) = e^{-T_i z^{-\theta}}, \tag{4}$$

where $T_i > 0$ and $\theta > 1$. We treat the distributions as independent across countries. The (country-specific) parameter T_i governs the location of the distribution. A bigger T_i implies that a high efficiency draw for any good j is more likely. The parameter θ (which we treat as common to all countries) reflects the amount of variation within the distribution. A bigger θ implies less variability. Specifically, Z_i (efficiency) has geometric mean $e^{r/\theta} T_i^{1/\theta}$ and its log has standard deviation $\pi/(\theta\sqrt{6})$. Here $\gamma = .577...$ (Euler's constant) and $\pi = 3.14....$ (We use γ and π differently below.)[13]

The parameters T_i and θ enable us to depict very parsimoniously a world of many countries that differ in the basic Ricardian senses of abso-

13. Kortum (1997) and Eaton and Kortum (1999) show how a process of innovation and diffusion can give rise to this distribution, with T_i reflecting a country's stock of original or imported ideas. Since the actual technique that would ever be used in any country represents the best discovered to date for producing each good, it makes sense to represent technology with an extreme value distribution. The distribution of the maximum of a set of draws can converge to one of only three distributions, the Weibull, the Gumbell, and the Fréchet (See Billingsley (1986)). Only for the third does the distribution of prices inherit an extreme value distribution, which is why we use it. As for our independence assumption, for our analysis here an observationally equivalent joint distribution that embeds correlation across countries is

$$F(z_1,\ldots,z_N) = \exp\left\{-\left[\sum_{i=1}^{N}\left(T_i z_i^{-\theta}\right)^{1/\rho}\right]^{\rho}\right\},$$

where $1 \geq \rho > 0$. Correlation decreases as ρ rises, with $\rho = 1$ implying independence. See, e.g., Small (1987). All that we do in this paper stands, with T_i reinterpreted as $T_i^{1/\rho}$ and θ as θ/ρ.

lute and comparative advantage across a continuum of goods. We will refer to the parameter T_i as country i's state of technology. In a trade context T_i reflects country i's absolute advantage across this continuum.

The parameter θ regulates heterogeneity across goods in countries' relative efficiencies. In a trade context θ governs comparative advantage within this continuum. As we show more formally below, a lower value of θ, generating more heterogeneity, means that comparative advantage exerts a stronger force for trade against the resistance imposed by the geographic barriers d_{ni}.[14]

2.2. Prices

What do these assumptions imply about the distribution of prices in different countries? Substituting the expression for P_{ni} into the distribution of efficiency (4) implies that country i presents country n with a distribution of prices $G_{ni}(p) = \Pr[P_{ni} \leq p] = 1-F_i\,(c_i d_{ni}/p)$ or:

$$G_{ni}(p) = 1 - e^{-[T_i(c_i d_{ni})^{-\theta}]p^{\theta}}. \tag{5}$$

The lowest price for a good in country n will be less than p unless each source's price is greater than p. Hence the distribution $G_n(p) = \Pr[P_n \leq p]$ for what country n actually buys is

$$G_n(p) = 1 - \prod_{i=1}^{N}[1 - G_{ni}(p)].$$

Inserting (5), the price distribution inherits the form of $G_{ni}(p)$:

$$G_n(p) = 1 - e^{-\Phi_n p^{\theta}}, \tag{6}$$

where the parameter Φ_n of country n's price distribution is

$$\Phi_n = \sum_{i=1}^{N} T_i (c_i d_{ni})^{-\theta}. \tag{7}$$

The price parameter Φ_n is critical to what follows. It summarizes how (i)

14. Our results translate nicely into the two-country world of Dornbusch, Fischer, and Samuelson(1997). They represent technology by a function $A(x)$, where x is the fraction of goods for which the ratio of home (country 1) to foreign (country 2) efficiency is at least A. Using a result on the distribution of the ratio of independent Type II extreme value random variables, our model delivers $A(x) = (T_1/T_2)^{1/\theta}((1-x)/x)^{1/\theta}$. It shifts up if the foreign state of technology T_1 rises relative to home's T_2.

states of technology around the world, (ii) input costs around the world, and (iii) geographic barriers govern prices in each country n. International trade enlarges each country's effective state of technology with technology available from other countries, discounted by input costs and geographic barriers. At one extreme, in a zero-gravity world with no geographic barriers (d_{ni} = 1 for all n and i), Φ is the same everywhere and the law of one price holds for each good. At the other extreme of autarky, with prohibitive geographic barriers ($d_{ni} \to \infty$ for $n \neq i$), Φ_n reduces to $T_n c_n^{-\theta}$, country n's own state of technology downweighted by its input cost.

We exploit three useful properties of the price distributions:

(a) The probability that country i provides a good at the lowest price in country n is simply

(8) $$\pi_{ni} = \frac{T_i (c_i d_{ni})^{-\theta}}{\Phi_n},$$

i's contribution to country n's price parameter.[15] Since there are a continuum of goods, this probability is also the fraction of goods that country n buys from country i.

(b) The price of a good that country n *actually buys* from any country i also has the distribution $G_n(p)$.[16] Thus, for goods that are purchased, conditioning on the source has no bearing on the good's price. A source with a higher state of technology, lower input cost, or lower barriers exploits its advantage by selling a wider range of goods, exactly to the point at which the distribution of prices for what it sells in n is the same as n's overall price distribution.

(c) The exact price index for the CES objective function (3), assuming $\sigma < 1 + \theta$, is

(9) $$p_n = \gamma \, \Phi_n^{-1/\theta}.$$

Here, $\gamma = \left[\Gamma\left(\frac{\theta + 1 - \sigma}{\theta} \right) \right]^{1/(1-\sigma)}$,

15. We obtain this probability by calculating

$$\pi_{ni} = \Pr\left[P_{ni}(j) \le \min\{ P_{ns}(j); s \neq i \} \right] = \int_0^\infty \prod_{s \neq i} [1 - G_{ns}(p)] \, dG_{ni}(p).$$

16. We obtain this result by showing that

$$G_n(p) = \frac{1}{\pi_{ni}} \int_0^p \prod_{s \neq i} [1 - G_{ns}(q)] \, dG_{ni}(q).$$

where Γ is the Gamma function.[17] This expression for the price index shows how geographic barriers, by generating different values of the price parameter in different countries, lead to deviations from purchasing power parity.

2.3. Trade Flows and Gravity

To link the model to data on trade shares we exploit an immediate corollary of Property (b), that country n's average expenditure per good does not vary by source. Hence the fraction of goods that country n buys from country i, π_{ni}, from Property (a), is also the fraction of its *expenditure* on goods from country i:

(10)
$$\frac{X_{ni}}{X_n} = \frac{T_i\left(c_i d_v\right)^{-\theta}}{\Phi_n} = \frac{T_i\left(c_i d_{ni}\right)^{-\theta}}{\sum_{k=1}^{N} T_k\left(c_k d_{nk}\right)^{-\theta}},$$

where X_n, is country n's total spending, of which X_{ni} is spent (c.i.f.) on goods from i.[18] Before proceeding with our own analysis, we discuss how expression (10) relates to the existing literature on bilateral trade.

Note that expression (10) already bears semblance to the standard gravity equation in that bilateral trade is related to the importer's total expenditure and to geographic barriers. Some manipulation brings it even closer to a gravity expression. Note that the exporter's total sales Q_i are simply

$$Q_i = \sum_{m=1}^{N} X_{mi} = T_i c_i^{-\theta} \sum_{m=1}^{N} \frac{d_{mi}^{-\theta} X_v}{\Phi_m}.$$

17. The moment generating function for $x = -\ln p$ is $E(e^{tx}) = \Phi^{t/\theta}\Gamma(1-t/\theta)$. (See, e.g., Johnson and Kotz (1970)). Hence $E[p^{-t}]^{-1/t} = \Gamma(1 - t/\theta)^{-1/t}\Phi^{-t/\theta}$. The result follows by replacing t with $\sigma - 1$. While our framework allows for the possibility of inelastic demand ($\sigma \leq 1$), we must restrict $\sigma < 1 + \theta$ in order to have a well defined price index. As long as this restriction is satisfied, the parameter σ can be ignored, since it appears only in the constant term (common across countries) of the price index.

18. Our model of trade bears resemblance to discrete-choice models of market share, popular in industrial organization (e.g., McFadden (1974), Anderson, dePalma, and Thisse (1992), and Berry (1994)): (i) our trade model has a discrete number of countries whereas their consumer demand model has a discrete number of differentiated goods; (ii) in our model a good's efficiency of production in different countries is distributed multivariate extreme value whereas in their's a consumer's preferences for different goods is distributed multivariate extreme value; (iii) in our model each good is purchased (by a given importing country) from only one exporting country whereas in their model each consumer purchases only one good; (iv) we assume a continuum of goods whereas they assume a continuum of consumers. A distinction is that we can derive the extreme value distribution from deeper assumptions about the process of innovation.

Solving for $T_i c_i^{-\theta}$, and substituting it into (10), incorporating (9), we get

$$X_{ni} = \frac{\left(\frac{d_{ni}}{p_n}\right)^{-\theta} X_n}{\sum_{m=1}^{N} \left(\frac{d_{mi}}{p_m}\right)^{-\theta} X_m} Q_i. \qquad (11)$$

Here, as in the standard gravity equation, both the exporter's total sales Q_i and, given the denominator, the importer's total purchases X_n enter with unit elasticity. Note that the geographic barrier d_{mi} between i and any importer m is deflated by the importer's price level p_m: Stiffer competition in market m reduces p_m, reducing i's access in the same way as a higher geographic barrier. We can thus think of the term $(d_{mi}/p_m)^{-\theta}X_m$ as the market size of destination m as perceived by country i. The denominator of the right-hand side of (11), then, is the total world market from country i's perspective. The share of country n in country i's total sales just equals n's share of i's effective world market.

Other justifications for a gravity equation have rested on the traditional Armington and monopolistic competition models. Under the Armington assumption goods produced by different sources are inherently imperfect substitutes by virtue of their provenance. Under monopolistic competition each country chooses to specialize in a distinct set of goods. The more substitutable are goods from different countries, the higher is the sensitivity of trade to production costs and geographic barriers. In contrast, in our model the sensitivity of trade to costs and geographic barriers depends on the technological parameter θ (reflecting the heterogeneity of goods in

19. The expressions for bilateral trade shares delivered by the Armington and monopolistic competition models make the connections among these approaches explicit. For the Armington case define a_i as the weight on goods from country i in CES preferences. Country i's share in country n's expenditure is then

$$\frac{X_{ni}}{X_n} = \frac{a_i^{\sigma-1}\left(c_i d_{ni}\right)^{-(\sigma-1)}}{\sum_{k=1}^{N} a_k^{\sigma-1}\left(c_k d_{nk}\right)^{-(\sigma-1)}}.$$

In the case of monopolistic competition with CES preferences define m_i as the number of goods produced by country i. Country i's share in country n's expenditure is then

$$\frac{X_{ni}}{X_n} = \frac{m_i\left(c_i d_{ni}\right)^{-(\sigma-1)}}{\sum_{k=1}^{N} m_k\left(c_k d_{nk}\right)^{-(\sigma-1)}}.$$

Returning to equation (10), the exporter's state of technology parameter T_i in our model replaces its preference weight $a_i^{\sigma-1}$ (in Armington) or its number of goods m_i (under monopolistic competition). In our model the heterogeneity of technology parameter θ replaces the preference parameter $\sigma - 1$ in these alternatives. (The standard assumption in these other models is that all goods are produced with the same efficiency, so that c_i reflects both the cost of inputs and the f.o.b. price of goods.)

production) rather than the preference parameter σ (reflecting the heterogeneity of goods in consumption). Trade shares respond to costs and geographic barriers at the extensive margin: As a source becomes more expensive or remote it exports a narrower range of goods. In contrast, in models that invoke Armington or (with some caveats) monopolistic competition, adjustment is at the intensive margin: Higher costs or geographic barriers leave the set of goods that are traded unaffected, but less is spent on each imported good.[19]

3. Trade, Geography, and Prices: A First Look

Our model implies a connection between two important economic variables that have been analyzed extensively, but only in isolation: trade flows and price differences. To establish this link we divide (10) by the analogous expression for the share of country i producers at home, substituting in (9), to get

$$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \frac{\Phi_i}{\Phi_n} d_{ni}^{-\theta} = \left(\frac{p_i d_{ni}}{p_n}\right)^{-\theta}. \tag{12}$$

We refer to the left-hand-side variable, country i's share in country n relative to i's share at home, as country i's normalized import share in country n. The triangle inequality implies that the normalized share never exceeds one.[20]

As overall prices in market n fall relative to prices in market i (as reflected in higher p_i/p_n) or as n becomes more isolated from i (as reflected in a higher d_{ni}), i's normalized share in n declines. As the force of comparative advantage weakens (reflected by a higher θ), normalized import shares become more elastic with respect to the average relative price and to geographic barriers. A higher value of θ means relative efficiencies are more similar across goods. Hence there are fewer efficiency outliers that overcome differences in average prices or geographic barriers.[21]

The relationship between normalized trade share and prices in equation (12) is a structural one whose slope provides insight into the value of our comparative advantage parameter θ. Before using this relationship to estimate θ we first exploit it to assess the role played by geographic barriers

20. Since a purchaser in country n can always buy all her goods in i at a price index $p_i d_{ni}$, p_n cannot be higher.

21. To obtain further intuition into expression (12) recall that the prices of goods actually sold in a country have the same distribution regardless of where they come from. Hence the price index of producers in country i selling at home is p_i. The subset of i producers who also sell in n have a price index in country n of p_n. (The triangle inequality ensures that anyone in i able to sell in n is also able to sell in i.) But to get into country n, country i producers have to overcome the geographic barrier d_{ni}. Hence, the price index at home of these exporters is p_n/d_{ni}. Of the set of producers able to compete in a market with price index p_i, the fraction who would survive in a market with price index $p_n/d_{ni} < p_i$, is $(p_i d_{ni}/p_n)^{-\theta}$.

in trade.

We measure normalized import shares, the left-hand side of equation (12), with data on bilateral trade in manufactures among 19 OECD countries in 1990, giving us 342 informative observations (in which n and i are different).[22] Normalized import shares never exceed 0.2, far below the level of one that would hold in a zero-gravity world with all $d_{ni} = 1$. Furthermore, they vary substantially across country-pairs, ranging over four orders of magnitude.

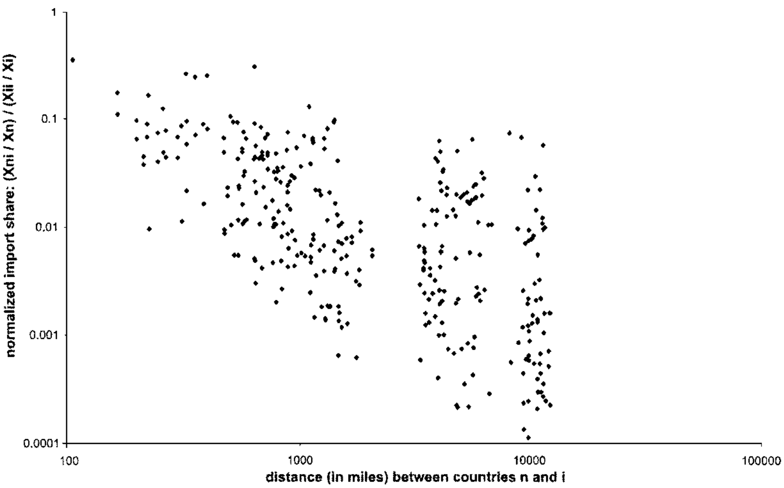

Figure 1. Trade and Geography

An obvious, but crude, proxy for d_{ni} in equation (12) is distance. Figure 1 graphs normalized import share against distance between the corresponding country-pair (on logarithmic scales). The relationship is not perfect, and shouldn't be. Imperfections in our proxy for geographic barriers aside, we are ignoring the price indices that appear in equation (12). Nevertheless, the resistance that geography imposes on trade comes through clearly.

Since we have no independent information on the extent to which geographic barriers rise with distance, the relationship in Figure 1 confounds the impact of comparative advantage (θ) and geographic barriers (d_{ni}) on trade flows. The strong inverse correlation could result from geographic barriers that rise rapidly with distance, overcoming a strong force of com-

22. When $i = n$ the equation degenerates to a vacuous identity. We use country n's manufactured imports from country i to obtain X_{ni} and country n's absorption of manufactures from all countries of the world to obtain X_n, defined as gross manufacturing production less exports plus imports of manufactures. The Appendix describes our sources of data.

parative advantage (a low θ). Alternatively, comparative advantage might exert only a very weak force (a high θ), so that even a mild increase in geographic barriers could cause trade to drop off rapidly with distance.

To identify θ we turn to price data, which we use to measure the term $p_i d_{ni}/p_n$ on the right-hand side of equation (12). While we used standard data to calculate normalized trade shares, our measure of relative prices, and particularly geographic barriers, requires more explanation. We work with retail prices in each of our 19 countries of 50 manufactured products.[23] We interpret these data as a sample of the prices $p_i(j)$ of individual-goods in our model. We use them to calculate, for each country-pair n and i and each good j, the logarithm of the *relative* price, $r_{ni}(j)=\ln p_n(j)-\ln p_i(j)$. We calculate the logarithm of p_i/p_n, as the mean across j of $-r_{ni}(j)$. To get at geographic barriers d_{ni} we use our model's prediction that, for any commodity j, $r_{ni}(j)$ is bounded above by $\ln d_{ni}$ with this bound attained for goods that n imports from i. (For goods that n does not buy from i, $r_{ni}(j)$ is below $\ln d_{ni}$.) Every country in our sample does in fact import from every other. We take the (second) highest value of r_{ni} across commodities to obtain a measure of $\ln d_{ni}$.[24] In summary, we measure $\ln(p_i d_{ni}/p_n)$ by the term D_{ni} defined as

$$D_{ni} = \frac{max\,2_j\{r_{ni}(j)\}}{\sum_{j=1}^{50}[r_{ni}(j)]/50}, \tag{13}$$

(where $max2$ means second highest).[25]

The price measure $\exp D_{ni}$ reflects what the price index in destination n would be for a buyer there who insisted on purchasing everything from

23. The United Nations International Comparison Program 1990 benchmark study gives, for over 100 products, the price in each of our countries relative to the price in the United States. We choose 50 products that are most closely linked to manufacturing outputs.

24. We used the second highest (rather than highest) value of $r_{ni}(j)$ to mitigate the effect of possible measurement error in the prices for particular commodities. Indeed, the second order statistic correlates more with the trade data than the first, and more than higher order statistics. Office and computing equipment is often an outlier. An alternative strategy is just to drop this sector from the calculation and use the highest value of the remaining $r_{ni}(j)$ to measure $\ln d_{ni}$. The correlation is almost identical to the one in the scatter. While direct measures of the cost of transporting goods exist (see, e.g. Hummels (2002), they fail to capture all the costs involved in buying things from far away, such as delay and the difficulty of negotiation across space.

25. Our prices are what domestic consumers pay (including taxes and retail markups) rather than what domestic producers receive. But to the extent that factors specific to individual countries but common to all goods drive the deviation between consumer and producer prices, the resulting errors in this expression cancel.

Table 2. Price Measure Statistics

Country	Foreign Sources		Foreign Destinations	
	Minimum	Maximum	Minimum	Maximum
Australia(AL)	NE (1.44)	PO (2.25)	BE (1.41)	US (2.03)
Austria (AS)	SW (1.39)	NZ (2.16)	UK (1.47)	JP (1.97)
Belgium (BE)	GE (1.25)	JP (2.02)	GE (1.35)	SW (1.77)
Canada (CA)	US (1.58)	NZ (2.57)	AS (1.57)	US (2.14)
Denmark(DK)	FI (1.36)	PO (2.21)	NE (1.48)	US (2.41)
Finland(FI)	SW (1.38)	PO (2.61)	DK (1.36)	US (2.87)
France(FR)	GE (1.33)	NZ (2.42)	BE (1.40)	JP (2.40)
Germany(GE)	BE (1.35)	NZ (2.28)	BE (1.25)	US (2.22)
Greece(GR)	SP (1.61)	NZ (2.71)	NE (1.48)	US (2.27)
Italy(IT)	FR (1.45)	NZ (2.19)	AS (1.46)	JP (2.10)
Japan(JP)	BE (1.62)	PO (3.25)	AL (1.72)	US (3.08)
Netherlands(NE)	GE (1.30)	NZ (2.17)	DK (1.39)	NZ (2.01)
New Zealand(NZ)	CA (1.60)	PO (2.08)	AL (1.64)	GR (2.71)
Norway(NO)	FI (1.45)	JP (2.84)	SW (1.36)	US (2.31)
Portugal(PO)	BE (1.49)	JP (2.56)	SP (1.59)	JP (3.25)
Spain(SP)	BE (1.39)	JP (2.47)	NO (1.51)	JP (3.05)
Sweden(SW)	NO (1.36)	US (2.70)	FI (1.38)	US (2.01)
United Kingdom(UK)	NE (1.46)	JP (2.37)	FR (1.52)	NZ (2.04)
United States(US)	FR (1.57)	JP (3.08)	CA (1.58)	SW (2.70)

Note: The price msasure D_{ni} is defined in Equation(13). For destination country n, the minimum Foreign Source is $\min_{i \neq n} \exp D_{ni}$. For source country i, the minimum Foreign Destination is $\min_{n \neq i} \exp D_{ni}$.

source i, relative to the actual price index in n (the price index for a buyer purchasing each good from the cheapest source). Table 2 provides some order statistics of our price measure. For each country we report, from its perspective as an importer, the foreign source for which the measure is lowest and highest. We then report, from that country's perspective as an exporter, the foreign destination for which the measure is lowest and highest. (In parentheses we report the associated values of $\exp D_{ni}$.) France, for example, finds Germany its cheapest foreign source and New Zealand its most expensive. A French resident buying all commodities from Germany would face a 33 per cent higher price index and from New Zealand a 142 per cent higher price index. A resident abroad who insisted on buying everything from France would face the smallest penalty (40 per cent) if she were in Belgium and the largest (140 per cent) if she were in Japan. Note how geography comes out in the price data as well as in the trade data: The cheapest foreign source is usually nearby and the most expensive far away. Note also, from column 4, that large countries would typically suffer the most if required to buy everything from some given foreign source.

Figure 2 graphs our measure of normalized import share (in logarithms) against D_{ni}. Observe that, while the scatter is fat, there is an obvious negative relationship, as the theory predicts. The correlation is −0.40. The relationship in Figure 2 thus confirms the connection between trade and prices predicted by our model.

Moreover, the slope of the relationship provides a handle on the value of the comparative advantage parameter θ. Since our theory implies a zero intercept, a simple method-of-moments estimator for θ is the mean of the left-hand-side variable over the mean of the right-hand-side variable. The implied θ is 8.28. Other appropriate estimation procedures yield very similar magnitudes.[26] Hence we use this value for θ in exploring counterfactuals. This value of θ implies a standard deviation in efficiency (for a given state of technology T) of 15 percent. In section 5 we pursue two alterna-

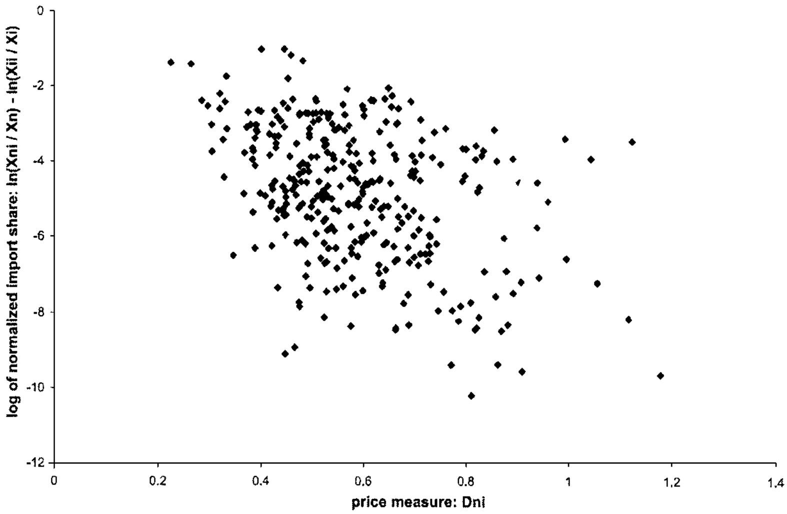

Figure 2. Trade and Prices

26. A linear regression through the scatter in Figure 2 yields a slope of −4.57 with an intercept of −2.17 (with respective standard errors 0.6 and 0.3). The fact that OLS yields a negative intercept is highly symptomatic of errors in variables, which also biases the OLS estimate of θ toward zero. (The reasoning is that in Friedman's 1957 critique of the Keynesian consumption function.) There are many reasons to think that there is error in our measure of $p_i d_{ni}/p_n$. Imposing a zero intercept, OLS yields a slope of −8.03, similar to our method-of-moments estimate. (Instrumental variables provide another way to tackle errors in variables, an approach we pursue in section 5, after we complete the general equilibrium specification of the model.) We also examined how the three components $\ln p_i$, $\ln p_n$, and $\ln d_{ni}$, contributed individually to explaining trade shares. Entering these variables separately into OLS regressions yielded the respective coefficients −4.9, 5.5, −4.6 (with a constant) and −9.0, 6.4, −6.8 (without a constant). All have the predicted signs. For 42 of our 50 goods similar price data are available from the 1985 Benchmark Study. Relating 1985 trade data to these price data yields very similar estimates of θ.

tive strategies for estimating θ, but we first complete the full description of the model.

4. Equilibrium Input Costs

Our exposition so far has highlighted how trade flows relate to geography and to prices, taking input costs c_i as given. In any counterfactual experiment, however, adjustment of input costs to a new equilibrium is crucial.

To close the model we decompose the input bundle into labor and intermediates. We then turn to the determination of prices of intermediates, given wages. Finally we model how wages are determined. Having completed the full model, we illustrate it with two special cases that yield simple closed-form solutions.

4.1. Production

We assume that production combines labor and intermediate inputs, with labor having a constant share β.[27] Intermediates comprise the full set of goods combined according to the CES aggregator (3). The overall price index in country i, p_i, given by equation (9), becomes the appropriate index of intermediate goods prices there. The cost of an input bundle in country i is thus

$$c_i = w_i^{\beta} p_i^{1-\beta}, \tag{14}$$

where w_i is the wage in country i. Because intermediates are used in production, c_i depends on prices in country i, and hence on Φ_i. But through equation (7), the price parameter Φ_i depends on input costs everywhere.

Before turning to the determination of price levels around the world, we first note how expression (14), in combination with (9), (7), and (10), delivers an expression relating the real wage (w_i/p_i) to the state of technology parameter T_i and share of purchases from home π_{ii}:

$$\frac{w_i}{p_i} = \gamma^{-1/\beta}\left(\frac{T_i}{\pi_{ii}}\right)^{1/\beta\theta}. \tag{15}$$

27. We ignore capital as an input to production and as a source of income, although our intermediate inputs play a similar role in the production function. Baxter (1992) shows how a model in which capital and labor serve as factors of production delivers Ricardian implications if the interest rate is common across countries.

Since in autarky $\pi_{ii} = 1$, we can immediately infer the gains from trade from the share of imports in total purchases. Note that, given import share, trade gains are greater the smaller θ (more heterogeneity in efficiency) and β (larger share of intermediates).

4.2. Price Levels

To see how price levels are mutually determined, substitute (14) into (7), applying (9), to obtain the system of equations:

$$p_n = \gamma\left[\sum_{i=1}^{N} T_i\left(d_{ni} w_i^{\beta} p_i^{1-\beta}\right)^{-\theta}\right]^{-1/\theta}. \tag{16}$$

The solution, which in general must be computed numerically, gives price indices as functions of the parameters of the model and wages.

Expanding equation (10) using (14) we can also get expressions for trade shares as functions of wages and parameters of the model:

$$\frac{X_{ni}}{X_n} = \pi_{ni} = T_i\left(\frac{\gamma d_{ni} w_i^{\beta} p_i^{1-\beta}}{p_n}\right)^{-\theta}, \tag{17}$$

with the p_i's obtained from expression (16) above.

We now impose conditions for labor market equilibrium to determine wages themselves.

4.3. Labor-Market Equilibrium

Up to this point we have not had to take a stand about whether our model applies to the entire economy or to only one sector. Our empirical implementation is to production and trade in manufactures. We now show how manufacturing fits into the larger economy.

Manufacturing labor income in country i is labor's share of country i's manufacturing exports around the world, including its sales at home. Thus

$$w_i L_i = \beta \sum_{n=1}^{N} \pi_{ni} X_n, \tag{18}$$

where L_i is manufacturing workers and X_n is total spending on manufactures.

We denote aggregate final expenditures as Y_n with α the fraction spent on manufactures. Total manufacturing expenditures are then

(19) $$X_n = \frac{1-\beta}{\beta} w_n L_n + \alpha Y_n,$$

where the first term captures demand for manufactures as intermediates by the manufacturing sector itself. Final expenditure Y_n consists of value-added in manufacturing $Y_n^M = w_n L_n$ plus income generated in nonmanufacturing Y_n^O. We assume that (at least some of) nonmanufacturing output can be traded costlessly, and use it as our numeraire.[28]

To close the model as simply as possible we consider two polar cases that should straddle any more detailed specification of nonmanufacturing. In one case labor is mobile. Workers can move freely between manufacturing and nonmanufacturing. The wage w_n is given by productivity in nonmanufacturing and total income Y_n is exogenous. Equations (18) and (19) combine to give

(20) $$w_i L_i = \sum_{n=1}^{N} \pi_{ni} \left[(1-\beta) w_n L_n + \alpha\beta Y_n \right],$$

determining manufacturing employment L_i.

In the other case labor is immobile. The number of manufacturing workers in each country is fixed at L_n. Nonmanufacturing income Y_n^O is exogenous. Equations (18) and (19) combine to form

(21) $$w_i L_i = \sum_{n=1}^{N} \pi_{ni} \left[(1-\beta+\alpha\beta) w_n L_n + \alpha\beta Y_n^0 \right],$$

determining manufacturing wages w_i.

In the mobile labor case we can use equations (16) and (17) to solve for prices and trade shares given exogenous wages before using (20) to calculate manufacturing employment. The immobile labor case is trickier in that we need to solve the three equations (16), (17), and (21) simultaneously for prices, trade shares, and manufacturing wages.

In the case of mobile labor, our model has implications not only for intra-industry trade within manufacturing, but for specialization in manufacturing. The technology parameter T_i then reflects not only absolute advantage within manufactures, but comparative advantage in manufacturing relative to non-manufacturing. In the immobile case labor specialization is exogenous, and T_i is reflected in manufacturing wages. In either case θ governs specialization within manufacturing.

28. Assuming that nonmanufactures are costlessly traded is not totally innocuous, as pointed out by Davis (1998).

4.4. Zero-Gravity and Autarky

While, in general, the rich interaction among prices in different countries makes any analytic solution unattainable, two special cases yield simple closed-form solutions. We consider in turn the extremes in which (i) geographic barriers disappear (zero gravity), meaning that all $d_{ni} = 1$, and (ii) geographic barriers are prohibitive (autarky), meaning that $d_{ni} \to \infty$ for $n \neq i$.

With no geographic barriers the law of one price holds. In either the mobile or immobile labor cases the condition for labor market equilibrium reduces to

$$\frac{w_i}{w_N} = \left(\frac{T_i/L_i}{T_N/L_N}\right)^{1/(1+\theta\beta)}. \tag{22}$$

Since prices are the same everywhere this expression is also the relative real wage.

When labor is mobile this expression determines the relative amounts of manufacturing labor in each country, which are proportional to $T_i/w_i^{1+\theta\beta}$. The country with a higher state of technology relative to its wage will specialize more in manufacturing. When labor is immobile the expression gives relative wages, which depend on the state of technology in per worker terms. Given T_i, as L_i increases workers must move into production of goods in which the country is less productive, driving down the wage.

Suppose manufacturing is the only activity so that $\alpha = 1$ and $Y_i = w_iL_i$. The wage must adjust to maintain trade balance. Real GDP per worker (our welfare measure) is then $W_i = (Y_i/L_i)/p = w_i/p$. Manipulating (22) and (16),

$$W_i = \gamma^{-1/\beta} T_i^{1/(1+\theta\beta)} \left[\sum_{k=1}^{N} T_k^{1/(1+\theta\beta)} \left(L_k/L_i\right)^{\theta\beta/(1+\theta\beta)}\right]^{1/\theta\beta}, \tag{23}$$

which increases with technology T_k anywhere. An increase at home confers an extra benefit, however, because it raises the home wage relative to wages abroad. How much country i benefits from an increase in T_k depends on k's labor force relative to i's. If the labor force in the source country k is small, w_k rises more, diminishing the benefits to others of its more advanced state of technology.[29]

We can solve for a country's welfare in autarky by solving (23) for a one-country world or by referring back to (15) setting $\pi_{ii} = 1$. Doing so, we get

$$W_i = \gamma^{-1/\beta} T_i^{1/\theta\beta}. \tag{24}$$

Note, of course, that there are gains from trade for everyone, as can be verified by observing that we derived (24) by removing positive terms from (23).[30]

While these results illustrate how our model works, and provide insight into its implications, the raw data we presented in Section 3 show how far the actual world is from either zero-gravity or autarky. For empirical purposes we need to grapple with the messier world in between, to which we now return.

5. Estimating the Trade Equation

Equations (16) and (17), along with either (20) or (21), comprise the full general equilibrium. These equations determine price levels, trade shares, and either manufacturing labor supplies (in the mobile labor case) or manufacturing wages (in the immobile case). In section 6 we explore how these endogenous magnitudes respond to various counterfactual experiments. In this section we present the estimation that yields the parameter values used to examine these counterfactuals.

29. If we plug these results for *zero* gravity into our bilateral trade equation (10), we obtain a simple gravity equation with no "distance" term:

$$X_{ni} = \frac{Y_n Y_i}{\beta Y^W}.$$

Bilateral trade equals the product of the trade partners' incomes, Y_i and Y_n, relative to world income, Y^W, all scaled up by the ratio of gross production to value added. Note that this relationship masks the underlying structural parameters, T_i and θ.

30. Note also that trade has an equalizing effect in that the elasticity of real GDP with respect to one's own state of technology T_i is greater when geographic barriers are prohibitive than when they are absent. The reason is that, with trade, the county that experiences a gain in technology spreads its production across a wider range of goods, allowing foreigners to specialize in a narrower set in which they are more efficient. The relative efficiency gain is consequently dampened. Under autarky, of course, every country produces the full range of goods.

5.1. Estimates with Source Effects

Equation (17), like the standard gravity equation, relates bilateral trade volumes to characteristics of the trading partners and the geography between them. Estimating it provides a way to learn about states of technology T_i and geographic barriers d_{ni}.

Normalizing (17) by the importer's home sales delivers

$$\frac{X_{ni}}{X_{nn}} = \frac{T_i}{T_n}\left(\frac{w_i}{w_n}\right)^{-\theta\beta}\left(\frac{p_i}{p_n}\right)^{-\theta(1-\beta)} d_{ni}^{-\theta}. \tag{25}$$

We can use equation (17) as it applies to home sales, for both country i and country n, to obtain

$$\frac{p_i}{p_n} = \frac{w_i}{w_n}\left(\frac{T_i}{T_n}\right)^{-1/\theta\beta}\left(\frac{X_i/X_{ii}}{X_n/X_{nn}}\right)^{-1/\theta\beta}.$$

Plugging this expression for the relative price of intermediates into (25) and rearranging gives, in logarithms:

$$\ln\frac{X'_{ni}}{X'_{nn}} = -\theta\ln d_{ni} + \frac{1}{\beta}\ln\frac{T_i}{T_n} - \theta\ln\frac{w_i}{w_n}, \tag{26}$$

where $\ln X'_{ni} \equiv \ln X_{ni} - [(1-\beta)/\beta]\ln(X_i/X_{ii})$. By defining

$$S_i \equiv \frac{1}{\beta}\ln T_i - \theta\ln w_i, \tag{27}$$

this equation simplifies to:

$$\ln\frac{X'_{ni}}{X'_{nn}} = -\theta\ln d_{ni} + S_i - S_n. \tag{28}$$

We can think of S_i as a measure of country i's "competitiveness," its state of technology adjusted for its labor costs. Equation (28) forms the basis of our estimation.[31]

We calculate the left-hand side of (28) from the same data on bilateral trade among 19 countries that we use in Section 3, setting $\beta = .21$, the average labor share in gross manufacturing production in our sample. As in Section 3, this equation is vacuous as it applies to $n = i$, leaving us 342 informative observations. Since prices of intermediates reflect imports from all sources, X_n includes imports from all countries in the world. In other respects this bilateral trade equation lets us ignore the rest of the world.

As for the right-hand side of (28), we capture the S_i as the coefficients on source-country dummies. We now turn to our handling of the d_{ni}'s.

We use proxies for geographic barriers suggested by the gravity literature.[32] In particular, we relate the impediments in moving goods from i to n to proximity, language, and treaties. We have, for all $i \neq n$

$$\ln d_{ni} = d_k + b + l + e_h + m_n + \delta_{ni}, \tag{29}$$

where the dummy variable associated with each effect has been suppressed for notational simplicity. Here d_k ($k = 1,...,6$) is the effect of the distance between n and i lying in the kth interval, b is the effect of n and i sharing a border, l is the effect of n and i sharing a language, e_h ($h = 1, 2$) is the effect of n and i both belonging to trading area h, and m_n ($n = 1,...,19$) is an overall destination effect. The error term δ_{ni} captures geographic barriers arising from all other factors. The six distance intervals (in miles) are: [0,375); [375,750); [750,1500); [1500,3000); [3000,6000); and [6000,maximum]. The two trading areas are the European Community (EC) and the European Freer-Trade Area (EFTA).[33] We assume that the error δ_{ni} is orthogonal to the other regressors (source country dummies and the proxies for geographic barriers listed above).

31. If $\beta = 1$ and $S = \ln Y$, equation (28) is implied by the standard gravity equation:

$$X_{ni} = \kappa d_{ni}^{-\theta} Y_i Y_n,$$

where κ is a constant. But from equation (11) our theory implies that S should reflect a country's production *relative* to the total world market from its perspective: Given the geographic barrier to a particular destination, an exporter will sell more there when it is more remote from third markets.

32. An alternative strategy would have been to use the maximum price ratios introduced in Section 3 to measure d_{ni} directly. The problem is that country-specific errors in this measure are no longer cancelled out by price level differences, as they are in (13).

33. An advantage of our formulation of distance effects is that it imposes little structure on how geographic barriers vary with distance. We explored the implications of the more standard specification of geographic barriers as a quadratic function of distance. There were no differences worth reporting.

To capture potential reciprocity in geographic barriers, we assume that the error term δ_{ni} consists of two components:

$$\delta_{ni} = \delta^2_{ni} + \delta^1_{ni}.$$

The country-pair specific component δ^2_{ni} (with variance σ^2_2) affects two-way trade, so that $\delta^2_{ni} = \delta^2_{in}$, while δ^1_{in} (with variance σ^2_1) affects one-way trade. This error structure implies that the variance-covariance matrix of δ has diagonal elements $E(\delta_{ni}\delta_{ni}) = \sigma^2_1 + \sigma^2_2$ and certain nonzero off-diagonal elements $E(\delta_{ni}\delta_{ni}) = \sigma^2_2$.

Imposing this specification of geographic barriers, equation (28) becomes

$$\ln\frac{X'_{ni}}{X'_{nn}} = S_i - S_n - \theta m_n - \theta d_k - \theta b - \theta l - \theta e_h + \theta\delta^2_{ni} + \theta\delta^1_{ni}, \tag{30}$$

which we estimate by generalized least squares (GLS).[34]

Table 3 reports the results. The estimates of the S_i indicate that Japan is the most competitive country in 1990, closely followed by the United States. Belgium and Greece are the least competitive. As for geographic barriers, increased distance substantially inhibits trade, with its impact somewhat attenuated by a shared language, while borders, the EC, and EFTA do not play a major role. The United States, Japan, and Belgium are the most open countries while Greece is least open.[35] Note that about a quarter of the total residual variance is reciprocal.

34. To obtain the parameters of the variance-covariance matrix for GLS estimation we first estimate the equation by OLS to obtain a set of residuals $\hat{\varepsilon}_{ni}\hat{\varepsilon}_{ni}$. We then estimate $\theta^2\sigma^2_2$ by averaging $\hat{\varepsilon}_{ni}\hat{\varepsilon}_{in}$ and $\theta^2(\sigma^2_2 + \sigma^2_1)$ by averaging $(\hat{\varepsilon}_{ni})^2$.

35. Our finding about the openness of Japan may seem surprising given its low import share reported in Table 1. Analyses that ignore geography (for example, the first part of Harrigan (1996)), find Japan closed. Once geography is taken into account, however, as (implicitly) later in Harrigan, it no longer appears particularly closed. (Eaton and Tamura (1994) find Japan relatively more open to U.S. exports than European countries as a group.) As equation (10) reveals, our concept of a country's openness controls for both its location and its price level (as reflected by its price parameter Φ). Not only is Japan remote, its competitiveness as a manufacturing supplier implies a high Φ, making it a naturally tough market for foreigners to compete in. At the other extreme, our finding that Greece is quite closed (even though it has a high import share) controls for both its proximity to foreign manufacturing sources and its own inability to export much anywhere else.

Table 3. Bilateral Trade Equation

Variable		est.	s.e.
Distance [0, 375)	$-\theta d_1$	−3.10	(0.16)
Distance [375, 750)	$-\theta d_2$	−3.66	(0.11)
Distance [750, 1500)	$-\theta d_3$	−4.03	(0.10)
Distance [1500, 3000)	$-\theta d_4$	−4.22	(0.16)
Distance [3000, 6000)	$-\theta d_5$	−6.06	(0.09)
Distance [6000, maximum]	$-\theta d_6$	−6.56	(0.10)
Shared border	$-\theta b$	0.30	(0.14)
Shared language	$-\theta l$	0.51	(0.15)
European Community	$-\theta e_1$	0.04	(0.13)
EFTA	$-\theta e_2$	0.54	(0.19)

Country		Source-Country			Destination-Country	
		est.	s.e.		est.	s.e.
Australia	S_1	0.19	(0.15)	$-\theta m_1$	0.24	(0.27)
Austria	S_2	−1.16	(0.12)	$-\theta m_2$	−1.68	(0.21)
Belgium	S_3	−3.34	(0.11)	$-\theta m_3$	1.12	(0.19)
Canada	S_4	0.41	(0.14)	$-\theta m_4$	0.69	(0.25)
Denmark	S_5	−1.75	(0.12)	$-\theta m_5$	−0.51	(0.19)
Finland	S_6	−0.52	(0.12)	$-\theta m_6$	−1.33	(0.22)
France	S_7	1.28	(0.11)	$-\theta m_7$	0.22	(0.19)
Germany	S_8	2.35	(0.12)	$-\theta m_8$	1.00	(0.19)
Greece	S_9	−2.81	(0.12)	$-\theta m_9$	−2.36	(0.20)
Italy	S_{10}	1.78	(0.11)	$-\theta m_{10}$	0.07	(0.19)
Japan	S_{11}	4.20	(0.13)	$-\theta m_{11}$	1.59	(0.22)
Netherlands	S_{12}	−2.19	(0.11)	$-\theta m_{12}$	1.00	(0.19)
New Zealand	S_{13}	−1.20	(0.15)	$-\theta m_{13}$	0.07	(0.27)
Norway	S_{14}	−1.35	(0.12)	$-\theta m_{14}$	−1.00	(0.21)
Portugal	S_{15}	−1.57	(0.12)	$-\theta m_{15}$	−1.21	(0.21)
Spain	S_{16}	0.30	(0.12)	$-\theta m_{16}$	−1.16	(0.19)
Sweden	S_{17}	0.01	(0.12)	$-\theta m_{17}$	−0.02	(0.22)
United Kingdom	S_{18}	1.37	(0.12)	$-\theta m_{18}$	0.81	(0.19)
United States	S_{19}	3.98	(0.14)	$-\theta m_{19}$	2.46	(0.25)

Total Sum of Squares	2937	Error Variance:	
Sum of squared residuals	71	Two-way($\theta^2\sigma_2^2$)	0.05
Number of observations	342	One-way($\theta^2\sigma_1^2$)	0.16

Note: Estimated by generalized least squares using 1990 data. The specification is given in equation (30) of the paper. The parameters are normalized so that $\sum_{i=1}^{19} S_i = 0$ and $\sum_{i=1}^{19} m_n = 0$. Standard errors are in parentheses.

On their own, the competitiveness measures and the coefficients on the proxies for geographic barriers reflect a combination of underlying factors. Below we use estimates of θ to extract from them the parameters that we need for our counterfactuals. We now provide two alternative estimates of θ to the one from Section 3.

5.2. Estimates Using Wage Data

One approach brings data on wages to bear in estimating (26). The coefficient on relative wages in the bilateral wage equation provides the first alternative estimate of θ. This approach no longer allows us to absorb the technology parameter T_i into a source country effect. Instead, based on Kortum (1997) and Eaton and Kortum (1996), we relate technology to national stocks of R&D and to human capital as measured by years of schooling. Table 4 presents the data. (Again, see the Appendix for a description.) Using our estimates of S_i from the previous section we estimate

$$S_i = \alpha_0 + \alpha_R \ln R_i - \alpha_H \left(\frac{1}{H_i} \right) - \theta \ln w_i + \tau_i,$$

where R_i is country i's R&D stock, H_i is average years of schooling, and τ_i the error. The wage w_i is adjusted for education.

Table 4. Data for Alternative Parameters

Country	Research Stock (U.S.=1)	Years of Schooling (years/person)	Labor Force (HK adjusted) (U.S.=1)	Density (pop/area) (U.S.=1)
Australia	0.0087	8.7	0.054	0.08
Austria	0.0063	8.6	0.024	3.43
Belgium	0.0151	9.4	0.029	12.02
Canada	0.0299	10.0	0.094	0.10
Denmark	0.0051	6.9	0.017	4.47
Finland	0.0053	10.8	0.019	0.55
France	0.1108	9.5	0.181	3.88
Germany	0.1683	10.3	0.225	9.50
Greece	0.0005	8.4	0.025	2.87
Italy	0.0445	9.1	0.159	7.16
Japan	0.2492	9.5	0.544	12.42
Netherlands	0.0278	9.5	0.043	13.64
New Zealand	0.0010	9.3	0.010	0.47
Norway	0.0057	9.2	0.015	0.49
Portugal	0.0007	6.5	0.026	4.01
Spain	0.0084	9.7	0.100	2.88
Sweden	0.0206	9.6	0.031	0.71
United Kingdom	0.1423	8.5	0.186	8.76
United States	1.0000	12.1	1.000	1.00

Note: Research stocks, in 1990, are from Coe and Helpman (1995). Average years of schooling H_i, in 1985, are from Kyriacou (1991). Labor forces, in 1990, are from Summers and Heston(1991).They are adjusted for human capital by multiplying the country i figure by $e^{0.06H_i}$. See the Appendix for complete definitions.

Labor-market equilibrium suggests that a country's wage will increase with its level of technology, introducing a positive correlation between $\ln w$ and τ. As suggested by our model, we use the total workforce and population density as instruments: Given its technology T_i, a country with more workers has a lower wage. Population density proxies (inversely) for productivity outside manufacturing. Table 5 reports the results.

Both the OLS and 2SLS estimates of θ are significant and of the correct sign, but lower than suggested by the trade-price relationship. As expected, accounting for the endogeneity of wages raises our estimate of θ, from 2.86 to 3.60.

Table 5. Competitiveness Equation

		Ordinary Least Squares		Two-Stage Least Squares	
		est.	s.e.	est.	s.e.
Constant		3.75	(1.89)	3.82	(1.92)
Research stock, $\ln R_i$	α_R	1.04	(0.17)	1.09	(0.18)
Human capital, $1/H_i$	$-\alpha_H$	−18.0	(20.6)	−22.7	(21.3)
Wage, $\ln w_i$	$-\theta$	−2.84	(1.02)	−3.60	(1.21)
Total Sum of Squares		80.3		80.3	
Sum of squared residuals		18.5		19.1	
Number of observations		19		19	

Note: Estimated using 1990 data. The dependent variable is the estimates $\hat{S}_i$ of source-cuntry competitiveness shown in Table 3. Standard errors are in parentheses.

5.3. Estimates Using Price Data

The second alternative is to estimate the bilateral trade equation (28) using our measure of $\ln(p_i d_{ni}/p_n)$, D_{ni}, defined in expression (13), instead of the geography terms in (29), along with source and destination effects. The coefficient on D_{ni} provides yet another estimate of θ. (The estimated source effects reflect the price level terms in D_{ni} as well as technology and wages, making them harder to interpret.)

OLS estimation yields $\theta = 2.44$ (with a standard error of 0.49). A potential objection is the errors-in-variables problem with our D_{ni} measure discussed in Section 3. We address this problem by using the observable geography terms in (29) as instruments for D_{ni}. Doing so we obtain a 2SLS estimate of $\theta = 12.86$ (with a standard error of 1.64). The increase in magnitude supports the errors-in-variables interpretation.

5.4. States of Technology and Geographic Barriers

For each of our estimates of θ we derive estimates of the states of technology T_i and geographic barriers as follows:

Following equation (27), we strip the estimates of S_i in Table 3 down to T_i using data on wages (adjusted for education) and an estimate of θ. Table 6 shows the results. Note, for example, that, while our estimates of S_i imply that Japan is more “competitive” than the United States, we find that her edge is the consequence of a lower wage rather than a higher state of technology. At the other end, our low estimate of Belgium's competitiveness derives in large part from the high wage there.

Table 6. States of Technology

Country	Estimated Source-Country Competitiveness	Implied States of Technology θ=8.28	θ=3.60	θ12.86
Australia	0.19	0.27	0.36	0.20
Austria	−1.16	0.26	0.30	0.23
Belgium	−3.34	0.24	0.22	0.26
Canada	0.41	0.46	0.47	0.46
Denmark	−1.75	0.35	0.32	0.38
Finland	−0.52	0.45	0.41	0.50
France	1.28	0.64	0.60	0.69
Germany	2.35	0.81	0.75	0.86
Greece	−2.81	0.07	0.14	0.04
Italy	1.78	0.50	0.57	0.45
Japan	4.20	0.89	0.97	0.81
Netherlands	−2.19	0.30	0.28	0.32
New Zealand	−1.20	0.12	0.22	0.07
Norway	−1.35	0.43	0.37	0.50
Portugal	−1.57	0.04	0.13	0.01
Spain	0.30	0.21	0.33	0.14
Sweden	0.01	0.51	0.47	0.57
United Kingdom	1.37	0.49	0.53	0.44
United States	3.98	1.00	1.00	1.00

Note: The estimates of source-country competitiveness are the same shown in Table 3. For an estimated parameter $\hat{S}_i$, the implied state of technology is $T_i = (e^{\hat{S}_i} w_i^{\theta})^{\beta}$. States of technology are normalized relative to the U.S. value.

Dividing the coefficients on geographic proxies in Table 3 by θ and exponentiating gives the percentage cost increase each imposes. Column two of Table 7 reports the results. For θ = 8.28, a typical country in the closest distance category faces a 45 percent barrier relative to home sales, rising to 121 percent in the farthest distance category. Sharing a border reduces the barrier by 4 percent while sharing a language reduces it by 6 percent. It costs 25 percent less to export into the United States, the most open country, than to the average country. At the high end it costs 33 percent more to export to Greece than to the average country.[36] Moving to al-

36. Wei (1996) obtains very similar results from a gravity model making the Armington assumption that each country produces a unique set of commodities. He does not estimate the elasticity of substitution between goods from different countries, but picks a value of 10 as his base. As discussed, the Armington elasticity plays a role like our parameter θ. Hummels (2002) relates data on actual freight costs for goods imported by the United States and a small number of other countries to geographical variables. His finding of a 0.3 elasticity of cost with respect to distance is reflected, roughly, in our estimates here.

ternative values of θ affects the implied geographic barriers in the opposite direction. Even for our high value of θ, however, geographic barriers appear substantial.

Table 7. Geographic Barriers

Source of Barrier	Estimated Geography Parameter	Implied Barrier's % Effect on Cost θ=8.28	θ=3.60	θ=12.86
Distance [0, 375)	−3.10	45.39	136.51	27.25
Distance [375, 750)	−3.66	55.67	176.74	32.97
Distance [750, 1500)	−4.03	62.77	206.65	36.85
Distance [1500, 3000)	−4.22	66.44	222.75	38.82
Distance [3000, 6000)	−6.06	108.02	439.04	60.25
Distance [6000, maximum]	−6.56	120.82	518.43	66.54
Shared border	0.30	−3.51	−7.89	−2.27
Shared language	0.51	−5.99	−13.25	−3.90
European Community	0.04	−0.44	−1.02	−0.29
EFTA	0.54	−6.28	−13.85	−4.09
Destination country:				
Australia	0.24	−2.81	−6.35	−1.82
Austria	−1.68	22.46	59.37	13.94
Belgium	1.12	−12.65	−26.74	−8.34
Canada	0.69	−7.99	−17.42	−5.22
Denmark	−0.51	6.33	15.15	4.03
Finland	−1.33	17.49	44.88	10.94
France	0.22	−2.61	−5.90	−1.69
Germany	1.00	−11.39	−24.27	−7.49
Greece	−2.36	32.93	92.45	20.11
Italy	0.07	−0.86	−1.97	−0.56
Japan	1.59	−17.43	−35.62	−11.60
Netherlands	1.00	−11.42	−24.33	−7.51
New Zealand	0.07	−0.80	−1.83	−0.52
Norway	−1.00	12.85	32.06	8.10
Portugal	−1.21	15.69	39.82	9.84
Spain	−1.16	14.98	37.85	9.40
Sweden	−0.02	0.30	0.69	0.19
United Kingdom	0.81	−9.36	−20.23	−6.13
United States	2.46	−25.70	−49.49	−17.40

Note: The estimated parameters governing geographic barriers are the same as those shown in Table 3. For an estimated parameter $\hat{d}$, the implied percentage effect on cost is 100 $(e^{-\hat{d}/\theta}-1)$.

Our simple method-of-moments estimator of θ = 8.28 from Section 3 lies very much in the middle of the range of estimates we obtain from our alternative approaches, θ = 3.60 using wage data and θ = 12.86 using price data. Hence, except where noted, we use it (and the consequent values of T_i and d_{ni}) in the analysis that follows.[37]

6. Counterfactuals

The estimation presented in Section 5 provides parameter values that allow us to quantify the full model, enabling us to pursue an analysis of counterfactuals. Given that the model is highly stylized (we have, for example, suppressed heterogeneity in geographic barriers across manufacturing goods), these counterfactuals should not be seen as definitive policy analysis. But regardless of how indicative they are of actual magnitudes, they do provide insight into the workings of the model.

To complete the parameterization we calculate $\alpha = 0.13$, the average demand for final manufactures as a fraction of GDP.[38] Table 8 summarizes the structural parameters of the model, their definitions, the values we assign to them, and where we got these numbers.

Table 8. Summary of Parameters

Parameter	Definition	Value	Source
θ	comprative advantage	8.28(3.60,12.86)	Section 3(Section 5.2, Section5.3)
α	manufactuing share	0.13	production and trade data
β	labor share in costs	0.21	wage costs in gross output
T_i	states of technology	Table 6	source effects stripped of wages
d_{ni}	geographic barriers	Table 7	geographic proxies adjusted for θ

We can examine counterfactuals according to a number of different criteria. One is overall welfare in country n, measured as real GDP: $W_n = Y_n/p_n^{\alpha}$. (Since nonmanufactures are numeraire, the price level in

37. Our estimates of θ, obtained from different data using different methodologies, differ substantially. Nonetheless, they are in the range of Armington elasticities for imports used in computable general equilibrium models. See, for example, Hertel (1997).

38. Specifically we solve for α from the relationship

$$X_{nn} + IMP_n = (1-\beta)(X_{nn} + EXP_n) + \alpha Y_n,$$

summed across our sample (with β = .21) in 1990. Here IMP_n is manufacturing imports and EXP_n is manufacturing exports, and Y_n is total GDP, each translated from local currency values into U.S. dollars at the official exchange rate.

country n is p_n^{α}. Since we hold labor supplies and populations fixed throughout, there is no need to distinguish between GDP and GDP per worker or GDP per capita.) Decomposing the change in welfare into income and price effects gives

$$\ln \frac{W_n'}{W_n} = \ln \frac{Y_n'}{Y_n} - \alpha \ln \frac{p_n'}{p_n} \approx \left(\frac{w_n' - w_n}{w_n} \right) \frac{w_n L_n}{Y_n} - \alpha \ln \frac{p_n'}{p_n}.$$

(Here x'_n denotes the counterfactual value of a variable x_n.) In the case of mobile labor, of course, only the price effect is operative. Aside from looking at welfare, for the case of mobile labor, we ask about manufacturing employment while, for the case of immobile labor, we look at the manufacturing wage w_n. We also investigate how trade patterns change.

Since we have data on both manufacturing employment and manufacturing wages, we can look at our model's implications for each given data on the other. Our fit is not perfect since we (i) impose a common manufacturing demand share α across countries and (ii) ignore sources of manufactures from outside our sample of 19 OECD countries.

We wish to distinguish the effects of any of the counterfactuals we examine in the next section from the initial misfit of our model. We therefore compare the various counterfactuals that we examine with a baseline in which wages are calculated to be consistent with equations (16), (17), and (20), given actual manufacturing employment and GDP. Comparing these baseline wages with actual data the root mean square error is 5.0 percent.[39]

In performing counterfactuals we proceed as follows: With mobile labor we treat total GDP and wages as fixed. We set GDPs to their actual levels and wages to the baseline. With immobile labor we treat nonmanufacturing GDP and manufacturing employment as fixed. We set manufacturing employment to its actual level and nonmanufacturing GDP to actual GDP less the baseline value for labor income in manufacturing (actual employment times the baseline wage).

6.1. The Gains from Trade

We first consider the effects of raising geographic barriers to their autarky levels ($d_{ni} \rightarrow \infty$ for $n \neq i$). We then perform what turns out to be the more extreme exercise of asking what would happen in a zero-gravity

39. Our model overstates the Canadian wage by 21 percent, but otherwise predictions are quite close. With our estimated parameters, Equation (30) predicts much more trade between Canada and the United States than actually occurs. Since U.S. purchases loom large in Canada, its labor market equilibrium condition (18) implies more demand for Canadian manufacturing labor than there really is.

world with no geographic barriers (with all $d_{ni} = 1$).[40]

Table 9 shows what happens in a move to autarky for each of our 19 countries. The first column reports the welfare loss in the case of mobile labor. The costs of moving to autarky range from one quarter of a percent for Japan up to ten percent for Belgium.[41] While these costs appear modest, it should be remembered that they reflect the effects of shutting down trade only in *manufactures* and hence understate the loss from not trading

Table 9. The Gains from Trade: Raising Geographic Barriers

Country	Percentage Change from Baseline to Autarky					
	Mobile Labor			Immobile Labor		
	Welfare	Mfg. Prices	Mfg. Labor	Welfare	Mfg. Prices	Mfg. Wages
Australia	−1.5	11.1	48.7	−3.0	65.6	54.5
Austria	−3.2	24.1	3.9	−3.3	28.6	4.5
Belgium	−10.3	76.0	2.8	−10.3	79.2	3.2
Canada	−6.5	48.4	6.6	−6.6	55.9	7.6
Denmark	−5.5	40.5	16.3	−5.6	59.1	18.6
Finland	−2.4	18.1	8.5	−2.5	27.9	9.7
France	−2.5	18.2	8.6	−2.5	28.0	9.8
Germany	−1.7	12.8	−38.7	−3.1	−33.6	−46.3
Greece	−3.2	24.1	84.9	−7.3	117.5	93.4
Italy	−1.7	12.7	7.3	−1.7	21.1	8.4
Japan	−0.2	1.6	−8.6	−0.3	−8.4	−10.0
Netherlands	−8.7	64.2	18.4	−8.9	85.2	21.0
New Zealand	−2.9	21.2	36.8	−3.8	62.7	41.4
Norway	−4.3	32.1	41.1	−5.4	78.3	46.2
Portugal	−3.4	25.3	25.1	−3.9	53.8	28.4
Spain	−1.4	10.4	19.8	−1.7	32.9	22.5
Sweden	−3.2	23.6	−3.7	−3.2	19.3	−4.3
United Kingdom	−2.6	19.2	−6.0	−2.6	12.3	−6.9
United States	−0.8	6.3	8.1	−0.9	15.5	9.3

Note: All percentage changes are calculated as $100\ln(x'/x)$ where x' is the outcome under autarky yatarky ($d_{ni} \to \infty$ for $n \neq i$) and x is the outcome in the baseline.

40. For simplicity, we ignore any tariff revenues that geographic barriers might generate. We consider the effect of reducing tariff barriers, taking revenue effects into account, in Section 6.4 below.

41. In the mobile labor case (with total GDP and the manufacturing wage fixed) the only welfare effect is from the decline in the manufacturing price level, which affects welfare with an elasticity α. As a consequence we can use expression (15) to obtain a simple analytic formula for the welfare effect of moving to autarky:

$$\ln \frac{W_n'}{W_n} = \frac{\alpha}{\theta\beta} \ln \pi_{nn}.$$

It follows that the gains from trade vary inversely with θ. The implied gains from trade more than double, for example, using our lower estimate of $\theta = 3.60$.

at all.[42] Manufacturing labor, shown in column three, rises everywhere except in Germany, Japan, Sweden, and the United Kingdom. That manufacturing employment shrinks in these four when trade is shut down could be seen as indicating their overall comparative advantage in manufactures.

The remaining columns consider the effects of moving to autarky with immobile labor. Column four reports the welfare loss. The effect on welfare is more negative than when labor is mobile, but usually only slightly so.

The net welfare effects mask larger changes in prices and incomes. In all but the four "natural manufacturers" (Germany, Japan, Sweden, the United Kingdom), the price rise is greater when manufacturing labor is immobile. (In Germany and Japan manufacturing prices actually fall.) But these greater price changes lead to only slightly larger effects on welfare because they are mitigated by wage changes (reported in column six): The wage in manufacturing rises in all but the four "natural manufacturers."[43]

Three of the four countries we have identified as "natural manufacturers," where manufacturing shrinks in moving to autarky, are quite large. A question is whether these countries' manufacturing prowess results from their state of technology relative to the cost of labor, or because of their size and location. In the first case a total elimination of geographic barriers would continue to favor these countries. In the second the elimination of geographic barriers would remove their advantage. Table 10 shows, in its first three columns, what our model says would happen in a zero-gravity world (setting all $d_{ni} = 1$). Looking at manufacturing employment in the case of mobile labor (column three), Germany and Japan experience large drops while Sweden continues to gain. Little happens in the United Kingdom. At the same time smaller, peripheral countries all experience expansion.

Our welfare measure indicates that we are very far from a world of zero gravity. Furthermore, world trade would be about five times its current

42. Since most trade is in manufactures, we could try to argue that we have captured most of the gains from trade. But trade volume may be a poor indicator of the gains from trade in other sectors relative to manufacturing. Since productivity in agriculture or mining is likely to be much more heterogeneous across countries, applying our model to trade in these goods could well deliver a much lower value of θ. An implication is that eliminating what trade does occur would inflict much more damage.

43. How much labor force immobility exacerbates the damage inflicted by autarky depends on the extent of specialization in manufacturing. A move to autarky raises the manufacturing wage the most in Greece, with the smallest manufacturing share. But since its share of manufacturing labor income (reported in Table 1) is so small, the overall welfare effect is swamped by the large increase in manufacturing prices. In Germany, with the largest manufacturing share, a move to autarky lowers the manufacturing wage. But since the share of manufacturing is so large, the welfare cost of this loss in income is not offset by the drop in manufacturing prices. For countries that are less specialized (in or away from manufactures), labor mobility makes less difference for overall welfare.

level in such a world. The last three columns of Table 10 report an experiment closer to reality: What happens if geographic barriers fall to 69 percent of their baseline levels across the board, leading to a doubling of world trade?[44] Welfare rises by 1 to 3 percent as the price of manufactures falls by 10 to 20 percent. These effects are of the same order of magnitude as the costs of moving to autarky, but with less variation around the mean. We already see the United States and Japan losing their size-based edge in manufactures from this more modest drop in geographic barriers, while manufacturing in most small countries rises.

Table 10. The Gains from Trade: Lowering Geographic Barriers

Country	Percentage Changes in the Case of Mobile Labor					
	Baseline to Zero Gravity			Baseline to Doubled Trade		
	Welfare	Mfg. Prices	Mfg. Labor	Welfare	Mfg. Prices	Mfg. Labor
Australia	21.1	−156.7	153.2	2.3	−17.1	−16.8
Austria	21.6	−160.3	141.5	2.8	−20.9	41.1
Belgium	18.5	−137.2	69.6	2.5	−18.6	68.8
Canada	18.7	−139.0	11.4	1.9	−14.3	3.9
Denmark	20.7	−153.9	156.9	2.9	−21.5	72.6
Finland	21.7	−160.7	172.1	2.8	−20.9	44.3
France	18.7	−138.3	−7.0	2.3	−16.8	15.5
Germany	17.3	−128.7	−50.4	1.9	−14.3	12.9
Greece	24.1	−178.6	256.5	3.3	−24.8	29.6
Italy	18.9	−140.3	6.8	2.2	−16.1	5.7
Japan	16.6	−123.5	−59.8	0.9	−6.7	−24.4
Netherlands	18.5	−137.6	67.3	2.5	−18.5	65.6
New Zealand	22.2	−164.4	301.4	2.8	−20.5	50.2
Norway	21.7	−161.0	195.2	3.1	−22.9	69.3
Portugal	22.3	−165.3	237.4	3.1	−22.8	67.3
Spain	20.9	−155.0	77.5	2.4	−18.0	−4.4
Sweden	20.0	−148.3	118.8	2.7	−19.7	55.4
United Kingdom	18.2	−134.8	3.3	2.2	−16.4	28.5
United States	16.1	−119.1	−105.1	1.2	−9.0	−26.2

Note: All percentage changes are calculated as 100ln (x'/x) where x' is the outcome under lower geographic barriers and x is the outcome in the baseline.

6.2. Technology vs. Geography

Our discussion of the gains from trade has already brought up the question, raised in the economic geography literature, of the roles of geography and technology in determining specialization. To allow specialization to vary, we consider the case in which labor is mobile. With zero gravity the fraction of a country's labor force devoted to manufacturing is then proportional to $(T_i/L_i)/w_i^{1+\theta\beta}$, so depends only on the state of technology per

44. We find an elasticity of trade volume with respect to overall geographic barriers of around 2 to 3.

worker and the wage. When geographic barriers are prohibitive the fraction is simply α, the share of manufactures in final demand, so that not even technology matters. But in neither case is geography relevant.

How do technology and geography compete in determining comparative advantage in between these extremes? Looking at what happens to the fraction of labor devoted to manufacturing as geographic barriers fall, two basic patterns emerge. For smaller countries manufacturing shrinks as geographic barriers diminish from their autarky level. Production shifts to larger countries where inputs are cheaper. As geographic barriers continue to fall, however, the forces of technology take over, and the fraction of the labor force in manufacturing grows' often exceeding its autarky level. The results for Denmark, depicted in Figure 3, illustrate this pattern nicely. For

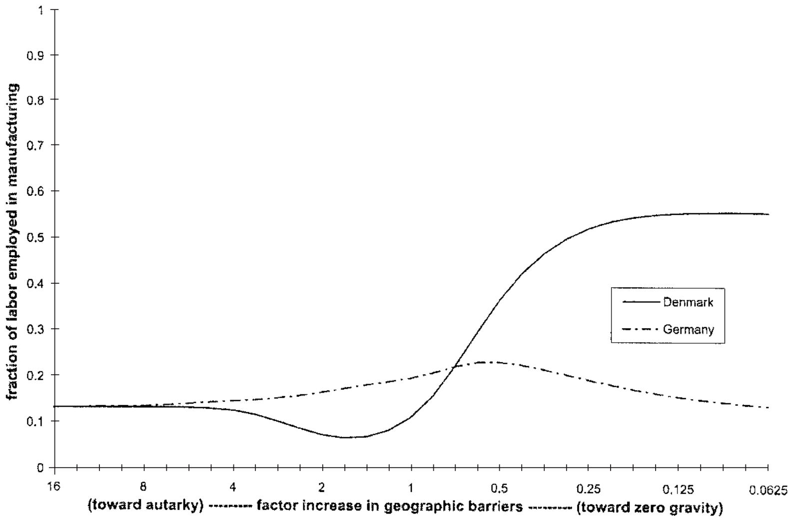

Figure 3. Specialization, Technology, and Geography

the largest countries in our sample, Germany, Japan, and the United States, the pattern is reversed. Their manufacturing sector at first grows and then shrinks as geographic barriers fall. Germany, also depicted in Figure 3, illustrates the pattern most starkly.

Extant geographic barriers place the world near a transition between one where the effects of geography dominate and one where technology governs comparative advantage. The results suggest a decline in barriers would lead to specialization more along Ricardian lines, with large countries starting to lose their edge.[45]

6.3. The Benefits of Foreign Technology

With geographic barriers as high as they are, how much does trade spread the benefit of a local improvement in technology? We increase the state of technology T_i by 20 percent, first for the United States and then for Germany. Table 11 reports what happens to welfare in different countries of the world as a percentage of the effect locally. Other countries always gain through lower prices. With labor mobile there is no additional income effect, so the net welfare effect is always positive. When labor is

Table 11. The Benefits of Foreign Technology

Country	Welfere Consequences of Improved Technology			
	Higher U.S. State of Technology		Higher German State of Technology	
	Mobile Labor	Immobile Labor	Mobile Labor	Immobile Labor
Australia	27.1	14.9	12.3	4.4
Austria	9.3	2.9	61.8	5.4
Belgium	13.2	3.0	50.7	4.8
Canada	87.4	19.9	9.3	1.3
Denmark	12.2	6.2	62.5	7.1
Finland	11.3	4.3	37.5	3.0
France	10.1	4.2	39.2	3.0
Germany	9.7	−11.6	100.0	100.0
Greece	14.0	18.3	38.9	8.0
Italy	9.7	3.9	38.4	3.0
Japan	6.6	−0.8	5.9	−0.2
Netherlands	12.8	6.8	63.5	8.3
New Zealand	33.8	13.5	15.6	3.9
Norway	13.2	11.7	43.8	6.1
Portugal	14.3	8.6	39.6	4.7
Spain	9.6	7.0	27.3	3.3
Sweden	12.8	1.1	42.7	2.3
United Kingdom	14.6	0.5	38.3	1.6
United States	100.0	100.0	9.7	1.4

Note: All numbers are expressed relative to the percentage welfare gain in the country whose technology expands. Based on a counterfactual 20 percent increase in the state of technology for either the United States or Germany.

45. Whether a further decline in geographic barriers (defined in the iceberg sense here) is in the works is an open question. Recent increases in trade volumes relative to output may have created a perception that technical progress in communication and transport is feeding an inexorable trend toward lower geographic barriers. Our model illustrates how, in order to increase trade, the rate of progress in international transactions must *exceed* that in production. A proportional increase in all states of technology T_i has no effect on trade shares. The reason is that technical progress implies a proportional reduction in the cost of delivering goods to any destination, whether at home or abroad, so does not affect the margin at which goods are imported or produced locally.

immobile, foreign countries also experience a negative income effect through lower wages in manufacturing. Hence the overall welfare effect is generally lower when countries cannot downsize their manufacturing labor forces.[46] Germany and Japan, with large manufacturing shares, actually suffer welfare losses in response to technological improvements elsewhere.

The percentage benefits decay dramatically with distance and size. With labor mobile the gain in nearby countries approaches that where the improvement occurred. Canada, for example, benefits almost as much as the United States from a U.S. technological improvement. Germany's smaller neighbors experience more than half the gain from an improvement in German technology as Germany itself. At the other extreme, Japan, which is both distant and large, gets little from either Germany or the United States.

The results point to the conclusion that trade does allow a country to benefit from foreign technological advances. But for big benefits two conditions must be met. First, the country must be near the source of the advance. Second, the country needs to be able to reallocate its labor to activities outside of manufacturing.

6.4. Eliminating Tariffs

In our analysis so far we have ignored, for simplicity, any revenues generated by geographic barriers, treating them as entirely natural. Our framework can, however, readily incorporate revenue-generating barriers. We assume that country n's imports from country i are subject to an *ad valorerm* tariff t_{ni} (on the c.i.f. price). Geographic barriers then decompose into their tariff $1 + t_{ni}$ and natural d^*_{ni} components, so that $d_{ni} = (1+t_{ni})\, d^*_{ni}$. We augment income Y_n by tariff revenue TR_n, where

$$TR_n = \sum_{i \neq n} \frac{t_{ni}}{1 + t_{ni}} X_{ni}.$$

We calculate a baseline world in which countries impose a uniform 5 percent tariff on all imports.[47] We then ask what happens when: (i) all countries remove tariffs, (ii) the United States removes its tariff unilaterally, and (iii) members of the European Community (as of 1990) drop tariffs against each other.

46. The exception is Greece. In the case of immobile labor the added benefit of lower wages in suppliers nearby more than offsets the reduction in the wages earned by its own small fraction of workers in manufacturing.

47. This figure corresponds roughly to average statutory rates among the OECD. See, e.g., Hertel (1997).

6.4.1. General Multilateral Tariff Elimination

Welfare rises almost everywhere if all 19 countries collectively remove tariffs. The benefits are substantially greater with mobile labor, varying from a high of 1.31 percent for Belgium to a low of 0.21 percent for Japan, with most countries gaining around one percent. With immobile labor the gains never exceed half a percent. Germany actually experiences a 0.05 percent loss (losing more in tariff revenue than its gain from lower prices and a slightly higher wage in manufacturing).

6.4.2. U.S. Unilateral Tariff Elimination

If the United States removes tariffs on its own, everyone benefits except the United States, which, for standard optimal tariff reasons, suffers a welfare loss of 0.005 percent with mobile labor (0.13 percent with immobile labor). The biggest winner is Canada, which enjoys a welfare gain of 0.5 percent with mobile labor (1.1 percent with immobile labor).

With mobile labor, the percentage gains for other countries roughly equal or exceed the U.S. loss. The results point to the importance of pursuing freer trade multilaterally, since the benefits to the rest of the world of U.S. liberalization far exceed the cost to the United States.

6.4.3. Trade Diversion in the European Community

Table 12 reports some effects of eliminating tariffs within the 1990 European Community. Who gains and who loses depends very much on the mobility of labor. As the second column reports, with immobile labor the major losers are nonmembers nearby, whose manufacturing wages must fall in order for them to remain competitive suppliers to the EC. Members of the EC consequently benefit from lower external prices and a greater premium placed on their own manufacturing workers.

With mobile labor, however, the losers (as reported in the first column) are the northern EC members. In this scenario workers in nonmember states move to other activities rather than suffer wage cuts. Northern EC members divert imports from these nonmember states to less efficient southern EC sources.

Note from the third and fourth columns that with market integration, intra-EC trade expands substantially, especially when labor is mobile. Moreover, in the mobile labor case, EC market share elsewhere generally expands: By making inputs cheaper, market integration provides EC countries a cost advantage outside.

Table 12. The European Community: Welfare and Trade

Country	Effect of Removing a all Tariffs on Intra-EC Trade			
	Aggregate Welfare		Imports the EC	
	Mobile Labor	Immobile Labor	Mobile Labor	Immobile Labor
Australia	0.13	0.11	27.7	2.8
Austria	0.32	−0.07	−1.9	−3.4
Belgium*	−0.91	0.54	61.3	26.3
Canada	0.01	0.01	28.0	2.2
Denmark*	−0.27	0.18	49.9	30.8
Finland	0.28	−0.02	4.6	−2.9
France*	0.08	0.05	46.3	33.7
Germany*	−0.03	−0.03	58.5	41.9
Greece*	0.28	0.13	30.8	24.0
Italy*	0.14	0.04	44.9	36.4
Japan	0.07	−0.01	32.4	2.3
Netherlands*	−0.58	0.33	56.3	26.9
New Zealand	0.14	0.09	24.1	1.9
Norway	0.34	0.05	3.2	−2.9
Portugal*	0.03	0.10	44.0	32.8
Spain*	0.21	0.05	43.7	34.3
Sweden	0.31	−0.10	2.0	−3.3
United Kingdom*	−0.02	0.02	51.9	36.1
United States	0.10	0.03	27.8	2.2

Note: All numbers are percentage changes from the baseline. In the baseline all trade is subject to a 5 percent tariff. The counterfactual is to remove tariffs between members (as of 1990) of the EC (appearing with a*). Each pair of columns shows the results of peforming the counterfactual first for the case of mobile labor and then for the case of immobile labor.

7. Conclusion

Comparative advantage creates potential gains from trade. The extent to which these gains are realized, however, is attenuated by the resistance imposed by geographic barriers. We have developed a Ricardian model that captures these two forces quite parsimoniously. The model delivers equations relating bilateral trade around the world to parameters of technology and geography. We use data on bilateral trade flows, prices, and geography to estimate the parameters.

While the gravity literature has recognized the importance of geographic barriers in curtailing trade flows, formal models of international trade have typically ignored them. The exceptions are models in which specialization is preordained by product differentiation, via either the Armington assumption or monopolistic competition. In contrast, our framework allows geographic barriers as well as technology to determine specialization. It also connects trade flows to the deviations from the law of one price that geographic barriers generate.

A Data Appendix

Our analysis uses data for manufacturing in 1990 for the 19 OECD countries listed in Table 1.

A.1. Trade Data

Our dependent variables are transformations (discussed in the text) of bilateral manufacturing imports. Country *i*'s imports from home are gross manufacturing production less manufacturing exports. Its total manufacturing expenditures are home purchases plus imports from everywhere else. These measures are reported by the STAN database in local currencies (OECD, 1995). We calculate imports from each of the other 18 countries, as a fraction of total manufactured imports, based on the United Nations-Statistics Canada bilateral merchandise trade data by 4-digit SITC, as described in Feenstra, Lipsey, and Bowen (1997).[48] All import measures are c.i.f. Since our dependent variables normalize imports either by home sales or by total expenditures, no exchange rate translation is required.

The first column of Table 1 shows that imports typically represent less than half of spending on manufactures, the exceptions being Belgium, the Netherlands, and Denmark. The second column shows that most of the imports of our sample of 19 OECD countries are purchased from one of the other 18 countries in the sample.

A.2. Price Data

Prices in 1990 for over 100 GDP categories in each of our 19 countries are from World Bank (1993). We use the 50 items identified by Hooper and Vrankovich (1995) as corresponding to either: (i) textile, apparel, and leather products, (ii) machinery, equipment, and fabricated metal products, or (iii) other manufactured products. We dropped the many items related to food and chemicals since we thought their prices would be unduly influenced by proximity to natural resources and taxes on petroleum products, two factors absent from our model.

A.3. Proxies for Geographic Barriers

Distances between countries serve as a determinant of geographic barriers. The distances are in thousands of miles measured between central cities in each country. (A list of the cities is in Eaton and Tamura, 1994.)

48. We used the concordance of Maskus (1991) to determine those SITC codes corresponding to manufactures. Using the concordance in Feenstra, Lipsey, and Bowen made virtually no difference.

Language groups are: (i) English (Australia, Canada, New Zealand, United Kingdom, United States), (ii) French (Belgium and France), and (iii) German (Austria and Germany).

A.4. Manufacturing Employment and Wages

Since we use the model itself to solve for the price of intermediates, the only input costs entering our empirical trade equations are manufacturing wages. Annual compensation per worker in manufacturing (which includes employers' compulsory pension and medical payments) is reported by the OECD (1995) in local currency. We translate into U.S. dollars at the current exchange rates to obtain measured compensation $comp_i$, reported in the third column of Table 1.[49] We then adjust by worker quality, setting $w_i = (comp_i)e^{-gH_i}$, where H_i is average years of schooling and g is the return to education. Column four of Table 1 reports the human-capital adjusted wage (human-capital adjusted manufacturing employment is shown in column five). We set $g = .06$, which Bils and Klenow (2000) suggest is a conservative estimate. Years of schooling is from Kyriacou (1991), as shown in Table 4.

A.5. Aggregate Income

In our counterfactuals we require total income in 1990. We use local-currency GDP in 1990 (from OECD (1997)) translated into U.S. dollars at the 1990 exchange rate. The last column of Table 1 shows manufacturing labor income as a percentage of total income.

A.6. Data for Alternative Parameters

Table 4 shows the data used to pursue our alternative estimate of θ, as described in Section 5.2. The first column shows stocks of research R_i for each country, from Coe and Helpman (1995). They use the perpetual inventory method (assuming a depreciation rate of five percent) to add up real R&D investment by business enterprises. The second column shows the human capital measure H_i, for which we use average years of schooling in 1985 from Kyriacou (1991).

We use two variables to instrument for wage costs. The first is aggregate workforce $work_i$, from Summers and Heston (1991, version 5.6), shown in the third column of Table 4. As with wages, we adjust for education setting $L_i = (work_i)e^{gH_i}$. The second instrument is density, defined as the aggregate workforce divided by a country's land area, shown in the last column of Table 4.

49. We used the official rather than the purchasing power exchange rate since it determines differences in costs of production. In our model, differences in purchasing power arise endogenously.

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13 Bilateral Trade Patterns and Welfare: An Egypt-EU Preferential Trade Agreement

Denise Konan and Keith Maskus*

1. Introduction

In recent years, computable general equilibrium (CGE) models have been used to analyze the impact of preferential trade liberalization for several countries. A standard approach is to rely on a model of a single, price-taking country where goods are differentiated by region of production and consumption follows the Armington assumption. An important parameter in determining the welfare implications of preferential trading arrangements (PTAs) is the pre-liberalization volume share of trade with the proposed partner. Yet, conventional theory has not examined the role of trade shares in this typical CGE modeling framework. This paper examines the role of the volume of partner country trade in determining the outcome of a PTA in a small-country CGE model where products are differentiated on a regional basis.

The traditional approach is characterized in Lipsey's (1970) model where a PTA between countries that already trade in large volumes with one another is less likely to be trade-diverting as the potential partner is already a low-cost supplier of the imported good. In contrast, the models of Panagariya (1996), Bhagwati and Panagariya (1996) and Schiff (1996) show that if a country is large (that is, able to influence the terms of trade) relative to the potential partner but is a small price taker in the rest of the world, then the smaller is the initial partner import share the lower are trade diversion (and overall) losses. In a partial-equilibrium, differentiated

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products model, Konan and Maskus (2000a), we show that an ambiguous relation exists between trade shares and gains from a PTA. For small levels of initial partner trade share, increases in that share are negatively related with welfare gains from a PTA. When initial trade volumes with the partner are relatively high, a positive relation exists between partner trade share and welfare gains.

The Bhagwati and Panagariya result relies on two key assumptions: that tradable products are homogeneous and that the domestic offer curve has finite elasticity. As de Melo and Robinson (1989) explained, however, this framework is not satisfying for single-country CGE model for several reasons. First, the homogeneity assumption is not consistent with the two-way trade, which is generally observed in aggregated trade statistics. Second, homogeneity implies that small price changes from liberalization lead to extreme and unrealistic specialization in production when products are not differentiated. Third, especially for most developing countries, it is reasonable to assume that international terms of trade will not be significantly influenced by domestic trade reform. De Melo and Robinson have shown that the assumption of a price-taking, general equilibrium economy is theoretically consistent with that of product differentiation by region (the Armington assumption) when multi-sector models are not heavily disaggregated.

To illustrate these issues, we employ a CGE model of Egypt.[1] The European Union (EU) is in the process of negotiating bilateral Euro-Mediterranean Agreements (EMAs) with several nations of the Middle East and North Africa (MENA) region (Hoekman and Djankov (1996)). The EU has already reached agreements with Turkey and Tunisia. The case of Egypt is particularly interesting as its trading pattern is much less focused on the EU than are those of some of its African neighbors. In this paper we consider the potential for Egypt to gain from participation in the EMA initiative and the importance of Egypt's share of trade with the EU in determining such gain. Given actual Egyptian trade patterns, the direct trade impact of an EMA is negative. Welfare may rise overall as trade liberalization interacts with the domestic tax structure to enhance efficiency, a process that we describe in detail in a companion paper (Konan and Maskus (2000b)).

2. Trade Creation and Trade Diversion with Differentiated Products

We extend the Vousden (1990, chapters 9 and 10) model of a small country to demonstrate the importance of partner trade shares.[2] While simple in dimension, this model provides our basic definitions and analytical

1. Our CGE model of Egyptian trade liberalization is established in the literature (Hoekman and Konan (2000), Hoekman, Konan, and Maskus (1998), Konan and Maskus (1997, 2000b), Maskus and Konan (1997)).

2. See also Harrison, et al. (1993).

results. It also illustrates important features of the more complicated CGE model that is described in the next section.

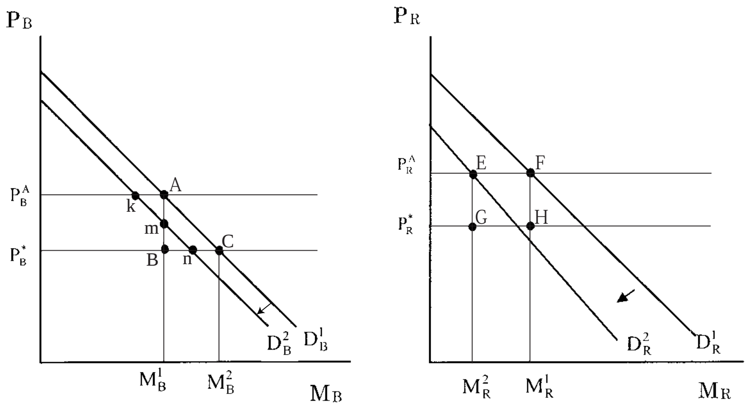

Figure 1. Import Markets

Assume that a small country (A) trades with two regions, a potential partner (B) and the rest of the world (R). Country A's importable goods are differentiated by region of origin, with imports labeled M_B and M_R. These imports are imperfect substitutes and are purchased at exogenous prices. Initially, suppose that imports face no domestic competition. The basic implications of a PTA with B are illustrated in Figure 1. At an initial non-discriminatory *ad valorem* tariff of $t = (P_i^A / P_i^* - 1)$ within a sector i, country A imports quantities M_B^1 and M_R^1. Suppose that A moves to a PTA that eliminates the tariff on B but maintains the tariff on ROW. Consumer surplus in A's market for the B good increases by the area $P_B^A ACP_B^*$ while tariff revenues fall by $P_B^A ABP_B$, resulting in a net welfare gain of area ABC, which may be defined as import trade creation. However, because imports from B and ROW are imperfect substitutes, the fall in the price of the B good engenders a fall in country A's demand for M_R, shown as a shift in Hicksian demand from D_R^1 to D_R^2. The revenue loss of area $EFGH$ may be defined as import trade diversion.

The net welfare effect in the import market, measured as the area ABC-$EFGH$, depends on three key parameters: the own-price elasticity of compensated demand for M_B, the elasticity of substitution between B and ROW imports, and the share of total import expenditures originating from B initially.

The import analysis is complicated when there is substitutability in consumption between imports and a domestically produced good. The fall in the price of country B's imports reduces the demand for (and the price of) A's substitute good. The demand for ROW imports declines also as the prices of B and A goods fall, represented by the shift from D_R^1 to D_R^2 in

Figure 1, resulting in trade-diversion welfare losses of area $EFGH$.[3] Demand for the B import also falls from D_B^1 to D_B^2 in response to the lower A and ROW prices. While consumer surplus increases by area $P_B^A knP_B^*$, tariff revenues on B imports fall by $P_B^A ABP_B^*$, resulting in an ambiguous change in welfare of area mBn minus area kAm. The greater is the elasticity of substitution between the domestic good and imports, the greater is the follow-on decline in import demand, the lower is trade creation, and the greater is trade diversion.

While the partner import share remains an important determinant of PTA effects, it is impossible to derive expressions for trade creation (TC) and trade diversion (TD) as closed-form functions of that parameter. Numerical simulations for a PTA between Egypt and the EU, reported later in the paper, reveal that both processes are concave and non-monotonic functions of EU's share of Egyptian imports. However, in this case economic welfare continuously increases in that share.

3. An Application Using a Computable General Equilibrium Model of Egypt

In this section we summarize our CGE model of a small country (Egypt) to demonstrate the importance of initial trade shares in the formation of a PTA. The basic framework extends the applied general equilibrium model developed by Maskus and Konan (1997).

We model Egypt as a small open economy (SOE) in which household and production decisions follow standard neoclassical assumptions of optimization. Of particular interest are the regional and sectoral aspects of Egypt's international trade. In the model, bilateral trade flows with the EU (including Turkey) and the rest of the world (ROW) are distinguished for each of 38 sectors (three in agriculture, two in mining and quarrying, 21 in manufacturing, and 12 in services).

Final demand by a representative agent (RA) is determined by a nested utility function for given prices and budget constraint.[4] In the first stage of the multi-level budgeting problem, the RA decides on aggregate purchases per sector according to a Cobb-Douglas subutility function. Given the first-stage allocation of income per sector, the RA decides how much to spend on domestic and imported goods of each sector according a CES subutility function. Egyptian importables in each sector are further differentiated by region of origin: the EU and ROW. These imports are imperfectly substitutable and are purchased at exogenous prices.

3. In general the shift in ROW demand would be different in this case than in the prior case but to avoid cluttering the diagram we use the same shift to depict both cases.

4. We assume that this demand structure also characterizes government consumption and investment spending.

Note that, computationally, Armington differentiation is not inconsistent with assuming Egypt faces fixed foreign prices. De Melo and Robinson (1989) demonstrated that the assumption of a price-taking, general equilibrium economy is theoretically consistent with that of product differentiation by region when multi-sector models are not extensively disaggregated. The Armington assumption implies that the components of a composite Egyptian vegetable product, for example, differ from those of the EU or ROW composite. Yet Egypt does not have price-setting power in the aggregate market for tomatoes. Moreover, to assume alternatively that goods are homogeneous would not be consistent with two-way trade, which is generally observed in aggregated trade statistics.

The model is static and requires two closure rules. First, to achieve saving-investment balance we assume that the aggregate capital stock is exogenously fixed at the benchmark level and financed by consumer savings that act as a lump-sum transfer. The interest rate of capital is endogenously determined by factor-demand conditions. Second, the current-account balance is exogenously fixed in real terms at its benchmark deficit level. As external prices are fixed, Egypt's real exchange rate, which we define as the shadow price of a foreign-currency index, will adjust to maintain the deficit as domestic prices and trade quantities vary.

Regarding the agent's budget constraint, she receives income from supplying the labor and capital endowments. Supplemental income is obtained through foreign borrowing via the current-account deficit. In addition to consumption, the agent must pay for government borrowing and investment. Domestic price indexes are CES aggregates across home prices and imported prices and are functions of producer prices, a consumption tax, and tariffs.

Production in each sector exhibits constant returns and requires production labor, non-production labor, capital, and intermediate inputs. Primary factors are assumed to be perfectly mobile across sectors but internationally immobile.[5] Firms maximize profits under perfectly competitive conditions. Intermediate goods and value added combine to produce final goods under a Leontief technology, with value added depending on labor and capital in a CES production function. The composite intermediate good is a CES aggregate of domestic and imported intermediates. Imported intermediates are further disaggregated into a CES nest of EU and ROW imports. Production costs depend on prices of factors and intermediate goods, tariffs and non-tariff barriers on intermediate inputs, and a tax on capital use. Production is sold into domestic and export markets using a constant elasticity of transformation (CET) nest, while exportables are further transformed into EU-bound and ROW-bound exports in a subsequent Arming-

5. Maskus and Konan (1997) also consider models with sector-specific capital in all sectors or selected resource-constrained sectors.

ton CET nest. Market-clearing conditions in each product and factor market are included.

As trade reform will directly alter tax collections, a detailed treatment of Egyptian public finance is critical. We assume that the public sector consumes a fixed bundle of goods and services evaluated at endogenous prices. The government maintains a fixed real budget deficit and endogenously adjusts domestic tax instruments to counteract the revenue effects of tariff reforms. The primary replacement tax mechanism is assumed to be a goods and service tax (GST) which acts as a sales tax on final consumption. In practice the government also taxes capital usage, with capital defined here as operating surplus less depreciation. Capital taxes vary substantially across sectors and these rates are held fixed in the counterfactual simulations.

To implement the model empirically, we develop an Egyptian data set consisting of a Social Accounting Matrix (SAM) and a variety of policy, trade, and technology parameters for the year 1990. Relationships for intermediate demand, final demand, and valued added are defined by the 1989/90 Input-Output (IO) table for Egypt (CAPMAS 1994a, b). To account for recent reform activities in Egypt we update policy parameters to a second benchmark year 1994. Thus, 1994 provides the benchmark for the ensuing simulations.

Major Egyptian import sectors include machinery, food processing, vegetable foodstuffs, and chemicals, while export flows are dominated by transportation (largely the Suez Canal), oil, and textiles. On a regional basis, Egypt provides an interesting case study as its trade structure is strongly diversified. According to 1994 trade data, less than half of all merchandise import and export trade is with the EU and these shares vary considerably across products. Egypt's trading relations are much less focused on the EU than are those of other North African countries, such as Morocco (Rutherford, Tarr and Rutström 1997). In the absence of regional data on services trade, we assume that the EU's initial shares are equivalent to its total merchandise import and export shares. Among the most important Egyptian production sectors are vegetable food products, animal products, food processing, trade, transport, social services, construction, and cotton textiles. Of these, services employ a disproportionate share of the labor force, while capital tends to be concentrated in agricultural sectors.

The IO Table is supplemented with data on government policy parameters. We apply effective rates of capital taxation calculated by the World Bank (1995) for 1990. There are no taxes levied on agriculture, an approximate 18% tax on manufactures (including mining and crude oil sectors), and approximately a 23% tax on services. By 1993 Egypt had phased in a goods and services tax and phased out indirect production taxes and most subsidies (World Bank, 1995). The GST is applied on the sales of goods and services, with rates that vary across industries. We treat the GST as a tax on domestic final demand (excluding government purchases).

Import-weighted tariff rates are computed from information on 1994 trade and tariff collections data by 8-digit Harmonized System classification. Currently, tariffs are levied on an MFN basis. We aggregate these tariff rates to the IO sectors by developing import weights consistent with a concordance constructed by the authors. Various tariff exemptions imply that Egypt does not collect full revenue on its legal tariff rates, forcing us to scale the weighted rates down by approximately 20% to be consistent with 1994 revenues. It is difficult to obtain information on trade barriers in Egyptian services. Conversations with Egyptian experts indicate that the service sector is largely closed to foreign competition. A conservative implicit service tariff rate of 15% is assumed in the benchmark.

There are no formal empirical estimates of various Egyptian elasticities of domestic substitution and transformation. A survey of previous Egyptian elasticity assumptions is provided by Lofgren (1994) and we select benchmark parameters consistent with his reported ranges. The elasticity of substitution between labor and capital is assumed to vary across sectors, as taken from Harrison et al. (1993). The various trade elasticities correspond to the central cases in Rutherford, Tarr and Rutström (1997). They include an Armington substitution elasticity between regional imports of 5.0 and between imported and domestic consumption of 2.0, and a transformation elasticity between regional exports of 8.0 and between domestic and exported output of 5.0.

4. Simulation Results

In this section we analyze various trade liberalization scenarios for Egypt: one MFN reform and two preferential trade agreements. The results of baseline counterfactual experiments are described. To illustrate the importance of initial bilateral trade shares with discriminatory tariff reform, we go on to perform detailed sensitivity analysis on trade shares.

4.1. Baseline Trade Liberalization Simulations

The baseline counterfactual experiments involve a set of trade liberalization exercises, the results of which are reported in Table 1. For comparison purposes, in Column (1) we report the results of a unilateral removal of all Egyptian tariffs, resulting in global free trade.[6] The EU is assumed to provide no additional market access. This policy generates estimated welfare gains (measured as Hicksian equivalent variation) of 0.81 percent over

6. Throughout the counterfactual simulations the beverage tariff is not changed to reflect Egypt's social policy for maintaining rigorous barriers on imported alcoholic beverages.

benchmark 1994 levels. The real exchange rate depreciates by 1.24 percent in order to maintain the benchmark current-account deficit. Tariff elimination requires an offsetting rise in the consumption tax (GST) rates of 24 percent to sustain real government revenues.

Two possible outcomes of an EU partnership agreement are reported in Columns (2) and (3). Scenario EU_AT considers an agreement whereby Egypt eliminates all tariffs on EU products while maintaining existing tariffs on ROW. The EU responds by providing improved access in agriculture and textiles and clothing. Based on the estimates of Harrison, et al. (1989), the benefit of inclusion in the EU's common agricultural policy and greater access under its quotas on textiles and clothing is approximated as an eight-percent price increase for Egyptian exports bound for the EU in these sectors.

Any PTA would result in trade creation and trade diversion. As in our earlier theoretical model, we compute import TC as the change in consumer surplus less tariff-revenue losses on imports arriving from the EU.[7] As Egypt also experiences an improvement in its terms of trade with the EU, the TC measure further includes the net increase in producer surplus for exporters to the EU. Trade diversion is computed as losses in tariff revenues on imports from ROW. The model estimates TC gains from this agreement of 500 million real Egyptian pounds and TD losses of 530 million pounds, implying a direct welfare loss of 30 million pounds. Thus, we find that the direct impact of this form of PTA would be negative for Egypt.

This direct measure of static welfare changes reflects the standard conception, in which TC and TD emerge against an idealized backdrop of an otherwise undistorted economy and no fiscal revenue target. However, other distortions exist in the Egyptian economy and interact with trade reform, while the government is constrained to offset changes in tariff revenues with altered tax rates. We find that in the context of this PTA, the Egyptian government could lower the GST by 3.4 percent while maintaining a fixed deficit, implying an added gain in welfare. That is, despite the preferential lowering of tariffs, there is a *reduction* in the GST as resources and consumption flow into higher-taxed sectors in general equilibrium. Overall, EU_AT provides a 0.14 percent static gain in welfare. The real exchange rate depreciates by 1.25 percent to maintain the benchmark current-account imbalance.

In the second preferential trade agreement scenario, EU_TOT, the EU offers the same concessions in textiles and agriculture described in EU_AT and, in addition, recognizes Egyptian inspection practices and production standards. We assume this generates a one-percent reduction in EU non-

7. Because preferences are homothetic, this measure is a monotonic transformation of Hicksian equivalent variation.

tariff barriers on Egyptian exports, yielding an equivalent improvement in Egyptian export prices across the board. Trade creation and trade diversion estimates are comparable to those observed in the EU_AT scenario, with a smaller net welfare loss. Accounting for tax neutrality, the overall welfare gains of 0.27 percent are double the gains available under the first case. The GST is reduced by 3.59% and the real exchange rate depreciates by 0.95 percent.

Table 1. Baseline Trade Liberalization Scenarios (% change)

	GLOBAL (1)	EU_AT (2)	EU_TOT (3)
CREATION*		0.50	0.51
DIVERSION*		0.53	0.52
NET WELFARE		−0.03	−0.01
EXCHANGE	1.24	1.25	0.95
GST	24.03	−3.39	−3.59
WELFARE	0.81	0.14	0.27

* Measured in billion Egyptian pounds (ELs).

SCENARIOS
EU_AT is a PTA with the EU in which Egypt eliminates all tariffs on EU imports. The EU provides improved access in agricultural goods and textiles and clothing, resulting in an eight-percent rise in those Egyptian export prices to the EU.
EU_TOT extends scenario EU_AT. Egypt eliminates all tariffs on EU imports. The EU provides more liberal access to domestic markets, resulting in a one-percent increase in all export prices to the EU, with an eight-percent price increase in agriculture and textiles.
GLOBAL involves unilateral tariff elimination by Egypt against all trading partners. The EU grants no concessions and export prices are unchanged.
VARIABLE ESTIMATES
CREATION is the real increase in GDP (in billion Egyptian pounds) due to trade creation.
DIVERSION is the real decrease in GDP (in billion Egyptian pounds) due to trade diversion.
NET WELFARE equals CREATION minus DIVERSION.
EXCHANGE is the percentage change in the real exchange rate, or shadow price of foreign currency, necessary to maintain the benchmark current account imbalance.
GST is the percentage change in the consumer tax (or GST) required for government revenue neutrality.
WELFARE is the percentage change in real benchmark 1994 GDP measured in equivalent variation.

4.2. Analysis of Different Bilateral Trade Shares

The preceding analysis was based on observed benchmark EU trade shares. Unlike the single-sector model in Section 2, these proportions vary across products, complicating the analysis of TC and TD as the aggregate EU trade shares change. To handle this problem, we simulate the impact of discriminatory trade reform under the supposition that Egypt's imports and exports are more or less concentrated with the EU than is actually observed. That is, a series of (fictitious) new benchmarks is created in which sectoral European trade flows are assumed to range from 50 percent of observed imports and exports to 150 percent of actual flows. Sectoral ROW trade flows are redefined as the residual of total imports (exports) less simulated EU imports (exports). Note that for trade multipliers exceeding one it is possible for simulated EU imports (exports) to exceed total imports (exports) in some sectors. Trade in these cases is characterized as a corner solution whereby all benchmark imports (exports) are assumed to originate in (be destined to) the EU and ROW trade flows are set to zero. The counterfactual experiments, EU_AT and EU_TOT, are run against this backdrop of contrived EU trade.

Consider the impact of the EU_AT tariff reform under the presumption that Egyptian trade flows with the EU are half the observed benchmark levels. The results (not shown) are an estimated 329 million Egyptian pounds in welfare gain from TC with the EU, while TD losses are approximately 483 million pounds. Thus, at our lowest partner trade shares, the net welfare loss is −154 million pounds, or five times that using the observed shares.

Trade creation, trade diversion, net welfare and welfare (including tax offsets) are graphed as functions of EU trade multipliers in Figure 2. Confirming our theoretical results, TC and TD are concave functions of partner trade shares. Focusing purely on the difference between TC and TD, the economy stands to suffer a fall in net welfare unless benchmark trade is approximately 1.11 times more heavily focused on the EU than that observed in our 1994 benchmark. Nonetheless, a *larger* simulated trade share with the EU appears to be associated with greater welfare gains (or smaller welfare losses).

As discussed above, aggregate welfare changes depend also on offsetting changes in tax rates for fiscal neutrality. Figure 2 also depicts aggregate change in welfare in response to the EU_AT trade agreement. Although they are highly correlated, aggregate welfare changes everywhere exceed direct welfare impacts, implying that TC and TD interact positively with endogenous domestic tax changes. The PTA generally results in an estimated rise in aggregate welfare except with small partner trade multipliers.

Similar results pertain with sensitivity analysis of trade shares in the EU _TOT case, as shown in Figure 3. Both TC and TD are concave with respect to the EU multiplier. Both net and aggregate welfare increase as the share of trade with the EU is scaled up. Direct welfare gains attributed directly to net trade creation are positive only for EU trade multipliers at or above about 1.07.

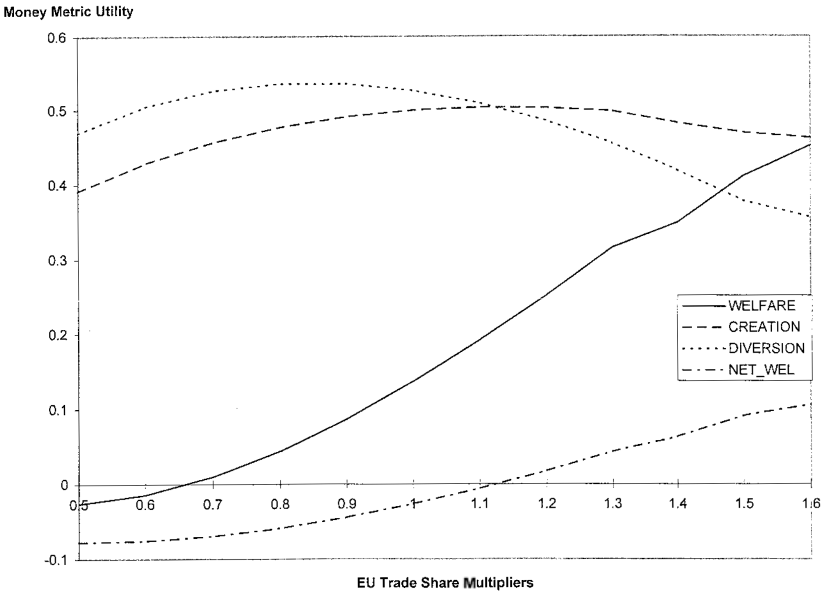

Figure 2. EU_AT Share Sensitivity Analysis

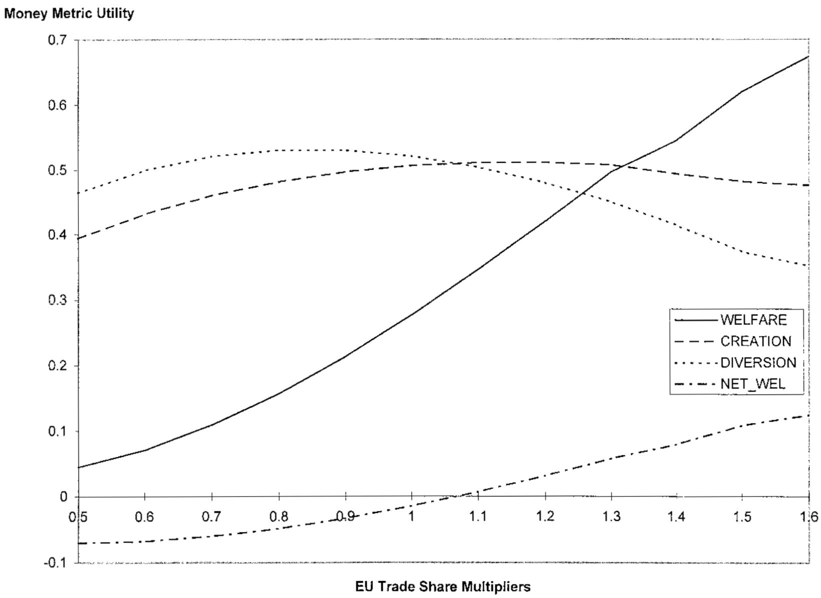

Figure 3. EU_TOT Share Sensitivity Analysis

5. Concluding Remarks

This paper considers the welfare implications of a discriminatory preferential trading arrangement in a general equilibrium model where imports are differentiated by region of origin and terms of trade are fixed. The relationship between the initial (pre-reform) relative volume of trade with the potential partner and welfare changes is theoretically ambiguous. Applied general equilibrium analysis of Egyptian trade illustrates the issues with regionally differentiated trade flows. Our simulations indicate that potential Egyptian welfare gains from a European PTA are modest. Experiments altering the composition of Egyptian trading patterns show that trade creation and diversion are non-monotonic, concave functions of the benchmark share of trade with the PTA partner. Nonetheless, aggregate welfare gains rise with the initial partner trade share. Thus, in the particular case considered here, the more focused Egypt's trade patterns are on the EU, the more the country would gain from a preferential trading arrangement.

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14 Is Free Trade Good for the Environment?

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and M. Scott Taylor*

The debate over the role international trade plays in determining environmental outcomes has at times generated more heat than light. Theoretical work has been successful in identifying a series of hypotheses linking openness to trade and environmental quality, but the empirical verification of these hypotheses has seriously lagged. Foremost among these is the pollution haven hypothesis that suggests relatively low-income developing countries will be made dirtier with trade. Its natural alternative, the simple factor endowment hypothesis, suggests that dirty capital-intensive processes will relocate to the relatively capital-abundant developed countries with trade. Empirical work by James A. Tobey (1990), Gene M. Grossman and Alan B. Krueger (1993), and Adam B. Jaffe et al. (1995) cast serious doubt on the strength of the simple pollution haven hypothesis because they find that trade flows are primarily determined by factor endowment considerations and apparently not by differences in pollution abatement costs. Does this mean that trade has no effect on the environment?

This paper investigates how "openness" to international markets affects pollution levels to assess the environmental consequences of international trade. We develop a theoretical model to divide trade's impact on pollution into scale, technique, and composition effects and then examine this theory using data on sulfur dioxide concentrations from the Global Environment

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Monitoring Project. The decomposition of trade's effect into scale, technique, and composition effects has proven useful in other contexts [see Grossman and Krueger (1993); Copeland and Taylor (1994, 1995)] and here we move one step forward to provide estimates of their magnitude.

We find that international trade creates relatively small changes in sulfur dioxide concentrations when it alters the composition, and hence the pollution intensity, of national output. Combining this result with our estimates of scale and technique effects yields a somewhat surprising conclusion: if trade liberalization raises GDP per person by 1 percent, then pollution concentrations fall by about 1 percent. Free trade is good for the environment.[1]

We obtain this conclusion by estimating a very simple model highlighting the interaction of factor endowments and income differences in determining the pattern of trade. Our approach, although relatively straightforward, is novel in four respects. First, by exploiting the panel structure of our data set, we are able to distinguish empirically between the negative environmental consequences of scalar increases in economic activity—the scale effect—and the positive environmental consequences of increases in income that call for cleaner production methods—the technique effect. This distinction is important for many reasons.[2] Grossman and Krueger (1993) interpret their hump-shaped "Kuznets curve" as reflecting the relative strength of scale versus technique effects, but they do not provide separate estimates of their magnitude. Our estimates indicate that a 1 percent increase in the scale of economic activity raises pollution concentrations by 0.25 to 0.5 percent for an average country in our sample, but the accompanying increase in income drives concentrations down by 1.25−1.5 percent via a technique effect.

Second, we devise a method for determining how trade-induced changes in the composition of output affect pollution concentrations. Many empirical studies include some measure of openness to capture the impact trade has in altering the composition (and hence the cleanliness) of national output, but there is very little reason to believe that openness affects the composition of output in all countries similarly. Both the pollution haven hypothesis and the factor endowment hypothesis predict that openness to trade will alter the composition of national output in a manner that depends on a nation's comparative advantage.

1. Free trade appears to lower sulfur dioxide concentrations for an average country in our sample, but may of course worsen the environment through other channels. Our evidence is specific to sulfur dioxide; however, sulfur dioxide emissions are highly correlated with other airborne emissions.

2. For example, income transfers across countries raise national income but not output, whereas foreign direct investment raises output more than national income. To evaluate the environmental consequences of either we need separate estimates of technique and scale effects.

For example, under the pollution haven hypothesis, poor countries get dirtier with trade, whereas rich countries get cleaner.[3] As a result, simply adding openness to trade as an additional explanatory variable for pollution (across a panel of both rich and poor countries) is unlikely to be fruitful. Instead we look for trade's effect by conditioning on country characteristics. We find that openness conditioned on country characteristics has a highly significant, but relatively small, impact on pollution.

Third, we show how to combine economic theory with our estimates of scale, composition, and technique effects to arrive at an assessment of the environmental impact of freer trade. Grossman and Krueger's influential study of NAFTA presented an argument based on the relative strength of these same three effects, but their estimate of the composition effect of trade was obtained from methods and data unrelated to their complementary work estimating the relative strength of scale and technique effects. Moreover, their evidence on composition effects was specific to the situation of Mexico. Here we estimate all three effects jointly on a data set that includes over 40 developed and developing countries.

Finally, our approach forces us to distinguish between the pollution consequences of income growth brought about by increased openness from those created by capital accumulation or technological progress. We find that income gains brought about by further trade or neutral technological progress tend to lower pollution, whereas income gains brought about by capital accumulation raise pollution. The key difference is that capital accumulation necessarily favors the production of pollution-intensive goods, whereas neutral technological progress and further trade do not. One immediate implication of this finding is that the pollution consequences of economic growth are dependent on the underlying source of growth.[4]

The theoretical literature on trade and the environment contains many papers in which pollution policy differences across countries drive pollution-intensive industries to countries with lax regulations.[5] One criticism of these papers is that, although they are successful in predicting trade patterns in a world where policy is fixed and unresponsive, their results may be a highly misleading guide to policy in a world where environmental protection responds endogenously to changing conditions.

Empirical work by Grossman and Krueger (1993) suggests that it is im-

3. That is, the composition effect of trade for poor countries makes them dirtier, whereas the composition effect for rich countries makes them cleaner. The full effect of trade may be positive even for poor countries, depending on the strength of the technique and scale effects. See, for example, Proposition 2.

4. Another more speculative implication of our results is that pollution concentrations should at first rise and then fall with increases in income per capita, if capital accumulation becomes a less important source of growth as development proceeds.

5. For example, Rüdiger Pethig (1976), Horst Siebert et al. (1980), and Martin C. McGuire (1982) all present models where the costs of pollution-intensive goods are lower in the region with no environmental policy.

portant to allow policy to change endogenously with income levels, and in our earlier work (Copeland and Taylor (1994, 1995)) we investigated how income-induced differences in pollution policy determine trade patterns. Although this earlier work produced several insights, it ignored the role factor abundance could play in determining trade patterns.

In contrast, the model we develop here allows income differences and factor abundance differences to jointly determine trade patterns. The model contains as one limiting case the canonical Heckscher-Ohlin-Samuelson (HOS) model of international trade and as another limiting case a simple pollution haven model. Considering these two motivations for trade is especially important in an empirical investigation because many of the most polluting industries are also highly capital intensive.[6] Moreover, it allows us to examine whether changes in dirty goods production brought about by trade is better explained by factor abundance motives or by pollution haven motives arising from an unequal distribution of world income.

The empirical literature in this area has progressed in three distinct ways. One influential group of studies asks: "How does economic growth affect the environment?". This literature was initiated by early work by Grossman and Krueger (1993, 1995) and has since produced a sizable and fast growing empirical literature examining what has come to be known as the "Environmental Kuznets curve."[7] Many of these studies also investigate the role of trade by adding a measure of openness as an additional regressor. The defining feature of this literature is its lack of explicit theory. Although the results from these studies are often interpreted within the context of scale, composition, and technique effects, they do not provide separate estimates of their magnitudes.

Our work is most closely related to this branch of the literature, but differs in that we employ an explicit theoretical model to guide our estimation; we present separate estimates of scale, composition, and technique elasticities; and we provide a methodology for adding up these effects to assess the environmental implications of freer trade. Despite the fact that this earlier work lacks a formal theory, some of their conclusions receive support in our work. Most notably, Grossman and Krueger's (1993) study of NAFTA had at its core the argument that technique effects offset scale effects—at least for Mexico—and that the composition effect created by further United States-Mexico trade was likely to be driven more by factor endowment considerations than by differences in environmental regulation. Our work supports these conclusions: *income effects appear to be eco-*

6. See Muthukumara Mani and David Wheeler (1997) and Werner Antweiler et al. (1998), Appendix Section B.l, for evidence linking capital intensity and pollution intensity.

7. Some authors refer to it as the Grossman-Krueger-Kuznets Curve. Other early contributions to this literature are Thomas M. Selden and Daqing Song (1994) and Nemat Shafik (1994).

nomically and statistically significant, and the trade-induced composition effects are not driven by differences in pollution regulations.

There is a second group of studies examining the link between the costs of pollution abatement cost and trade flows. This approach was pioneered by Tobey (1990) and was employed in the context of the NAFTA agreement by Grossman and Krueger (1993).[8] This branch of the literature asks a slightly different question: "How do environmental regulations affect trade flows?". Nevertheless some of their results are also relevant to our work. For example, a common result from these studies is that measures of environmental stringency have little effect on trade flows. This result immediately casts doubt on the pollution haven hypothesis, which holds that trade in dirty goods primarily responds to cross-country differences in regulations. Although our work is quite different in approach and method, we too find little support for the pollution haven hypothesis. We do not infer from this, however, that the cost of regulations does not matter to trade flows; instead, we suggest it is because other offsetting factors more than compensate for the costs of tight regulation in developed economies.

Finally, there are those studies that employ either the U.S. Toxic Release Inventory, U.S. emission intensity data, or simple rules to categorize goods industries as dirty or clean, to construct measures of the toxic (or pollution) intensity of production and trade flows. Work along these lines includes Patrick Low and Alexander Yeats (1992), Robert E. B. Lucas et al. (1992), and Mani and Wheeler (1997). The strength of this branch of the literature is its broad cross-country coverage; its weakness is that this coverage arises from the construction of data under various assumptions regarding the similarity of emission intensities across countries. This literature typically asks: "How has the pollution intensity of exports or production changed over time?" By comparing the answer to this question across countries differing in development level, income, or trade stance, the authors hope to identify links between various policy options, country characteristics, and environmental outcomes. Although this work is useful in documenting trends in the pollution intensity of output and trade, it cannot answer why these trends exist. Our work differs from this method by using theory to identify those factors we believe to be crucial to environmental outcomes, and by using regression analysis to hold all else equal when evaluating the links between country characteristics and environmental outcomes.

The overall impression one gets from this literature is that, even though there are many interesting findings, a consensus view does not exist—and the path to building such a consensus view is unclear. The unsettled nature of the literature arises, at least in part, because existing studies are ham-

8. Arik Levinson (1996) reviews this work.

strung by the lack of a well-defined theory. This naturally makes inference difficult. Additional difficulties arise because good data on pollution levels are scarce, and even the best data reflect not only anthropogenic influences but also the little-understood natural processes of dispersion and absorption. As a consequence, our simple first-generation pollution and trade model carries a heavy burden in providing us with the structure needed to isolate and identify the implications of international trade. Although this is a concern, we suggest that earlier empirical investigations failed to find a strong and convincing link between environmental outcomes and freer trade precisely because they lacked a strong theoretical under-pinning. With a more complete theoretical framework to guide us, we are able to look in the "right directions" for trade's effect. Moreover, our simple pollution demand-and-supply model may play a useful role in focusing future efforts in this area.

The rest of the paper is organized as follows. In Section 1 we develop a relatively simple general equilibrium model of trade to determine how a fall in trade barriers affects pollution levels. In Section 2 we then describe our strategy for dealing with econometric difficulties and present our estimating equation. In Section 3 we present our empirical results. Section 4 concludes. Appendices A and B contain proofs of propositions and a description of our data. An additional Technical Appendix, available on request from the authors, contains further supporting materials.

1. Theory

A. The Model

A population of N agents lives in a small open economy that produces two final goods, X and Y, with two primary factors, labor L and capital K. Industry Y is labor intensive and does not pollute. Industry X is capital intensive and generates pollution as a by-product. We assume constant returns to scale, and hence the production technology for X and Y can be described by unit cost functions $c^X(w, r)$ and $c^Y(w, r)$. Let Y be the numeraire, and denote the relative price of X by p. Because countries differ in their location, proximity to suppliers, and existing trade barriers, domestic prices will not be identical to world prices. Accordingly we write

$$p = \beta p^w, \tag{1}$$

where β measures the importance of trade frictions and p^w is the common world relative price of X. Note $\beta > 1$ if a country imports X and $\beta < 1$ if a country exports X.[9]

Pollution Abatement.—We denote pollution emissions by Z. Pollution is generated by X production, but firms have access to an abatement technology. Abatement is costly but uses the same factor intensities as all other activities in the X industry; hence, we simply treat units of X as inputs into abatement. If a firm has a gross output of x units, and allocates x_a units to abatement, then its net output is $x_n = x(1 - \theta)$, where $\theta = x_a/x$ is a measure of the intensity of abatement. If pollution is proportional to output and abatement is a constant returns activity, then we can write pollution emissions as

$$z = e(\theta)\, x, \tag{2}$$

where $e(\theta)$ is emissions per unit of X produced and is decreasing in θ.[10] We assume abatement is worthwhile $[e'(0) = -\infty]$, but with physical limits $[e(1) > 0]$.

The government uses pollution emission taxes to reduce pollution. Given the pollution tax τ, the profits π^x for a firm producing X are given by revenue less factor payments, pollution taxes, and abatement costs. Using (1) and our definition of θ, we may write profits succinctly as

$$\pi^x = p^N x - wL_x - rK_x, \tag{3}$$

where $p^N = p(1 - \theta) - \tau e(\theta)$ is the net producer price for gross output. Because of constant returns, the output of an individual firm is indeterminate, but for any level of output, the first-order condition for the choice of θ implies

$$p = -\tau e'(\theta). \tag{4}$$

Hence, we have $\theta = \theta(\tau/p)$ with $\theta' > 0$ and we can write emissions per unit output as

9. For example, let v be the level of iceberg transport costs (that is, $v < 1$ is the fraction of the good that arrives at the destination when a unit is exported). Then if the good is exported from home, we have $p^d = vp^w$, and if the good is imported, we have $p^d = p^w/v$. Freer trade (an increase in v) raises p^d if X is exported and lowers p^d if X is imported.

10. When x units of gross output are produced, and x_a units are devoted to abatement, emissions are given by $E(x_a, x)$. Given our assumptions, E is decreasing in x_a, increasing in x, strictly convex in x_a, and linearly homogeneous in x and x_a together. Convexity in abatement inputs follows from diminishing returns to the variable factor and implies increasing marginal abatement costs. Linear homogeneity follows from constant returns. Using the linear homogeneity of E, we then write $E(x_a, x) = e(\theta)x$.

$$e = e(\tau/p), \tag{5}$$

where $e' < 0$. The production side equilibrium conditions are simply (2), (4), and the standard zero profit and full employment conditions:

$$\begin{aligned} p^N &= c^X(w, r), \quad 1 = c^Y(w, r), \\ K &= c_r^X x + c_r^Y y, \quad L = c_w^X x + c_w^Y y. \end{aligned} \tag{6}$$

Consumers.—For most of our analysis, consumers differ only in their preferences over pollution. There are two groups in society: N^g Green consumers who care greatly about the environment (Greens); and $N^b = N - N^g$ Brown consumers (Browns) who care less about the environment. Each consumer maximizes utility, treating pollution as given. For simplicity, we write the indirect utility function of a consumer in the ith group as

$$V^i(p, G/N, z) = u\left(\frac{G/N}{\rho(p)}\right) - \delta^i z \tag{7}$$

for $i = \{g, b\}$ and where $\delta^g > \delta^b \geq 0$, G is national income (so G/N is per capita income), $\rho(p)$ is a price index, and μ is increasing and concave. Implicit in (7) is the assumption of homothetic preferences over consumption goods. Pollution is a pure public bad, but Greens suffer a greater disutility than Browns. It is now convenient to define real per capita income as $I = [G/N]/\rho(p)$ and rewrite indirect utility as simply $u(I) - \delta^i z$.

Government.—We model the policy process very simply. We assume the government chooses a pollution tax to maximize a weighted sum of each group's preferences. It solves

$$\max_{\tau} N\left[\lambda V^g + (1-\lambda)V^b\right], \tag{8}$$

where λ is the weight put on Greens. λ may vary across governments.[11] We introduce this formulation to allow for the realistic possibility that government behavior varies across countries (perhaps across Communist and non-Communist countries), while allowing for an endogenous link between pollution policy and economic conditions.

The optimal pollution tax maximizes the weighted sum of utilities in (8) subject to private sector behavior, production possibilities, fixed world prices, and fixed trade frictions (see, however, Section 3, subsection E, for

11. For example, if the government is utilitarian, then $\lambda = N^g/N$; if the government is controlled by the Greens, $\lambda = 1$, and if controlled by Browns, $\lambda = 0$.

a consideration of optimal tariffs). Private sector behavior can be represented by a standard GNP function giving maximized private sector (net of tax) revenue as $R(p^N, K, L)$.[12] Overall income is private sector revenue plus rebated taxes $G = R(p^N, K, L) + \tau z$. The first-order condition yields

$$u'(I)\frac{dI}{d\tau} - \left[\lambda\delta^g + (1-\lambda)\delta^b\right]\frac{dz}{d\tau} = 0.$$

With world prices fixed we have

$$\begin{aligned}\frac{dI}{d\tau} &= \frac{1}{N\rho(p)}\left[R_{p^N}\frac{dp^N}{d\tau} + z + \tau\frac{dz}{d\tau}\right] \\ &= \frac{\tau}{N\rho(p)}\frac{dz}{d\tau}.\end{aligned}$$

Rearranging our first-order condition now yields an amended Samuelson rule:

$$\tau = N\left[\lambda MD^g(p,I) + (1-\lambda)MD^b(p,I)\right], \tag{9}$$

where $MD^i(p, I) = \delta^i\rho(p)/u'$ is marginal damage per person, and $MD^i_I > 0$ given the concavity of the utility function. Simplifying allows us to rewrite (9) slightly as:

$$\tau = T\phi(p, I). \tag{10}$$

We refer to $T = \lambda N\delta^g + (1 - \lambda)N\delta^b$ as "country type" and $T\phi(p, I)$ as effective marginal damage (MD). Pollution policy therefore varies with economic conditions and government type.

B. Pollution Demand and Supply

Our model yields a relatively simple reduced form linking pollution emissions to a short list of (predetermined) economic factors. To isolate the role of trade, it is important to understand how these different economic factors affect the demand for, and supply of, pollution. To do so, we use the terminology of scale, composition, and technique effects. We start by noting the private sector's demand for pollution is implicitly defined by (2). To rewrite this demand in a more convenient form for empirical work, we define an economy's scale as the value of national output at

12. See Avinash K. Dixit and Victor Norman (1980) and Alan D. Woodland (1982).

base-year world prices. In obvious notation, our measure of scale S is

$$S = p_x^0 x + p_y^0 y. \tag{11}$$

Choosing units so that base-year prices are unity, we now write pollution emissions as

$$z = ex = e\varphi S, \tag{12}$$

where φ is the share of X in total output. Equation (12) provides a simple decomposition: pollution depends on the pollution intensity of the dirty industry $e(\theta)$, the relative importance of the dirty industry in the economy φ, and the overall scale of the economy S. In differential form,

$$\hat{z} = \hat{S} + \hat{\varphi} + \hat{e}, \tag{13}$$

where hats denote percent change. The first term is the scale effect. It measures the increase in pollution generated if the economy were simply scaled up, holding constant the mix of goods produced φ and production techniques $e(\theta)$. For example, if all endowments of the economy grew by 10 percent, and if there was no change in the composition of output or emission intensities, then we should expect to see a 10 percent increase in pollution. The second term in (13) is the composition effect. If we hold the scale of the economy and emissions intensities constant, then an economy that devotes more of its resources to producing the polluting good will pollute more. Fina1ly, we have the technique effect, captured by the last term. All else constant, an increase in the emission intensity will increase pollution.

We will use a quantity index of output to measure the scale effect. Because a change in prices creates opposing composition and technique effects, however, it is necessary to divide each into its more primitive determinants. Using (6) we can solve for the share of X in total output φ as a function of the capital/labor ratio $\kappa = K/L$, the net producer price p^N and base-year world prices (suppressed here). That is, the composition of output is $\varphi = \varphi(\kappa, p^N)$, and we have the composition effect given by

$$\hat{\varphi} = \varepsilon_{\varphi K}\hat{\kappa} + \varepsilon_{\varphi p}\hat{p}^N, \tag{14}$$

where the elasticity of φ with respect to κ and p^N are both positive. Next differentiate p^N and employ (1) and (4) to find

$$\hat{p}^N = \left(\hat{\beta} + \hat{p}^w\right)(1 + a) - a\hat{\tau}, \tag{15}$$

where a = $e(\theta)\tau/p^N$. Similarly, using (1) and (5) we find

$$\hat{e} = \varepsilon_{e,p/\tau}\left(\hat{\beta} + \hat{p}^w - \hat{\tau}\right), \tag{16}$$

where the elasticity of emission intensity with respect to p/τ is positive.[13] Combining (13)−(16) we obtain a decomposition of the private sector's demand for pollution:

$$\begin{aligned} \hat{z} = \hat{S} + \varepsilon_{\varphi,K}\hat{\kappa} + \left[(1+a)\varepsilon_{\varphi,p} + \varepsilon_{e,p/\tau}\right]\hat{\beta} \\ + \left[(1+a)\varepsilon_{\varphi,p} + \varepsilon_{e,p/\tau}\right]\hat{p}^w - \left[a\varepsilon_{\varphi,p} + \varepsilon_{e,p/\tau}\right]\hat{\tau}. \end{aligned} \tag{17}$$

All elasticities are positive. If we draw this derived demand in $\{z, \tau\}$-space, then (17) shows that an increase in scale, capital abundance, or the world price of dirty goods shifts the pollution demand curve to the right. A movement of β toward 1 captures a reduction in trade frictions. However, because β is greater than 1 for a dirty good importer this implies $\hat{\beta} < 0$; and because β is less than 1 for a dirty good exporter, a reduction in trade frictions implies $\hat{\beta} > 0$. Therefore, a reduction in trade frictions shifts the pollution demand curve to the right for a dirty good exporter, but to the left for a dirty good importer.

Increases in the pollution tax reduce the quantity demanded of pollution through two channels. First they lower the demand for pollution by raising abatement and lowering the emissions per unit of X produced. This is captured by the elasticity $\varepsilon_{e,\, p/\tau} > 0$. Second, higher pollution taxes lower the producer price of X and induce a shift in the composition of output that lowers X output for any given emissions intensity. The strength of this effect depends on the importance of pollution taxes in the net producer price (a) and the elasticity of φ with respect to a change in producer prices, $\varepsilon_{\varphi,p}$.

Pollution supply is in effect given by government policy that sets the price for polluting. From (1) and (10) we obtain a decomposition of pollution supply:

$$\hat{\tau} = \hat{T} + \varepsilon_{MD,p}\hat{\beta} + \varepsilon_{MD,p}\hat{p}^w + \varepsilon_{MD,I}\hat{I}, \tag{18}$$

where $\varepsilon_{MD,\, p} > 0$ and $\varepsilon_{MD,\, I} > 0$. If we draw (18) in $\{z, \tau\}$ -space, then increases in real income, relative prices, or country type shift the pollution supply curve upward. For example, if Greens are given a greater weight in social welfare, or become a larger fraction of the population over time, then policy becomes more stringent and pollution supply shifts upward. Similarly, an increase in real income will increase the demand for environ-

13. It is convenient to define elasticities so that they are positive. Note that e is decreasing in τ/p, and therefore increasing in p/τ.

mental quality and shift up the pollution supply curve. An increase in the world relative price of X makes consumption of market goods more expensive relative to environmental protection. This creates a pure substitution effect toward more environmental protection, reflected in (18) by $\varepsilon_{MD,p} > 0$. As a result pollution supply shifts up. An identical substitution effect is at work when trade frictions fall.

A Reduced Form.—Combining supply in (17) and demand in (18) yields a simple reduced form linking pollution emissions to a small set of economic factors:

$$\hat{z} = \pi_1 \hat{S} + \pi_2 \hat{\kappa} - \pi_3 \hat{I} + \pi_4 \hat{\beta} + \pi_5 \hat{p}^w - \pi_6 \hat{T}, \tag{19}$$

where all π_i are positive, and none of the right-hand-side variables are determined simultaneously with emissions. Two features of (19) warrant further comment. First, because a change in domestic prices shifts pollution supply and demand in opposing directions, it is not obvious that π_4 and π_5 are positive. We evaluate this claim more formally in Proposition 1 below. Second, we claim "a reduced form" links emissions to our economic factors, despite the fact that emissions and these same factors are clearly endogenous variables. In our framework, emissions are determined endogenously, but recursively. As a result, the factors on the right-hand side of (19) are not simultaneously determined with or by the level of emissions.[14] This feature of our simple general equilibrium model has the benefit of providing us a simple, straightforward, and parsimonious reduced form linking pollution emissions to economic determinants. We evaluate our first claim below.

The Trade-Induced Composition Effect

Proposition 1. *Consider two economies that differ only in their trade frictions: (i) if both countries export the polluting good, then pollution is higher in the country with lower trade frictions; (ii) if both import the polluting good, then pollution is lower in the country with lower trade fric-*

14. To see this, note that $R(p^N, K, L) + \tau z = p(1 - \theta)x + y$, which is independent of z. Next, note that (4), (6), and (10) solve for I, τ, and θ, given world prices. With τ, θ, and p determined, p^N is given. Outputs are determined by p^N, and z follows from $z = e(\theta)\,x$. This result follows for two reasons. First, a society may decide to spend some of its potential income on improving environmental quality and the remainder on consumption goods—but higher pollution does not *cause* higher real income. Second, because marginal damage is independent of z, the equilibrium level of emissions does not affect the pollution tax. As a result, a change in emissions does not cause second-order changes in the composition of output or our measures of scale and income. As a result of these two features, real income, scale, and the pollution tax are set simultaneously, whereas emissions are set recursively.

tions.

Proof

See Appendix A.

Proposition 1 isolates the *trade-induced composition effect.* The sign of this composition effect differs across countries. For an exporter of the polluting good, β rises with freer trade and this raises the relative price of the dirty good X. This shifts a dirty good exporter's pollution demand curve to the right and shifts its pollution supply curve up. Pollution demand shifts out for two reasons: the composition of national output shifts toward X; and emission intensities rise because abatement inputs are now more costly. The shift in the pollution supply curve dampens this increase in pollution as the pure substitution effect of the goods price increase leads the government to raise the pollution tax. However, the direct demand-side effects swamp the substitution effect in supply, and pollution rises.[15] Consequently, holding all other determinants of pollution supply and demand constant, emissions must rise. This increase in emissions represents the trade-induced composition effect for a dirty good exporter.

In contrast, β falls with freer trade for an importer of the polluting good. This raises the relative price of the clean good Y, and again shifts both pollution demand and supply. Demand-side determinants dominate and emissions fall. This reduction in emissions represents the trade-induced composition effect for a clean good exporter.

Proposition 1 therefore implies that, if we look across all countries and hold other determinants of emissions constant, we should not expect to find openness per se related in any systematic way to emissions. Although Proposition 1 is useful, it is limited in two respects. First, although it isolates the trade-induced composition effect, any fall in trade frictions will alter the scale of output and income per capita of the liberalizing country as well. Therefore to account for the full environmental impact of a fall in trade frictions we must also account for the accompanying scale and technique effects. Proposition 1 captures the partial effect of trade liberalization; an overall assessment needs the full effect. Second, the results from the proposition are conditional on trade patterns, but the proposition itself is silent on the determinants of trade patterns. We treat each of these issues in turn below.

The Full Impact of Openness.—To find the full impact of a change in trade frictions we must account for the change created in real incomes, the scale of output, and its composition. Differentiate (12) with respect to β,

15. To see this, note that the increase in τ is less than proportional to the increase in β, because the increase in τ induced by β is a pure substitution effect, which is proportional to the share of X in consumption (which is less than one). This ensures both that emission intensity e rises, and that the share of X in production rises. Details are in the Appendices.

holding world prices, country type, and factor endowments constant, to find

$$\frac{dz}{d\beta}\frac{\beta}{z} = \pi_1 \frac{dS}{d\beta}\frac{\beta}{S} - \pi_3 \frac{dI}{d\beta}\frac{\beta}{I} + \pi_4. \tag{20}$$

A fall in trade frictions produces a scale effect, a technique effect, and the trade-induced composition effect, discussed previously. To understand how these three effects interact to determine the environmental consequences of trade, we employ Figure 1.

In the top panel of Figure 1 we depict the production response of a dirty good exporter to a fall in trade frictions. In the bottom panel we depict the pollution consequences of these changes. Before the reduction in trade frictions, production is at point A, the world price is p^w, and the net price is p^N. We have assumed this country is an exporter of the dirty good and therefore has consumption at a point to the northwest of A along the economy's budget constraint (not drawn). Note that the value (in world prices) of domestic output at A measures this economy's scale. In the bottom panel we depict the equilibrium pollution level both before and after the fall in trade frictions. Recall that $z = e(\theta)x$. Hence when production is at A, and emissions intensity is $e(\theta^A)$, pollution is given by z^A.

When trade frictions fall the domestic price approaches the world price and production moves to point C at the new producer price of p^N. At C, real income is higher and there is a change in the techniques of production. The emissions intensity falls to $e(\theta^C)$ and overall pollution falls to z^C. Our methodology divides the movement from z^A to z^C into three component parts. First, holding both the scale of the economy and the techniques of production fixed, trade creates a change in the composition of output given by the movement from A to B. Corresponding to this movement is the in-

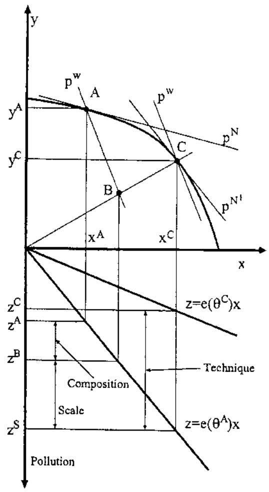

Figure 1. A Dirty Good Exporter

crease in pollution from z^A to z^B in the bottom panel. This is the trade-induced composition effect isolated in Proposition 1.

The movement in the top panel from point B to point C is the scale effect. The increase in pollution from z^B to z^S in the bottom panel gives the pollution consequences of this scale effect. Finally, note that the value of output measured at world prices rises because of trade and this real income gain (indirectly) creates the technique effect shown in the bottom panel. The technique effect is the fall in pollution from z^S to z^C as producers switch to cleaner techniques with lower emissions intensity.

In total the diagram shows that trade liberalization for a dirty good exporter leads to less pollution if the composition and scale effects are overwhelmed by the technique effect. Because this is only a possibility, and not a necessity within our model, we formalize our results in Proposition 2.

Proposition 2. *Consider a small reduction in trade frictions for our small open economy, then:*

(*i*) *if the small open economy exports the clean good, the full effect of this trade liberalization is to lower pollution emissions;*

(*ii*) *if the small open economy exports the dirty good and the elasticity of marginal damage with respect to income is below one, then the full effect of this trade liberalization is to raise its pollution emissions;*

(*iii*) *if the small open economy exports the dirty good and the elasticity of marginal damage with respect to income is sufficiently above one, then the full effect of this trade liberalization is to lower its pollution emissions.*

Proof

See Appendix A.

The first part of the proposition concerns dirty good importers. For dirty good importers the trade-induced composition effect is negative and because X production falls, the sum of composition and scale effects must also be negative.[16] Consequently, pollution emissions will fall for a dirty good importer. For a dirty good exporter, both the trade-induced composition effect and the scale effect are positive. Pollution demand shifts right from these two forces, and Proposition 2 indicates that if the policy response is sufficiently weak (an elasticity of marginal damage with respect to income less than one) emissions will rise. That is, the upward shift in pollution supply is overwhelmed by the demand shifts. Alternatively, if the elasticity of marginal damage is sufficiently strong, then emissions will fall as the technique effect dominates. The full effect of a trade liberalization

16. This is a product of our two-good model. With many polluting goods the scale effect may dominate the composition effect, leading to a rise in pollution from these two sources.

differs from the partial effect because of two additional effects, and because these new effects can be strong enough to overwhelm the composition effect.

C. Adding up Scale, Composition, and Technique Effects

The amount of information required to implement an adding-up exercise akin to (20) is great. In our empirical work we develop estimates for π_1, π_3, and π_4. But even with these estimates in hand we are faced with disentangling the effects of trade liberalization on income growth from all other potential sources. Because attempts to link trade to growth and income levels are the subject of an already large and somewhat controversial literature, we do not attempt to measure trade's effect on GDP ($dS/d\beta$) or GNP per person ($dI/d\beta$). Instead we employ economic theory to add up our estimated scale, composition, and technique effects. Taking factor endowments as fixed, a lowering of transport costs or trade barriers raises the value of domestic output and real income in a small open economy. The value of output and income rise by the same percentage and this creates both scale and technique effects.[17] Therefore, we can simplify (20) slightly and write

$$\frac{dz}{d\beta}\frac{\beta}{z} = [\pi_1 - \pi_3]\frac{dI}{d\beta}\frac{\beta}{I} + \pi_4. \tag{21}$$

In some circumstances we can add up these three effects to come to an overall assessment of trade without knowledge of trade's effect on income or scale. For example, consider a dirty good exporter. Note that $dI/d\beta$ is positive because an increase in β represents lower trade frictions. If we find $\pi_1 > \pi_3$ and $\pi_4 > 0$, then we conclude that trade liberalization raises pollution for a dirty good exporter: scale effects dominate technique and the trade-induced composition effect is positive. Under these same circumstances, trade liberalization would have an ambiguous effect on emissions for a clean good exporter. Consequently, even to implement our more limited adding-up exercise, it is necessary to ask: who exports dirty goods and why?

Pollution Haven versus Factor Abundance Motives.—In our model comparative advantage is primarily a function of relative factor abundance and relative incomes. Although limiting cases of our model reflect only pollution haven motives or pure factor endowment motives, in general we expect both determinants of comparative advantage to matter. To investigate

17. If GNP differs from GDP because of receipts or payments from abroad, then we would need to correct for the (generally small) share of these payments in GNP.

further we solve for autarky prices. Let $RD(p)$ denote the demand for good X relative to good Y. Then the relative price of good X is determined by the intersection of the (net) relative supply and demand curves

$$RD(p) = (1 - \theta)\,\chi(\kappa, p^N), \tag{22}$$

where $\chi = x/y$ is determined from (6), and net relative supply is $(1 - \theta)\chi$. Totally differentiating, using (15), (16), and (18), and rearranging gives an expression linking autarky prices to real income and endowments:

$$\hat{p} = \frac{\varepsilon_{MD,I}\left[a\varepsilon_{\chi,p^N} + \dfrac{\theta}{1-\theta}\varepsilon_{\theta,\tau/p}\right]\hat{I} - \varepsilon_{\chi,\kappa}\hat{\kappa}}{\Delta}, \tag{23}$$

where all elasticities and Δ are positive. Equation (23) shows that in general, the pattern of trade is determined by both factor abundance and income-driven differences in pollution policy. For example, unless both the dirty and clean sectors use identical factor proportions then $\varepsilon_{\chi,\kappa}$ is not zero and capital abundance matters to comparative advantage. Similarly, if the environment is a normal good, then $\varepsilon_{MD,I}$ is nonzero and real income matters as well.

The Role of Factor Endowments.—Standard factor endowment theories predict capital abundant countries export capital-intensive goods. In our model this need not be true because pollution policy can reverse this pattern of trade. Nevertheless, capital abundance is still a key determinant of comparative advantage in our model. Because X is relatively capital intensive, an increase in κ, holding all else constant, increases Home's relative supply of X, and lowers Home's autarky relative price of X. Using (23) we obtain $\hat{p} < 0$ because $\varepsilon_{\chi,\kappa} > 0$. All else equal, an increase in the abundance of the factor used intensively in the pollution-intensive sector increases the likelihood that a country will be an exporter of pollution-intensive goods. We can show that if the country is sufficiently capital abundant, it must export the capital intensive (polluting) good:

Proposition 3. *Suppose the world price p^w is fixed. Then, for a given level of real income I, there exists a $\underline{\kappa}$ such that if $\kappa > \underline{\kappa}$, then Home exports X. Moreover, for such a country, the trade-induced composition effect will be positive.*

Proof

See Appendix A.

The Role of Income Differences.—An alternative theory of trade patterns is the *pollution haven hypothesis.* According to this view, poor countries have a comparative advantage in dirty goods because they have lax pollution policy, and rich countries have a comparative advantage in clean goods because of their stringent pollution policy.[18] This result can be obtained as a special case of our model: if all countries have the same relative factor endowments, but differ in per capita incomes, then richer countries will have stricter pollution policy and this will lead to a comparative advantage in clean goods. Using (23) we obtain $\hat{p} > 0$ whenever $\hat{I} > 0$. When countries differ in factor endowments and income levels, we can show that if the country is *sufficiently* rich, it must export the labor-intensive (clean) good.

Proposition 4. *Suppose the world price p^w is fixed and there exists an ε such that $\varepsilon_{MD,I} > \varepsilon > 0$. Then, for a given level of the capital/labor ratio κ, there exists an $\underline{I}$, such that if $I > \underline{I}$, then Home exports Y. Moreover, for such a country, the trade-induced composition effect will be negative.*

Proof

See Appendix A.

From Theory to Estimation.—Proposition 1 contains a very simple message: comparative advantage matters. If we compare countries with similar incomes and scale, openness should be associated with higher pollution in dirty good exporters and lower pollution in dirty good importers. Therefore to isolate the trade-induced composition effect, we must condition on country characteristics. This observation begs three questions: how are we to measure openness, what country characteristics should we use, and how should we condition on these characteristics?

Various measures of "openness" exist. We need a measure with both time-series variation and a wide cross-country coverage. In our theory a lowering of trade frictions brings domestic prices closer to world prices and it does not matter whether this occurs because of a fall in transport and communication costs or (apart from revenue effects) because of a GATT-inspired reduction in trade restrictions.[19] However, because we do not observe movements in β directly we must make use of an observable consequence of heightened integration: increases in a country's trade inten-

18. See Copeland and Taylor (1994) for a model that explores this issue.

19. See, however, Section 3, subsection E, on the tariff-substitution effect in a large open economy.

sity ratio (defined as the ratio of exports plus imports to GDP valued at world prices). We formalize this link below.

Proposition 5. *If preferences over consumption goods are homothetic, trade intensity rises as β approaches 1.*

Proof

See Appendix A.

Proposition 5 links unobservable trade frictions with observable trade intensity. Lower trade frictions means greater trade intensity, regardless of a country's comparative advantage. Therefore, in our empirical application we replace unobservable trade frictions with observable trade intensity.[20]

To address our second question, interpret the hat notation in equation (23) as describing small differences across countries. With this interpretation, (23) links differences in autarky relative prices across countries to differences in their relative factor abundance and real income levels. If we take the rest of the world as our small country's partner in this exercise, then the strength and direction of country i's comparative advantage will depend on its capital abundance relative to a world average (denoted by κ_i), and its real income relative to a world average (denoted by ι_i). Although other factors play a role in determining comparative advantage, capital abundance and real income are the key country characteristics within our model.

Finally, to condition on these characteristics we let Ψ be a function measuring the partial effect of an increase in trade intensity on pollution. Our theory tells us that we can write $\Psi = \Psi(\kappa_i, \iota_i)$, but does not give us much more guidance in this regard. The interaction between factor abundance and pollution haven motives depends quite delicately on elasticities of substitution, factor shares, and (unknown) third derivative properties of our more basic functions. This is apparent from (23) because the elasticities in this expression are functions of prices, incomes, and, trade frictions. Consequently, we adopt a flexible approach to capturing these influences by adopting a second-order Taylor series approximation to Ψ in our empirical work. That is, we employ

(24) $$\Psi_i \cong \psi_0 + \psi_1\kappa_i + \psi_2\kappa_i^2 + \psi_3\iota_i + \psi_4\iota_i^2 + \psi_5\kappa_i\iota_i,$$

20. If trade frictions are not exogenous, but are endogenously determined along with pollution policy, then our proxy (trade intensity) may be correlated with unmeasured determinants of pollution policy. In Section 3, subsection E, we discuss the likely implications of such a link between trade and pollution policy.

and then interact this measure with trade intensity to capture the trade-induced composition effect.

This method has several advantages. It allows the impact of further openness on pollution to depend on country characteristics. It does not dictate whether one or both motives are present in the data or how they interact. And we can evaluate Ψ using our estimates to provide some simple reality checks. For example, does the pollution demand curve shift right for some countries and not for others (i.e., does Ψ_i vary in sign depending on country characteristics)? For which countries does it shift right? Are these countries poor countries as predicted by the pollution haven hypothesis, or are they capital abundant countries as predicted by the factor abundance hypothesis? Finally, the formulation is a relatively parsimonious and reasonably flexible method for estimating an unknown nonlinear function.

2. Empirical Strategy

This section describes how we move from our theory to an estimating equation. To do so we need to discuss our data, its sources and limitations (subsection A), and address the links between theory and our estimating equation (subsection B).

A. Data Sources and Measurement Issues

A real-world pollutant useful for our purposes would: (1) be a by-product of goods production; (2) be emitted in greater quantities per unit of output in some industries than others; (3) have strong local effects; (4) be subject to regulations because of its noxious effect on the population; (5) have well known abatement technologies available for implementation; and (6), for econometric purposes, have data available from a mix of developed and developing as well as "open" and "closed" economies. An almost perfect choice for this study is sulfur dioxide.

Sulfur dioxide (SO_2) is a noxious gas produced by the burning of fossil fuels. Natural sources include volcanoes, decaying organic matter, and sea spray. Anthropogenic sources are thought to be responsible for somewhere between one-third and one-half of all emissions (United Nations Environment Programme (1991); Kraushaar and Ristinen (1998)). SO_2 is primarily emitted as either a direct or indirect product of goods production and is not strongly linked to automobile use. Because energy-intensive industries are also typically capital intensive, a reasonable proxy for dirty SO_2-creating activities may be physical-capital-intensive production processes. Readily available, although costly, methods for the control of emissions exist and their efficacy is well established. In addition, in many countries SO_2 emissions have been actively regulated for some time.

The Global Environment Monitoring System (GEMS) has been recording SO_2 concentrations in major urban areas in developed and developing countries since the early 1970s. Our data set consists of 2,555 observations from 290 observation sites located in 108 cities representing 43 countries spanning the years 1971-1996. The GEMS network was set up to monitor the concentrations of several pollutants in a cross section of countries using comparable measuring devices.[21] The panel of countries includes primarily developed countries in the early years, but from 1976 to the early 1990s the United Nations Environment Programme provided funds to expand and maintain the network. The coverage of developing economies grew over time until the late 1980s. In the 1990s coverage fell with data from the United States only for 1996. The World Health Organization (1984) reports that until the late 1970s data comparability may be limited as monitoring capabilities were being assessed, many new countries were added, and procedures were being developed to ensure validated samples. Accordingly, we investigate the sensitivity of our findings to the time period.

The GEMS data are comprised of summary statistics for the yearly distribution of concentrations at each site. In this study we use the log of median SO_2 concentrations at a given site, for each year, as our dependent variable. We use a log transform because the distribution of yearly summary statistics for SO_2 appears to be lognormal (WHO (1984)). Previous work in this area by the WHO and others has argued that a lognormal distribution is appropriate because temperature inversions or other special pollution episodes often lead to large values for some observations. In contrast, even weather very helpful to dissipation cannot drive the level of the pollutant below zero.

In addition to the data on concentrations, the GEMS network also classifies each site within a city as either city center, suburban, or rural in land type, and we employ these land-type categories in our analysis. A list of the cities involved, the years of operation of GEMS stations, and the number of observations from each city along with a frequency distribution of SO_2 emissions is given in our Technical Appendix (available upon request).

In moving from our theoretical model to its empirical counterpart we need to include variables to reflect scale, technique, and composition effects. As well, we have to include site-specific variables to account for meteorological conditions. Our estimations will require the use of data on real GDP per capita, capital-to-labor ratios, population densities, and various measures of "openness." The majority of the economic data were obtained from the Penn World Tables 5.6. The remainder was obtained from several sources. A description of data sources and our methods for collection are

21. The range of sophistication of monitoring techniques used in the network varies quite widely, but the various techniques have been subject to comparability tests over the years. Some stations offer continuous monitoring, whereas others measure only at discrete intervals.

provided in Appendix B together with a table of means, standard deviations, and units of measurement for the data.

B. The Estimating Equation

In moving from our theoretical model to estimation we face several issues. Here we discuss three: identification, excluded variables, and functional form.

Identification.—The private sector's demand for pollution, written in differential form, is given by (17). The pollution supply curve is given by (18). A problem arises because most measures of the scale of economic activity that shifts pollution demand (for example real GDP or real GDP per person) will be highly or perfectly correlated with real income per capita that shifts pollution supply.

We address this problem by exploiting three different sources of variation in our data. First, we note that changes in the scale of output must have contemporaneous effects on pollution concentrations, whereas pollution policy is likely to respond slowly, if at all, to changes in income levels. Consequently, we use as our proxy for income a one-period lagged, three-year moving average of income per capita, but link pollution concentrations to a contemporaneous measure of economic activity. To the extent that there is significant variation over time in activity measures, this source of variation will help in our identification.[22]

Second, the scale of economic activity should be measured by economic activity within a country's borders (i.e., GDP), whereas the income relevant to the technique effect should reflect the income of residents wherever it is earned (i.e., GNP). Therefore, we can exploit the difference between GDP and GNP measures to separate technique from scale effects. Even though the gap between these two figures is not large for most economies, it is significant for some. This cross-country variation will be useful in separating scale from technique.

Finally, we measure the scale of economic activity S at any site by an intensive measure of economic activity per unit area. This intensive measure is GDP per square kilometer. Lacking detailed data on "Gross City Product," we construct GDP per square kilometer for each city and each year by multiplying city population density with country GDP per person.

22. For example, we expect that a significant recession would drive down concentrations (a scale effect) but not lead to a rewriting of pollution control laws (i.e., a technique effect). This source of variation in pollution data has been exploited before. See Kenneth Y. Chay and Michael B. Greenstone (1999).

As a result, scale is now measured in intensive form, as is our dependent variable.[23] To explain *concentrations of pollution* we need a measure of scale reflecting the *concentration of economic activity* within the same geographical area. Other possible measures of scale fail this test. Moreover, since we assume pollution policy is determined by national averages for income per capita and the number of exposed individuals, we are in effect fixing the pollution supply curve for all cities within a given country. This "allows" us to employ the within-country variation in scale across cities to separate the influence of scale from that of technique.

Unobservable Variables: Fixed or Random Effects?—Several variables relevant to our theory are unobservable. To account for these exclusions we estimate an individual effects model for ε_{ijkt} given by

$$\varepsilon_{ijkt} = \xi_t + \theta_{ijk} + \nu_{ijkt}, \qquad (25)$$

where ξ_t is a time-specific effect, θ_{ijk} is a site-specific effect, and ν_{ijkt} is an idiosyncratic measurement error for observation station i in city j in country k in year t.

Our common-to-world but time-specific effect is included to capture changes in knowledge concerning pollution, changes in the world relative price of dirty goods, and improvements in abatement technologies. Although proxies for some of these variables could be constructed, choosing proxies will of course introduce new issues of data quality, coverage, and so forth. Instead we note that, because each of these variables affects all countries in a similar way, a preferred method may be to treat them as unobservable. For example, a rise in the world price of dirty goods affects all countries in a similar way. Accordingly, we capture these common-to-world excluded variables with a set of unrestricted time dummies.

θ_{ijk} is a site-specific effect representing excluded site (or country-specific) variables such as excluded economic determinants or excluded meteorological variables. For example, country type T appears in (19) but is virtually unobservable in that it relies on both knowledge of the weight governments apply to Greens and Browns in their economy and the share of each in the overall population. Because the panel is relatively short for almost all countries, we take these country-type and distribution parameters as fixed over time. As well, there are unmeasured topographical and mete-

23. This is admittedly a rough measure of economic activity, and the quality of this proxy may vary systematically with a country's development level. To investigate this concern we have allowed the scale effect to vary across countries divided by income category, by allowing for nonlinearities in the response to scale, and by excluding the perhaps most troubling rural observations. Our results are similar to those reported for our simpler specification. For one such sensitivity test see Table 2.

orological features that undoubtedly affect the dissipation of pollution at each site. Finally, we allow for an idiosyncratic measurement error v_{ijkt}. Two sources of this error would be machine error in reading concentrations and human error in calculation or tabulation.

Throughout we present both fixed- and random-effects estimates for every model. Whereas random-effects estimation is in theory more efficient, it is unclear whether excluded country-specific effects subsumed in our error term are uncorrelated with our regressors. Although fixed-effects estimation is preferable in just these cases, fixed effects limits the cross-sectional variation we can exploit for separating scale from technique effects.

Functional Form.—Our model predicts emission levels but our data are on concentrations. Meteorological models mapping emissions from a (single) stack into measured concentrations at a receptor are functions of emission rates, stack height, the distance to the receptor, wind speed, temperature gradients, and turbulence. Much of this information is not presently available. In view of these limitations we adopt a linear approximation to measured concentrations by writing concentrations at site *ijk*, at time *t* as

$$\begin{aligned}
Z^C_{ijkt} &= X'_{jkt}\alpha + Y'_{ijkt}\gamma + \varepsilon_{ijkt} \\
X'_{jkt}\alpha &= \alpha_0 + \alpha_1 SCALE_{jkt} + \alpha_2 KL_{kt} + \alpha_3 INC_{kt} + \alpha_4 \Psi_{kt} TI_{kt} \\
\Psi_{kt} &= \psi_0 + \psi_1 REL.KL_{kt} + \psi_2 REL.KL^2_{kt} + \psi_3 REL.INC_{kt} \\
&\quad + \psi_4 REL.INC^2_{kt} + \psi_5 REL.KL_{kt} REL.INC_{kt},
\end{aligned} \tag{26}$$

where SCALE is city-specific GDP/km^2, KL is the national capital-to-labor ratio, INC is a one-period-lagged three-year moving average of GNP/N, TI is the trade intensity (X+M)/GDP, REL.KL is country *k*'s capital-to-labor ratio measured relative to the world average, and REL.INC is country *k*'s real income measured relative to the world average (see Appendix B for further details). Note that world price and country-type variables are captured in (25), and trade intensity has replaced trade frictions in (19), as discussed previously. Y contains site-specific weather variables and site-specific physical characteristics (discussed below), and ε_{ijkt} is a site-specific error reflecting unmeasured economic and physical variables. We refer to equation (26) as Model A in our estimations.

Model A follows from our reduced form if we assume linearity in the response to scale, technique, and composition variables. This linearity assumption is, however, somewhat at odds with our theory. In theory, the impact of capital accumulation on pollution depends on the techniques of production in place. But when countries differ in income per capita, they will also differ in producer prices and hence their techniques of production.

Consequently, the Rybczyinski derivatives embedded in (26) will differ across countries. As well, the impact of capital accumulation on the composition of output is not a linear function of KL. Similarly, the impact of income gains on pollution depends on the existing composition of output and hence the existing capital-to-labor ratio and income per capita. To account for these possibilities we amend Model A by adding the squares of income per capita (INC^2_{kt}) and the capital-to-labor ratio (KL^2_{kt}) as well as their cross-product ($INC_{kt}\, KL_{kt}$). We refer to this amended form of (26) as Model B. As a consequence, the impact of factor accumulation can now differ across countries and over time in closer accord with our theory. Finally, we consider a further nonlinearity by adding $SCALE^2_{kt}$ to Model B. A nonlinearity in the impact of scale could arise from nonhomotheticicities in production or consumption. We refer to this slightly amended model as Model C.

Models A, B, and C differ from those previously estimated in several regards. For example, empirical work within the Environmental Kuznets curve tradition employ measures only of site-specific attributes and income per capita as regressors, leaving out a role for factor endowments or scale to play independent effects. Grossman and Krueger (1993, 1995) are the most prominent examples of this approach, but there are many others. Lewis Gale and Jose A. Mendez (1998) add measures of factor endowments to a Kuznet's curve regression, but their (one-year) cross-sectional analysis cannot distinguish between constant-over-time site attributes and scale effects. Empirical work using (constructed) cross-country emission data or emission intensity data has tried to link country characteristics (factor endowments, growth in income, fuel use, etc.) to environmental outcomes, but these studies always fail to condition the impact of openness on country characteristics. For example, see Low and Yeats (1992) and Lucas et al. (1992). As a result, we are not aware of even one study where the impact of trade is conditioned on those country characteristics determining comparative advantage, despite the fact that the trade-induced composition effect should vary across countries according to comparative advantage.

3. Empirical Results

A. Main Results

Table 1 presents the main results from our estimations. We present estimates from Models A, B, and C in Table 1 using both random and fixed effects.

Table 1. Alternative Hypotheses Tests

Estimation method:	Random effects			Fixed effects		
Model specification:	A	B	C	A	B	C
Variable/column:	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	−2.865***	−3.279***	−3.311***	−2.506***	−4.324***	−4.299***
City economic intensity GDP/km^2	0.042***	0.058***	0.070***	0.024*	0.058***	0.089*
(City economic intensity)^2/1,000			−0.244			−0.340
Capital abundance(K/L)	0.102**	0.293**	0.286*	0.165**	0.461**	0.437*
(K/L)^2		0.014	0.013		0.006	0.008
Lagged per capita income	−0.982***	−1.248***	−1.312***	−1.326***	−0.096	−0.228
(Income)^2		0.708***	0.669***		0.559***	0.578***
$(K/L)\times(I)$		−0.309***	−0.285***		−0.381***	−0.386***
Trade intensity TI=$(X+M)$/GDP	−0.915	−0.488	−0.510	−3.677***	−3.142**	−3.216**
TI×REL.K/L	−0.462	−1.952*	−1.828*	0.159	−2.252*	−2.121
TI×(REL.K/L)^2	0.018	−0.230	−0.248	−0.168	−0.123	−0.176
TI×REL.INC	0.470	1.056*	1.011*	2.128**	2.687***	2.614***
TI×(REL.INC)^2	0.118	−0.308*	−0.285*	−0.108	−0.595**	−0.584**
TI×(REL.K/L)×(REL.INC)	−0.165	0.870***	0.822***	−0.280	0.900**	0.924**
Suburban dummy	−0.299	−0.435*	−0.422*			
Rural dummy	−0.623	−0.674	−0.631			
Communist country(C.C.)dummy	0.312	−0.252	−0.257			
C.C.dummy×income	−0.283	4.569*	4.641*	1.170	9.621**	9.639**
C.C.dummy×(income)^2		−5.755**	−5.788**		−8.931***	−8.806**
Average temperature	−0.055***	−0.052***	−0.052***	−0.060*	−0.057*	−0.056*
Precipitation variation:	3.446	5.860	6.158	8.599	10.810*	10.716*
Helsinki Protocol:	−0.232*	−0.092	−0.114	−0.179	0.016	0.016
Observations	2,555	2,555	2,555	2,555	2,555	2,555
Groups	290	290	290	290	290	290
R^2	0.3395	0.3737	0.374	0.2483	0.131	0.1499
Log-likelihood	−2550	−2523	−2522	−3964	−3906	−3905
LR test/χ^2(df)	55.596***	1.604		118.42**	2.035	
Hausman test/Wald χ^2(df)	65.761**	15.158	53.789			
Scale elasticity	0.192***	0.265***	0.315***	0.112*	0.266***	0.398**
Composition elasticity	0.583**	0.948***	0.993***	0.945**	1.006**	0.975*
Technique elasticity	−0.905***	−1.577***	−1.577***	−1.222***	−1.153**	−1.266**
Trade intensity elasticity	−0.436***	−0.388***	−0.394***	−0.641***	−0.864***	−0.882***

Notes: To conserve space, no standard errors or t-statistics are shown.The dependent variable is the log of the median of SO_2 concentrations at each observation site. Model A follows directly from our empirical implementation, whereas model B allows for additional interaction between capital abundance and income. In addition to model B, model C allows for nonlinearity in our scale variable. All model specifications use time-fixed effects. Elaticities are evaluated at sample means using the Delta method.

*Significance at the 95 percent confidence level.
**Significance at the 99 percent confidence level.
***Significance at the 99.9 percent confidence level.

Scale, Composition, and Technique Effects.—Consider our core variables representing scale, composition, and technique effects. In all columns of Table 1 we find a positive and significant relationship between the scale of economic activity as measured by GDP/km^2 and concentrations. From the bottom of Table 1 we see that the coefficient estimates imply a sample-mean elasticity of concentrations to an increase in scale somewhere between 0.1 and 0.4. The scale elasticity estimates increases in magnitude as we move from Model A through to Model C, although the estimates differ only slightly across random and fixed effects. Because the models are nested, we can test the restrictions imposed in Models A and B via a likelihood ratio (LR) test. It appears there is little gained in moving to the slightly more general Model C from Model B; conversely, the restrictions imposed by Model A are rejected by the data as shown by the significant LR test statistics in columns (1) and (4). These empirical results together with our knowledge of theory suggest that less emphasis be placed on the estimates from Model A.

Next consider the impact of a nation's capital-to-labor ratio. In all columns of Table 1, we find a positive composition effect arising from an increase in capital-to-labor ratios. The estimated effect is typically quite large. With the exception of column (1), we find a 1 percent increase in a nation's capital-to-labor ratio—holding scale, income, and other determinants constant—leads to perhaps a 1 percent-point increase in pollution. Our success in finding a link between factor endowments and pollution may appear surprising given the universal difficulties researchers have had in finding a strong link between factor endowments and trade flows. We would note, however, that the production side of the HOS model has received some support (see especially Harrigan (1995, 1997)), and our model focuses on a highly aggregate relationship between overall pollution intensive output and factor endowments.

The estimates in Table 1 also predict a strong and significantly negative relationship between per capita income levels and concentrations. The elasticity of concentrations to an increase in income is typically quite large and is always significant. Using the estimates from Table 1, the technique elasticity varies between −0.9 and −1.5. This technique effect seems surprisingly strong, but the result appears to be robust. Alternative specifications (discussed below) lead to somewhat different conclusions, although the elasticity is almost universally estimated to be greater than −1 in magnitude, suggesting a strong policy response to income gains.

The Trade-Induced Composition Effect.—Next consider the estimates for the trade-induced composition effect. In all columns we reject the hypothesis that the terms reflecting the trade-induced composition effect are jointly zero.[24] Although the sign and significance of some individual coefficients vary across specifications, the results from Model B and Model C in both random and fixed effects are very similar. At the sample mean, the overall elasticity of concentrations to an increase in trade intensity is relatively constant, ranging from approximately −0.4 to −0.9. Therefore, for an aver-

24. This is in contrast to the case where trade intensity appears alone or is replaced by other measures of "openness." We investigated this issue more fully in Antweiler et al. (1998 Table 2 p. 29).

age country in our sample the trade-induced composition effect is negative. Considering the individual coefficients, it is clear that country characteristics describing both relative income and abundance are important, but it is difficult to evaluate the relative strength of pollution haven and factor abundance motives. We present several methods of evaluation below.

Site-Specific and Country-Type Considerations.—Because income gains may not equally translate into policy responses we note it is important to distinguish between Communist and non-Communist countries. The Communist country interactions with income and income squared in Models B and C suggest that the technique effect is very small or nonexistent in Communist countries. For example, using the fixed-effects results from column (6), we cannot reject the hypothesis of a zero technique effect in Communist countries! In the random-effects case in column (3), the technique elasticity is fully one-third of that for our average, non-Communist country.[25] We investigated other country-type effects by including a dummy variable for those years a country was bound by the Helsinki protocol on acid rain. Our results indicate this variable has little explanatory power. The results, however, do indicate that site-specific land use and weather variables have a bearing on concentrations as expected. Higher temperatures both dissipate pollution faster and reduce the need for home heating; precipitation highly concentrated in one season reduces the ability of rain to wash out concentrations.

B. Discussion and Evaluation

Although the results in Table 1 appear to be supportive of our theory, it is important to go beyond sign and significance tests to investigate whether the magnitude of these estimates are in some sense plausible. We pursue several of these reality checks below.

To start note that the implied scale, composition, and technique elasticities are not implausibly high, and all are significantly different from zero. Together these elasticities provide some simple reality checks. For example, suppose our average economy experienced neutral technological progress of 1 percent, raising both GDP and GNP per person by 1 percent. According to our estimates from Table 1, the positive scale effect from this growth will always be dominated by the negative technique effect.[26] Al-

25. The technique elasticity in the random-effects case is much smaller −0.50 but is significantly different from zero; the technique elasticity in the fixed-effects case is −0.062 with a 95 percent confidence interval of [−0.90, 0.78].

26. Holding input use constant (capital, labor, and pollution), neutral technological progress raises output in our model. Each unit of pollution is more productive than before, and this via a scale effect argues for more pollution. Because real incomes are now higher, however, pollution may in fact fall from a technique effect. Whether we have more or less pollution in equilibrium after the shock therefore depends on the relative strength of these two effects.

though the estimates differ across columns, in all cases our results indicate neutral technological progress lowers pollution concentrations. Alternatively, when an increase in income and production is fueled entirely by capital accumulation, the picture is far less favorable to the environment. If we assume a share of capital in output of 1/3, then the full impact of capital accumulation working through scale, composition, and technique effects is to raise pollution concentrations.[27] Even though these two exercises are not tests of our theory, the results are reassuringly close to what we may have expected *ex ante*.

To assess the plausibility of our trade intensity elasticity, we calculated the trade intensity elasticity for all countries in our sample. From Proposition 1 we note that the sign of the trade-induced composition effect should reflect a country's comparative advantage in clean versus dirty goods. Therefore it is not plausible that all countries in the world have negative trade intensity elasticities. Although we have only a sample of countries it seems reasonable to expect both positive and negative elasticities.

As a check on our theory we present in Figures 2 and 3 below a plot of country-specific elasticities against relative income using estimates from

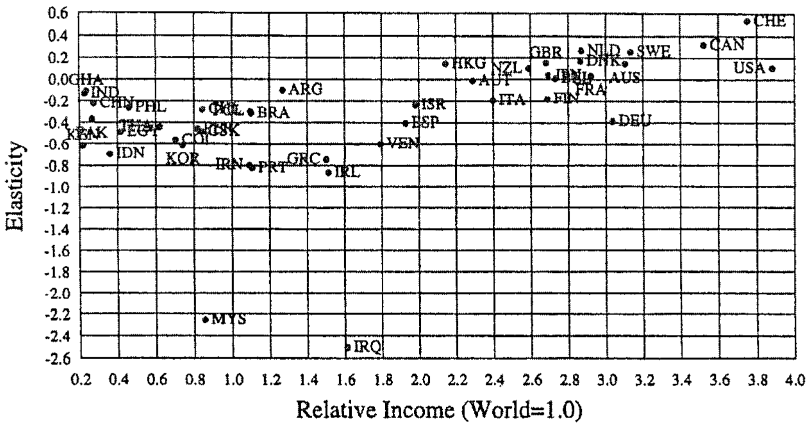

Figure 2. Country-Specific Trade Elasticities [Model B, Random Effects, Corresponding to Table 1 Column(2)]

27. Take, for example, the estimates from column (6). Then our estimates indicate that a 1 percent increase in the capital-to-labor ratio raises concentrations by perhaps 1 percent, all else equal. However, an increase in the capital-to-labor ratio will have accompanying impacts on the scale of economic activity and on real incomes. If we make a back-of-the-envelope calculation by taking capital's share in the value of domestic output at 1/3, then capital accumulation leading to a 1 percent increase in the capital-to-labor ratio creates a 1/3 percentage-point increase in GDP per capita and GDP/km^2. Therefore, capital accumulation also creates an induced technique effect of approximately $-1.2/3 = -0.4$ and an induced scale effect of perhaps $0.13 = 0.39/3$. Adding the direct composition effect to these estimates suggests that economic growth fueled entirely by capital accumulation raises pollution concentrations.

Model B in columns (2) and (5) of Table 1. Although there are more positive elasticities in Figure 2 than 3, in both there is a distribution of elasticities around zero. Our inference is simply that some countries' pollution demand shifts right with a fall in trade frictions and some shift left *because countries differ in their comparative advantage.*[28] For example, from either Figure 2 or Figure 3 we would conclude a small trade liberalization in Canada, all else equal, shifts its pollution demand curve to the right. The inference is that, despite Canada's relatively high income, its comparative advantage lies in capital-intensive dirty products. Alternatively, we would conclude a small trade liberalization in India shifts its pollution demand curve to the left, the inference being that, despite its relatively low income, its comparative advantage lies in labor-intensive and relatively clean goods production. Although these two countries estimates may accord well with our intuition, other country-specific elasticities are harder to explain [e.g., why is Malaysia's elasticity (MYS) so negative and Switzerland's (CHE) so positive?]. Because our country-specific estimates do vary across specifications, we caution the reader from drawing too strong an inference from any one of them.

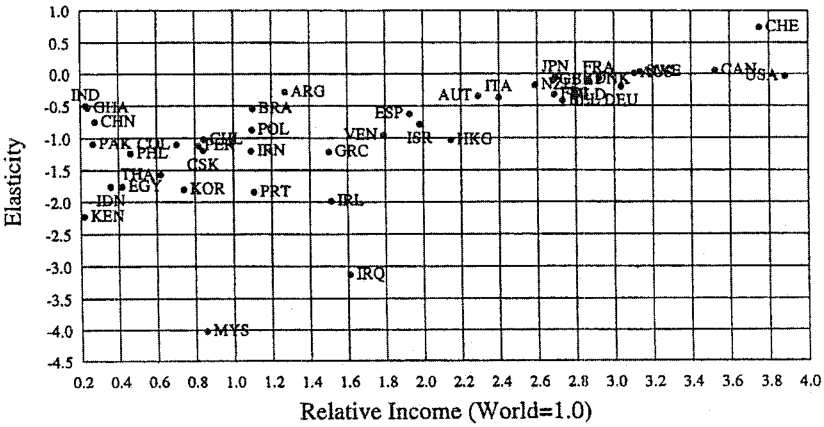

Figure 3. Country-Specific Trade Elasticities [Model B, Flxed Effects, Corresponding to Table 1 Column(5)]

28. The random-effects implementation in Figure 2 has more positive point elasticities than the fixed effects in Figure 3, but relatively minor changes in specifications moves the entire set of fixed-effects estimates upward.

Pollution Haven and Factor Abundance Motives.—The second feature of note in Figures 2 and 3 is that the elasticity estimates increase with relative income. Note that if the simple pollution haven hypothesis were literally true and the sole determinant of trade in dirty products, we would expect just the opposite—a strong negative correlation between relative income and the magnitude of our country-specific elasticities. This is because, under the pollution haven hypothesis, poor countries specialize in dirty goods and rich countries specialize in clean goods. A small movement toward free trade would shift the pollution demand curve inward for a rich country and outward for a poor country. In fact, as shown in the figures, the relationship is definitely nonnegative and, in fact, slightly positive.[29] It appears that if anything, high-income countries have a comparative advantage in dirty capital-intensive products.

In total, although changes in trade intensity seem to matter, the magnitude of the induced change in pollution concentrations appears relatively small. In Figure 2 the vast majority of countries have trade intensity elasticities less than 1 in absolute value; in Figure 3 the majority of countries also satisfy this requirement.

One explanation for these findings is simple: low-income countries typically have both low incomes per capita and low capital-to-labor ratios. The pollution haven hypothesis suggests that a low-income economy should be made dirtier by trade, but if pollution-intensive industries are also capital-intensive then, whatever benefits accrue from lax pollution regulation could be largely undone by the relatively higher price of capital in this capital-scarce country. As a result, further openness to trade will have a very small effect on the pollution intensity of output for low-income countries. Similarly, high-income countries have both high income and high capital-to-labor ratios. The former argues in favor of trade lowering the pollution intensity of output, whereas the latter argues in favor of trade raising it.

Judging from Figure 2 and 3 it appears that, if anything, factor endowment motives are offsetting tighter pollution policy in relatively rich countries. This may explain why other investigations have failed to find a significant relationship between the strictness of pollution regulations and decreased trade in capital-intensive dirty goods. It may also explain why previous researchers have found it quite difficult to find pollution haven effects in the data. It is not that the (ceterus paribus) pollution haven hypothesis is wrong, or that the (ceterus paribus) factor endowment driven basis for trade is absent. But rather, because these two partial theories work against each other, the net result of the potentially very large composition effects predicted by either theory turn out to be rather small in practice.

29. Even excluding the strongly negative elasticities of Malaysia (MYS) and Iraq (IRQ), the relationship is significantly positive in both Figures 2 and 3.

C. An Environmental Assessment of Freer Trade

Taking factor endowments as fixed, a lowering of transport costs or trade barriers raises the value of domestic output and real income in a small open economy. The value of output and the value of income rise by (approximately) the same percentage, and this creates both scale and technique effects. Using the estimates from either Model B or Model C in Table 1, the net effect of a 1 percent change in income created by trade is a 0.8-0.9 percent fall in emissions: that is, using (21) we have $\pi_1 - \pi_3 < 0$. The composition effect of trade for our average country is also negative; that is, from (21) we have $\pi_4 < 0$. Therefore, for an average country in our sample, the full impact of further openness to international trade—through scale, technique, and composition effects—will be a reduction in SO_2 concentrations!

Similar results follow from all of our specifications: the scale elasticity is dominated by the technique elasticity, whereas the trade-induced composition effect of trade is typically small in magnitude.[30] How large a reduction any one country reaps from a fall in trade frictions will, of course, depend on country characteristics, the impact further trade has on domestic income and output, and how the ongoing process of globalization is affecting country characteristics elsewhere in the world. Given that countries will differ somewhat in their particular elasticities, some may indeed be made dirtier from a reduction in trade frictions, but we expect that trade's effect—whether positive or negative—will be small.[31] After all, the estimated impact of even a large trade liberalization on GDP is small, and when this small increase in GDP is filtered through our estimated scale and technique elasticities, the net effect is likely to be smaller still. Although, in theory, trade's impact on the pollution intensity of output can be large, in practice our estimates suggest a much more muted response.

These conclusions, however, rely on our assumption that factor endow-

30. In the Technical Appendix we investigate a two-equation two-stage least-squares (2SLS) fixed-effects model where our city scale measure and pollution are determined simultaneously. We find a scale elasticity in excess of 1, but also a much larger technique elasticity (approaching −2). As a result, our conclusion on their relative magnitude remains unchanged.

31. Averaging across countries and years, the average trade intensity is 41 percent with a standard deviation of 32 percentage points. A one-standard-deviation change in trade intensity is then equal to a 79 percent change in trade intensity from its average value, whereas a one-standard-deviation change in pollution concentrations is equivalent to a 203 percent change from its average value. Using our fixed-effects estimate of the trade intensity elasticity from Table 1, column (6), a 79 percent increase in trade intensity amounts to a 69 percent reduction in pollution concentrations, or about one-third of a standard deviation of pollution concentration. Using the random-effects estimate from column (3) in Table 1, the same one-standard-deviation change in trade intensity amounts to a change of less than one-sixth of the standard deviation in pollution concentration.

ments and technology remain fixed when trade frictions fall. If further trade spurs capital accumulation or brings knowledge spillovers and hastens technological progress, then other calculations must come into play. Whether these trade-induced changes bring about a net improvement in the environment will depend on their estimated size because they have opposing effects on pollution concentrations. There is a burgeoning empirical literature linking openness to growth and technology adoption and we have nothing new to add here. But clearly our estimates, together with input from these other sources, might provide another method for assessing trade's full impact.

D. Alternative Specifications

The results from Table 1 and Figures 2 and 3 suggest that our approach of dividing the determinants of pollution into scale, technique, and composition effects is fruitful. It is, however, important to investigate whether our results are robust to reasonable changes in specification, time period, and so forth. We have conducted numerous sensitivity tests of our specification and report four alternatives in Table 2. Additional results are available in our Technical Appendix, available upon request from the authors. In all columns we amend our full Model C from Table 1 to include other determinants, investigate other time periods, or adopt more flexible specifications.

In columns (1) and (5) we have restricted the time period of our analysis to the years 1976-1991. Before 1976 only a few countries participated and after funding ceased in 1991 country coverage is reduced. To allow for possible data quality and sample selection problems we consider this shorter time period. This shortened period has 489 fewer observations, although as shown in columns (1) and (5) the results are similar both in terms of elasticity estimates and significance levels. Our overall conclusions regarding the relative strength of scale versus technique effects remains, as does the muted response to changes in trade intensity.

In columns (2) and (6) we investigate the importance of other factor endowments. In our parsimonious model of pollution demand and supply "factor endowments" enter directly only through the inclusion of the capital-to-labor ratio. Other potential factor endowments were excluded because, even though they are undoubtedly relevant to income levels, there is little reason to believe that they have an *independent* effect on either the demand for a clean environment or the derived demand for pollution emissions; however, local abundance either in clean or dirty fuels may affect emissions. We investigate this possibility by adding in columns (2) and (6) country-specific measures of hard and soft coal deposits per worker. Over-

Table 2. Sensitivity Tests

Estimation method:	Random effects				Fixed effects			
Model specification:	Time	Factors	FDI	Scale	Time	Factors	FDI	Scale
Variable/column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	−2.545***	−3.141***	−3.650***	−3.635***	−1.697	−4.679***	−4.679***	−4.345***
City economic intensity GDP/km^2	0.068***	0.075***	0.070***	0.154***	0.091*	0.087*	0.092*	0.029
(City economic intensity)^2/1,000	−0.054	−0.275	−0.231		−0.254	−0.329	−0.373	
Capital abundance(K/L)	−0.115	0.289*	0.439***	0.279*	−0.077	0.426*	0.754***	0.489**
(K/L)^2	0.036**	0.012	−0.002	0.010	0.032	0.008	−0.024	0.006
Lagged per capita income	−1.771***	−1.629***	−1.451***	−0.852*	−3.109**	−0.428	−0.981	−0.052
(Income)^2	0.585***	0.717***	0.660***	0.611***	0.512*	0.757***	0.563***	0.564***
(K/L)×(I)	−0.147*	−0.276***	−0.255***	−0.278***	−0.041	−0.401***	−0.297***	−0.400***
Trade intensity TI=(X+M)/GDP	−2.466***	−0.671	−0.198	−0.501	−7.161***	−3.333**	−3.747***	−2.964**
TI×REL.K/L	0.934	−1.758*	−2.879**	−1.890*	1.699	−2.281*	−2.737*	−2.541*
TI×(REL.K/L)^2	−0.876**	−0.252	0.304	−0.142	−1.043**	−0.131	0.811	−0.112
TI×REL.INC.	1.344**	1.167*	1.518**	1.212*	4.495***	3.097***	2.720**	2.677***
TI×(REL.INC.)^2	−0.228	−0.309*	−0.308*	−0.354**	−0.742**	−0.723***	−0.360	−0.617**
TI×(REL.K/L)×(REL.INC.)	0.333	0.803***	0.519	0.784**	0.164	0.922**	0.092	0.993**
Suburban dummy	−0.284	−0.424*	−0.445*	−0.490**				
Rural dummy	−0.519	−0.620	−0.655	−0.730*				
Inward FDI stock/capital stock			0.039				1.234*	
FDI/K×poor countries			4.736				6.314	
FDI/K×rich countries			−0.362				−0.828	
Communist country(C.C.)dummy	−0.971*	−0.326	−0.110	−0.475				
C.C.dummy×income	7.785***	4.602*	4.201	5.668**	16.809***	11.751***	10.271**	9.819**
C.C.dummy×(income)^2	−8.683***	−5.683*	−5.677*	−7.127**	−14.13***	−10.84***	−8.840**	−9.039***
Average temperature	−0.061***	−0.056***	−0.051***	−0.052***	−0.072*	−0.055*	−0.049	−0.062*
Precipitation variation	8.867*	5.859	7.633	5.882	14.298**	10.893*	13.972**	11.471*
Hard coal (per worker)		−0.690				4.217		
Soft coal (per worker)		2.998*				4.120		
Helsinki Protocol	−0.242*	−0.157	−0.092	−0.094	−0.173	−0.054	0.036	0.035
Observations	2066	2555	2525	2555	2066	2555	2525	2555
Groups	274	290	284	290	274	290	284	290
R^2	0.3243	0.3779	0.3684	0.389	0.1677	0.0605	0.1577	0.1337
Log-likelihood	−2030	−2519	−2496	−2512	−2982	−3900	−3858	−3899
Hausman test/Wald χ^2(df)	94.211***	55.536	84.269***	59.331*				
Scale elasticity(all/middle)	0.314***	0.333***	0.318***	0.499***	0.414*	0.388*	0.412**	0.094
Scale elasticity(poor countries)				0.643***				0.355*
Scale elasticity(rich countries)				0.537***				0.598***
Composition elasticity	0.985***	1.008***	1.026***	0.803***	1.442**	0.864*	1.150**	1.056**
Technique elasticity	−1.425***	−1.740***	−1.551***	−1.218***	−2.220***	−1.230**	−1.505***	−1.204**
Trade intensity elasticity	−0.266**	−0.351***	−0.364**	−0.292**	−0.543**	−0.791***	−1.189***	−0.899***
FDI elasticity(poor countries)			0.091				0.143	
FDI elasticity(middle)			0.004				0.121*	
FDI elasticity(rich countries)			−0.039				0.049	

Notes: No standard errors or *t*-statistics are shown. The dependent variable is the log of the median of SO_2 concentrations at each observation site. All model specifications use time fixed effects. Elasticities are evaluated at sample means using the Delta method. Model "Time" includes only the years 1976-1991 of the primary GEMS phase; model "Factors"introduces factor endowment-related variables; and model "FDI" allows for an inward foreign direct investment stock relative to the overall capital stock, interacted with income. The terms rich countries and poor countries refer to the top and bottom 30 percent of countries in the Penn World Tables with respect to per capita GDP.

*Significance at the 95 percent confidence level.
**Significance at the 99 percent confidence level.
***Significance at the 99.9 percent confidence level.

all the results support our earlier conclusions.

Although a greater endowment of high sulfur soft coal leads to more concentrations, at least in the random-effects implementation in column (2), this effect disappears in the fixed-effects estimation in column (6). These results are not surprising: an abundance of soft coal means that countries like China will have higher concentrations, all else equal, but because mineral endowments have very little time series variation they will be well captured by country fixed effects. Consequently, although abundance of high sulfur coal surely adds to emissions, its explicit inclusion has very little effect on our results.

In columns (3) and (6) we investigate the impact foreign direct investment may have on our results. If multinational corporations have common production methods in both developed and developing countries for engineering, quality control, or other reasons, then the pollution intensity of their production will be determined by the income per capita of the source country. As a result, a larger multinational presence in a poor country may mean it is cleaner, all else equal; however, there is an alternative hypothesis working in the other direction. If multinationals locate in poor countries because of their lax environmental protection, then we may instead find a positive relationship between foreign direct investment (FDI) and pollution. To investigate this issue we have calculated for each year and country in our sample the ratio of its inward stock of FDI to its overall capital stock.[32] We refer to this as FDI intensity: it measures the share of the domestic capital stock that may have cleaner than expected techniques of production. We then interact this measure with a categorical variable representing a country's income per capita to allow the multinational effect to differ across rich and poor countries. The results from this exercise are mixed. In the fixed-effects estimation, there is a slight positive relationship between FDI and concentrations for poor, middle-income, and rich countries. Only the middle-income relationship is statistically significant. Moreover, the coefficient estimates imply that a 10 percentage point increase in the *ratio* of the FDI stock to K stock would raise concentrations by about 1 percent. This is a small effect on pollution concentrations arising from a very large change in FDI. In the random-effects estimation, none of the coefficients is significantly different from zero. Overall, we find little relationship between the extent of FDI in an economy (even a poor one) and its pollution level. Again our elasticity estimates are changed only slightly from our earlier specification.

Finally, in columns (4) and (8) we investigate whether our scale effect differs significantly across countries categorized by income per capita lev-

32. In theory we may want to distinguish between acquisitions of brownfields, capacity expansions, and greenfield investments because greenfield investors are perhaps more likely to bring their own plant-specific technology to the foreign country.

els. If there were important nonhomotheticities in production or consumption, or if our method of constructing scale was more appropriate for some income categories than others, this may show up when we allow for disaggregation. The results in column (4) indicate that, whereas separate estimation of scale across income categories tends to raise the overall elasticity estimates to approximately 0.5 or 0.6, the results are very similar to those presented earlier. In column (8) we find similar results for the poor and rich categories, but the middle-income group has a much lower elasticity and it is not precisely estimated. The middle-income group results may be a consequence of the exclusive reliance of fixed effects on the (now smaller) within-group variation for estimation. Despite these caveats, the elasticity estimates, although different across classes, are not significantly different from each other.[33]

E. Alternative Theories: Tariff Substitution and Distributional Motives

In our framework, governments use pollution policy only to target pollution, and not for other purposes, such as to influence the terms of trade or to redistribute income. As a result, the pollution tax is always equal to effective marginal damage, and changes in openness affect our pollution supply curve only through its impact on real income and relative prices. More generally, pollution policy and openness may be linked through other channels if governments use pollution policy for other purposes. To examine this possibility further we need to specify the potential theoretical links involved and then ask what variation in the data such a link would create. There are (at least) two reasons why trade and environmental policies may be linked. Each of these links is probably deserving of a paper-length treatment of both theory and further empirical work, but here our goal is merely to sketch two possibilities and identify their probable impact on our empirical results.

Tariff Substitution.—The first link arises from market power. If countries were large and had complete discretion in setting both trade and pollution policy, then both instruments would be targeted: the tariff would be set at its optimal level according to the inverse elasticity rule, and the pollution tax would equal effective marginal damage as in our small open economy case. But if tariff choices are constrained by international agreements, then governments may find it useful to substitute environmental

33. In our random-effects implementation we can go further and divide the components of our scale measure into population density and contemporaneous GDP/N. Doing so yields an elasticity of concentrations to population density of 0.57; an elasticity with respect to contemporaneous GDP/N of 0.25; and an overall scale elasticity of 0.65. We cannot reject our restriction that both population density and contemporaneous GDP/N share the same elasticity.

policy for trade policy. We will refer to this as the *tariff substitution motive.* To proceed further consider the optimal pollution tax for a large open economy:

(27) $$\tau = T\phi(p,I) + pE_p^*\left(t - \frac{1}{\varepsilon^*}\right)\left|\frac{dp/d\tau}{dz/d\tau}\right|,$$

where ε^* is the elasticity of foreign export supply, E_p^* is the price derivative of foreign export supply, and t is the ad valorem tariff. To highlight the tariff substitution motive, rewrite (27) to obtain the gap between the pollution tax and effective marginal damage:

(28) $$\tau - T\phi(p,I) = pE_p^*\left(t - \frac{1}{\varepsilon^*}\right)\left|\frac{dp/d\tau}{dz/d\tau}\right|.$$

This gap reflects the tariff substitution motive. Consider first a dirty good importer. When the tariff is set at its optimal level, the right-hand side of (28) is zero: each instrument is targeted and there is no tariff substitution motive. If the tariff is constrained to be below its optimal level, then the right-hand side of (28) is negative and a dirty good importer sets the pollution tax below marginal damage to substitute for the tariff. Increased openness therefore induces a loosening of pollution policy that was not accounted for in our empirical work.[34] For a dirty good exporter, a similar argument works in reverse as trade restrictions are reduced below their optimal level, there is an incentive to tighten pollution policy because pollution taxes can be used as a substitute for an export tax. Increased openness in this case leads to a tightening of pollution policy not accounted for in the empirical work.

The Redistribution Motive.—Even if countries are small in world markets, governments may adjust pollution taxes to try to undo the redistribution of income caused by increased openness. We refer to this as the *redistributive motive.* To illustrate this motive, retain our small open economy framework, but now assume Greens and Browns differ in factor ownership, with Browns having greater capital per person than Greens; for simplicity, let $u(I) = \ln(I)$. Then given the government's weight λ on Greens, the pollution tax will be used both to target pollution and also to influence the

34. We know that the gap is zero when tariffs are optimal and is negative when tariffs are zero, so "on average" we expect an increase in openness to widen the gap. However, it should be noted that because the right-hand side of (28) includes the elasticity of foreign export supply, world prices and so forth, the gap between τ and marginal damage may not increase monotonically as tariffs fall.

income distribution. This again yields a gap between the pollution tax and effective marginal damage:

$$\tau - T\phi(p, I) = \frac{\lambda - s}{s(1-s)} G \left| \frac{dp/d\tau}{dz/d\tau} \right|, \tag{29}$$

where s is the share of Greens in national income. Note that if the weight given to Greens exceeds their current share of national income, then the pollution tax is higher than marginal damage. This is because higher pollution taxes lower the producer price of X and raise the real return to labor. Alternatively, if the weight given to Browns is greater than their current income share, the right-hand side of (29) is negative: the pollution tax is set below marginal damage to raise the real return to capital.

Consider the effects of increased openness, starting from the position where $\lambda = s$. In this case, the pollution tax in a dirty good exporting country rises above marginal damage to compensate for the Greens loss in income.[35] Increased openness hurts workers in this case, and the government cushions the blow by tightening the pollution tax to raise wages. For a dirty good importer, the result is reversed: increased openness leads to a loosening of pollution policy to compensate for Browns' loss in income.

Implications of the Theories.—Each theory adds a country-specific unmeasured factor to our simpler determinants of pollution. The factor is a country-type effect, and it is relevant to both a country's degree of openness and its pollution supply curve. In the large-country case, the unmeasured country type is described by its trade pattern and market power; and in the redistributive theory, by its preferred and actual income distribution.

The impact these country-type effects have on our empirical results depends on whether they are time varying. If the country differences are simple level effects and do not vary over time, then our fixed-effects implementation is appropriate, even if country type is correlated with other right-hand-side regressors. If country type is uncorrelated with the right-hand-side variables, then our random-effects estimation is more efficient and still unbiased. On average, countries of different types would have different pollution levels, but they would respond similarly to changes in openness, scale, and so forth. Given that the panel is quite short for many countries, this constant-over-time country-type assumption may be appropriate.

If these country-type effects are time varying, then they will be corre-

35. Let $\Gamma = \tau - T\phi(p, I)$. Then, evaluating at $\lambda = s$, we have $d\Gamma/d\beta = -s_\beta G|s_\tau| / [|z_\tau| s(1-s)] > 0$, because $s_\beta < 0$ (an increase in openness reduces workers' share of income).

lated with our measure of openness. Consequently, our results concerning the effects of further openness and income on pollution may be undermined. To assess whether these motives could be responsible for our results, consider what is left out by our simpler specification. Start with tariff substitution. When tariffs are reduced and openness rises, tariff substitution creates an unaccounted-for upward shift in pollution supply for a dirty good exporter. This leads to *less* pollution than our model would predict. Alternatively, tariff substitution produces an unaccounted-for downward shift in pollution supply for a dirty good importer. In this case, tariff substitution leads to *more* pollution than our model would predict. In both cases, unaccounted-for shifts in supply work against the shift in pollution demand created by further openness. Similarly, the redistributive motive shifts the pollution supply curve up for a dirty good exporter and down for a dirty good importer in response to increased openness. Again, we find that this additional potential determinant of pollution tends to dampen the composition effect created by further openness.

Could tariff substitution or redistribution motives be responsible for the large technique effects we find? Both of these alternative theories lead to an unmeasured positive relationship between pollution and openness for some countries. Therefore, it is difficult to see how the omission of either of these two additional determinants would manifest itself in a stronger measured negative relationship between income and pollution.

These two alternative theories, however, do suggest a smaller (than we would otherwise predict) change in the composition of output created by a fall in trade frictions. As such, another interpretation of our findings of a small trade-induced composition effect is that governments may be simultaneously dampening the impact of increased openness on pollution with compensating changes in pollution taxes. To disentangle the additional shifts in pollution supply suggested by either theory from the other effects in our data would require us to obtain information on changes in both tariff levels and pollution regulations over time for many countries in our sample; or employ knowledge about the preferred and actual income distribution in many countries over time. But good cross country and time-series data on pollution regulations and trade protection are unavailable, and the preferred income distribution is unobservable. These two alternative theories are perhaps best examined within a single country context where data on regulations, tariffs, and income distribution are available.[36]

36. We discuss here the extreme case where pollution policy is the only available instrument. There are many other instruments (such as production subsidies), which are a better substitute for a tariff; and similarly there are many other instruments (such as income transfers), which can redistribute income. To the extent that these other instruments are available, then the dampening shift in pollution supply that we find above will be less relevant.

4. Conclusions

This paper investigates how openness to trading opportunities affects pollution concentrations. We started with a theoretical specification highlighting scale, technique, and composition effects and then showed how this theoretical decomposition is useful in thinking about the relationship between openness to international markets and the environment. In our empirical section we adopted a specification directly linked to our earlier theory. We then estimated this specification, paying special attention to the potentially confounding influences introduced by the panel structure of our data set. Our results consistently indicate that scale, technique, and composition effects are not just theoretical constructs with no empirical counterparts; rather, these theoretical constructs can be identified and their magnitude measured. Moreover, once measured they can play a useful role in determining the likely environmental consequences of technological progress, capital accumulation, or increased trade. These estimates may also be useful in aggregate CGE modeling of the effects of various free trade agreements and other trade reforms (see, e.g., Michael J. Ferrantino and Linda A. Linkins (1996)).

Our work is distinguished by the endogeneity of pollution policy and the close connection we have tried to draw between theory and empirical estimation. Although it represents a useful first step toward answering our title's question, it is clearly not the last. The benefits of our approach are transparency, simplicity, and explicitness. We have presented an explicit model of trade and pollution and we have moved from theory to empirical estimation in a transparent manner. Transparency immediately leads to suggestions for extension along both theoretical and empirical lines. Simplicity means additional questions can be addressed within our framework. And the benefit of presenting an explicit pollution demand-and-supply model is that researchers should now be drawn to deeper questions concerning endogeneity, omitted variables, and sample selection. We view this paper's attempt at integrating theory with empirical work as its major contribution to ongoing research in this area.

Several extensions seem natural. One cost of reduced-form estimation is that structural parameters remain hidden. Reduced-form estimation was essentially forced on us by the lack of data on regulations in many developing countries. If we adopt similar methods but restrict the sample to industrialized countries, we could then employ measures of pollution stringency as proxies for pollution regulations. With data on both the quantity and "price" of pollution, the identification of structural parameters seems possible. A shift to a narrower set of countries with more detailed data may also allow us to examine the tariff substitution and redistributive motives we discussed, but did not estimate, here. Finally, our method for adding up scale, composition, and technique effects could be enhanced by direct estimates of the income gains brought about by trade liberalization, and improved by explicit consideration of foreign direct investment and technology transfer.

As with any empirical exercise some questions remain unanswered, but overall our estimates indicate that increases in a country's exposure to international markets create small but measurable changes in pollution concentrations by altering the pollution intensity of national output. Although our estimates indicate that greater trade intensity creates only relatively small changes in pollution via a composition effect, economic theory and numerous empirical studies demonstrate that trade also raises the value of national output and income. These associated increases in output and incomes will then exert an impact on pollution concentrations via our estimated scale and technique effects. Our estimates of the scale and technique elasticities indicate that, if openness to international markets raises both output and income by 1 percent, pollution concentrations fall by approximately 1 percent. Putting this calculation together with our earlier evidence on composition effects yields a somewhat surprising conclusion with regard to sulfur dioxide: freer trade is good for the environment.

Appendix A. Proof of Propositions

Proof of Proposition 1

Use (17) and (18), and hold *T, S, I, K/L*, and p^w constant:

$$\hat{z} = \left[(1+a)\varepsilon_{\varphi,p} + \varepsilon_{e,p/\tau}\right]\hat{\beta} - \left[a\varepsilon_{\varphi,p} + \varepsilon_{e,p/\tau}\right]\hat{\tau}$$
$$= \left[\varepsilon_{\varphi,p} + \left(a\varepsilon_{\varphi,p} + \varepsilon_{e,p/\tau}\right)\left(1-\varepsilon_{MD,p}\right)\right]\hat{\beta}.$$

Using Roy's identity, we can show that $\varepsilon_{MD,p}$ is equal to the share of x in consumption (note that when calculating this elasticity, real income I is held constant, and so we obtain a pure substitution effect). Hence, $\varepsilon_{MD,p} < 1$, and z rises as β rises. For a dirty good exporter, increased openness corresponds to an increase in β, and hence all else equal, a reduction in trade frictions raises pollution. For a dirty good importer, a reduction in trade frictions lowers β, and pollution falls.

Proof of Proposition 2

Note $z = -R_\tau$ (where $R_\tau = -eR_{p^N}$ and $R_{\tau\tau} > 0$). Then

$$dz = -\left[R_{\tau\tau}d\tau + p^w(1-\theta)R_{\tau p^N}d\beta\right]$$
$$= R_{\tau\tau}\left[p^w \left.\frac{d\tau}{dp}\right|_z d\beta - d\tau\right],$$

where the last step follows from differentiating $z = -R_\tau$, holding z constant. Next eliminate $d\tau$ by differentiating (10), noting that $I = G/(N\rho)$ and that $dG = p^w(1-\theta)\, R_{p^N}\, d\beta + \tau dz$. Rearranging and converting to elasticity form yields

$$\frac{dz}{d\beta} = \left[\frac{p}{\tau}\frac{d\tau}{dp}\bigg|_z - \varepsilon_{MD,p} + \varepsilon_{MD,I}\frac{pM}{G} \right] \Big/ H,$$

where M is imports of X and H is a positive expression. From the proof of Proposition 1, $\varepsilon_{MD,p} < 1$. But $(p/\tau)(d\tau/dp)|_z > 1$ because $z = ex$ and e is decreasing in τ/p. (An increase in p raises x, and so to keep z constant, we need τ/p to rise.) Hence, if $M > 0$, then $dz/d\beta > 0$ and so increased openness reduces pollution for a dirty good importer (β falls). For a dirty good exporter, $M < 0$ and β rises when openness rises. From the proof of Proposition 1, $\varepsilon_{MD,p}$ is the share of X in consumption, and so with $\varepsilon_{MD,I} \leq 1$, we have

$$\frac{dz}{d\beta} > \left[\frac{p}{\tau}\frac{d\tau}{dp}\bigg|_z - \frac{px}{G} \right] \Big/ H > 0,$$

where $px/G < 1$ is the share of X in output at domestic prices. So pollution rises for a dirty good exporter if $\varepsilon_{MD,I} \leq 1$. Finally, if $\varepsilon_{MD,I}$ is sufficiently large, the sign of $dz/d\beta$ is reversed for a dirty good exporter and pollution falls as openness rises.

Proof of Proposition 3

For a given p and I, Home's relative demand $RD(p)$ is fixed. For given p and I, the unit input coefficients given in (6) are fixed, and hence χ approaches infinity as κ rises. Consequently, there exists a $\underline{\kappa}$ such that for $\kappa > \underline{\kappa}$, χ exceeds relative demand, and Home exports X. The increase in pollution via the trade-induced composition effect follows from Proposition 1.

Proof of Proposition 4

The relative producer price of X is $p^N < p(1-\theta) - \tau e(1)$, where $e(1) > 0$. Because $\varepsilon_{MD,I} > \varepsilon > 0$, τ increases without bound as income rises given (18). Moreover, θ rises from (4), and hence there exists some I for which p^N falls to 0, in which case X output is 0. The relative demand for X is, however, independent of income. Hence for sufficiently large I, Home must import X and export Y. The fall in pollution from the trade-induced composition effect follows from Proposition 1.

Proof of Proposition 5

Define trade intensity as the value of exports plus imports at world prices (excluding transportation services). Using the trade balance constraint,

$$\mathrm{TI} = 2p^w \frac{|M_x|}{p^w(1-\theta)x + y},$$

where M_x is imports of X. Consider first an importer of X ($M_x > 0$). Let $G^w = p^w(1 - \theta)x + y$, and $G = \beta p^w(1 - \theta)x + y$. By homotheticity, we can write the demand for X as $D^x = h(p)G$. Letting $\delta^x = p^w D^x/G^w$, and $\varphi = p^w(1 - \theta)x/G^w$, we have $\mathrm{TI} = 2(\delta^x - \varphi)$. With some rearranging, we can write

$$\delta^x = p^w h[1 + (\beta - 1)\varphi].$$

Then

$$\begin{aligned}\frac{1}{2}\frac{\partial TI}{\partial \beta} &= \frac{\partial \delta^x}{\partial \beta} - \frac{\partial \varphi}{\partial \beta} \\ &= \frac{(p^w)^2}{G^w}\left[\left.\frac{\partial D^x}{\partial p}\right|_u - \frac{\partial D^x}{\partial G}M_x\right] + [p^w h(\beta - 1) - 1]\varphi_\beta < 0,\end{aligned}$$

where we have used the Slutsky decomposition. Note that the substitution effect in demand is negative ($\partial D^x/\partial p|_u < 0$) and the income effect ($\partial D^x/\partial G$) is positive, so the bracketed term involving demand changes is negative. As well, $p^w\beta h < 1$ from the consumer's budget constraint, and $\varphi_\beta > 0$ (an increase in β shifts production toward X) and so the last term is negative as well. Thus $\partial \mathrm{TI}/\partial\beta < 0$ for an importer of X. Hence a fall in β (a movement toward 1) increases trade intensity. For an exporter of X, one can proceed most simply by replacing $|p^w M_x|$ with imports of Y, M_y in the definition of trade intensity and following a similar analysis as earlier to conclude that an increase in β (a movement toward 1) raises trade intensity.

Appendix B. Data Set Description

The dependent variable in our study is the concentration of sulfur dioxide at observation sites in major cities around the world as obtained through the GEMS/AIR data set supplied by the World Health Organization. Measurements are carried out using comparable methods. Each observation station reports annual summary statistics of SO_2 concentrations such as the median, the arithmetic and geometric mean, as well as 90th and 95 th percentiles.

We have chosen to use a logarithmic transformation of the median SO_2 concentration as our dependent variable. The distribution of concentrations is highly skewed toward zero when viewed on a linear scale. As was pointed out in the WHO (1984) report about the GEMS/AIR project, concentrations are more suitably described by a lognormal distribution with a number of observations concentrated at the measurement threshold of the measurement devices. There is also an ambient level of SO_2 in the air that has natural causes.

A large share of observations were from the United States because of this country's extensive network of air quality measurement stations. Other large contributor countries were China, Canada, and Japan. Many of the other observation stations provided short or discontinuous streams of data while participating in the GEMS/AIR project. All in all, our analysis is based on over 2,600 observations from 293 observation stations in 109 cities around the world; these cities are located in 44 countries.

The primary source for our data is the *AIRS Executive International Database* that contains information about ambient air pollution in nations that voluntarily provide data to the GEMS/AIR program sponsored by the United Nations World Health Organization.[37] We had problems with the identification of several observation stations. The longitude and latitude information provided in one of the ancillary files was in some cases incorrect and was corrected case by case based on the description of the location.

Additional data sources for our regressors include the *Penn World Tables*[38] for macroeconomic data, the *World Investment Report*[39] for inward FDI stock data, the CIESIN *Global Population Distribution Database*[40] for

37. This package is available from the United States Environmental Protection Agency (US-EPA) at http://www.epa.gov/airs/aexec.html. The US-EPA kindly provided a much more complete version of this data set that included not only averages but also median and other percentiles of SO_2 concentrations. We would like to express our gratitude to Jonathan Miller of the US-EPA for providing additional GEMS/air data not contained in the public release of the data base, and for patiently answering our numerous technical questions.

38. Robert Summers and Alan Heston, "The Penn World Table (M5): Expanded Set of International Comparisons, 1950-1988." *Quarterly Journal of Economics,* May 1991, 106(2), 327-68. Available in revision 5.6 from the Center for International Comparisons at the University of Pennsylvania at http://pwt.econ.upenn.edu/.

39. United Nations Centre on Transnational Corporations, 1992 and 1999 volumes.

40. This data set from the Consortium for International Earth Science Information Network (CIESIN) is available only for 1990. It can be obtained freely from the United Nations Environmental Programme server maintained by the U.S. Geological Survey at http://grid2.cr.usgs.gov/globalpop/ l-degree/description.html.

population density data, the World Resources Institute *World Resources Database*[41] for natural resources and physical endowments, and data from the *Global Historical Climatology Network*[42] (GHCN) for weather conditions at the observation stations. Yet more time series were obtained for tariff and nontariff trade barriers[43] and educational attainment.[44]

Summary statistics for the major variables appear in Table B1. Some of the variables warrant further explanation. First, our scale measure of economic activity GDP per square kilometer is calculated by multiplying a country's real per capita GDP ($/person) with each city's population density (people/km^2). Extrapolations for per capita GDP were carried out for the years past 1993 based on real growth rates obtained from the IMF/IFS statistics. Population densities were available only for 1990.

Table B1. Summary Statistics

Variable	Dimension	Number of observations	Mean	SD	Min	Max
Log of SO_2	$\log_{10}$(ppm)	2,555	−2.112	0.481	−3.000	−0.939
City economic intensity	$m per km^2	2,555	0.790	0.878	0.010	5.934
GDP per capita(current)	$10k	2,555	1.478	0.862	0.109	2.718
Population density	1,000 people/km^2	2,555	0.063	0.055	0.001	0.276
Capital abundance(adjusted)	$10K/worker	2,555	5.612	2.497	0.829	17.189
Capital abundance(unadjusted)	$10K/worker	2,555	3.207	1.763	0.130	7.750
Education attainment	0-1 range	2,555	0.540	0.226	0.088	0.799
GNP per capita, 3-yr average	$10k	2,555	1.396	0.815	0.111	2.635
Communist country(C.C.)	[—]	2,555	0.125	0.331	0.000	1.000
C.C.× income	$10k	319	0.302	0.208	0.127	0.716
Trade intensity$(X+M)$/GDP	[—]	2,555	0.409	0.322	0.088	2.617
Relative(K/L)(adjusted)	World=1.00	2,555	1.357	0.605	0.203	4.174
Relative income	World=1.00	2,555	2.500	1.392	0.221	4.138
Inward FDI stock/capital stock	[—]	2,555	0.106	0.250	0.001	2.193
Average temperature	℃	2,555	14.689	5.600	2.617	28.967
Precipitation coefficient of variation	[—]	2,555	0.011	0.006	0.001	0.054
Hard coal reserves	GJoule/worker	2,555	0.040	0.043	0.000	0.146
Soft coal reserves	GJoule/worker	2,555	0.038	0.052	0.000	0.348

Notes: All monetary figures are in 1995 U.S. dollars. The interaction term for income with the Communist countries dummy shows the case only where the dummy is equal to 1; thus the mean for this line is the mean for the Communist countries only.

41. *World resources 1998-1999: A guide to the global environment*, Oxford: Oxford University Press, 1998.

42. Information is available on monthly average temperatures, monthly precipitation, and atmospheric pressure. The raw data and description file are available from the National Climatic Data Center of the U.S. National Oceanic and Atmospheric Administration at ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/.

43. See Jeffrey D. Sachs and Andrew M. Warner: "Economic Convergence and Economic Policies." National Bureau of Economic Research (Cambridge, MA) Working Paper No. 5039, February 1995.

44. These figures were obtained from Robert J. Barro and Jong-Wha Lee's (1994) study, available from the NBER website at http://www.nber.org/pub/barro.lee/ZIP/.

The capital abundance (K/L) of countries was obtained from the physical capital stock per worker variable in the Penn World Tables. We have adjusted this series for human capital by applying a 0-1 average education index (in which 1 represents 16 years of schooling) obtained from the Barro/Lee data set. Relative capital abundance is obtained by dividing each country's capital abundance by the corresponding world average for the given year, where "world average" is defined by all the countries in the Penn World Tables.

Our income (I) variable is the three-year average of lagged GNP per capita. This addresses two problems. First, contemporaneous income and the level of pollution may be determined simultaneously. Lagged income, however, is exogenous. Second, it is reasonable to assume that income changes translate only slowly into policy changes. We therefore smooth out some of the variation introduced through business cycles and include three years of data. (We also experimented with longer lags, without much effect on our results.) More concretely, for a given year t we compute $I_t = (y_{t-1} + y_{t-2} + y_{t-3})/3$. Relative income is constructed in the same fashion as our relative capital-abundance measure. GNP figures were obtained by adjusting GDP figures with a GNP/GDP correction factor obtained from the International Monetary Fund's *International Financial Statistics.* However, such correction factors were unavailable for the former Czechoslovakia, Egypt, Hong Kong, Iraq, Peru, Poland, and the former Yugoslavia. Unadjusted GDP figures were used in these cases.

The data on foreign direct investment (FDI) were obtained as percentages of the stock of inward FDI relative to GDP, and interpolated where necessary. These figures were then divided by GDP to capital stock ratios obtained from the Penn World Tables to obtain the percentage of inward FDI stock relative to a country's entire capital stock.

The suburban and rural location type dummy variables are from the original GEMS/AIR data set. The third (default) location type is central city. Our trade intensity measure is calculated as the sum of exports and imports expressed as a percentage of gross domestic product. The Communist country dummy used in our study identifies the following countries: China, Czechoslovakia, Poland, and Yugoslavia. The country dummy for the Helsinki Protocol identifies Austria, Belgium, Bulgaria, Canada, Czechoslovakia, Denmark, Finland, France, Germany, Hungary, Italy, Luxembourg, The Netherlands, Norway, and Switzerland, in the years after 1985.

For the purpose of calculating sample-mean elasticities we used averages of the relevant variables calculated as follows. An average country value for variable X is calculated by first averaging X's values over time for each country, and then averaging across countries. This procedure gives equal weight to all countries.

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Program

March 22-24, 1998

Kobe University, Kobe

8:45-9:00	**Welcome Address** Seiichi Katayama, Organizer (Kobe University)
	Opening Address Ken-ichi Ishigaki, Director of RIEB (Kobe University)
Session 1.	Sunday, March 22, 1998 9:00-12:15 Chair: Yasuhiro Sakai (Tsukuba University)
9:00-9:55	Satya Das (Indian Statistical Institute) "Trade and Personal Distribution of Wealth and Income :Beyond the Stolper-Samuelson Theorem" Discussant: Shunpei Takemori (Keio University)
10:10-11:05	Sajal Lahiri (University of Essex and Osaka) "Export-Oriented Foreign Direct Investment and Local Content Requirement" Discussant: Kotaro Suzumura (Hitotsubashi University)
11:20-12:15	Tatsuo Hatta (Osaka University) "A Theory of Optimum Tariff under Revenue Constraint" Discussant: Takashi Fukushima (Tokyo Metropolitan University)
12:15-2:15	**Lunch Break**
Session 2.	Sunday, March 22, 1998 2:15-5:30 Chair: Michihiro Ohyama (Keio University)
2:15-3:10	Brian Copeland (University of British Columbia) "Trade and the Environment: Theory and Empirical Results"

	Discussant: Makoto Tawada (Nagoya City University)
3:25-4:20	James Levinsohn (University of Michigan) “Merger Policies and Trade Liberalization” Discussant: Fumio Dei (Kobe University)
4:35-5:30	Jonathan Eaton (Boston University) “Technology and Bilateral Trade” Discussant: Keith Maskus (University of Colorado)
Session 3.	Monday, March 23, 1998 9:00-12:15 Chair: Tadashi Inoue (Hosei University)
9:00-9:55	Michihiro Ohyama (Keio University) “International Adjustment under Capital Mobility” Discussant: Yoshiyasu Ono (Osaka University)
10:10-11:05	Carsten Kowalczyk (Tufts University) “Trade, Transfers, Developing Countries, and the Core” Discussant: Noritsugu Nakanishi (Kobe University)
11:20-12:15	Keith Maskus (University of Colorado) “Is Small Beautiful? Trade Shares and Trade Creation with Differentiated Products” Discussant: Brian Copeland (University of British Columbia)
12:15-2:15	**Lunch Break**
Session 4.	Monday, March 23, 1998 2:15-5:30 Chair: Kotaro Suzumura (Hitotsubashi University)
2:15-3:10	Wilfred Ethier (University of Pennsylvania) “Unilateralism in a Multilateral World” Discussant: Koji Shimomura (Kobe University)
3:25-4:20	Alan Deardorff (University of Michigan) “Fragmentation in Simple Trade Models” Discussant: Makoto Yano (Keio University)
4:35-5:30	Ronald Jones (University of Rochester) “Trade, Technology, and Income Distribution” Discussant: Michihiro Ohyama (Keio University)

5:45-7:30	**Conference Party** Second Floor of New Kanematsu Building Rokkodai Campus, Kobe University
Session 5.	Tuesday, March 24, 1998 9:00-12:15 Chair: Kazuo Nishimura (Kyoto University)
9:00-9:55	Yuka Ohno and Kaz Miyagiwa (Rice University and Kobe University) “Nuclear Bombs and Sanctions” Discussant: Jota Ishikawa (Hitotsubashi University)
10:10-11:05	Ngo Van Long (McGill University) “Protection, Lobbying, and Market Structure” Discussant: Sajal Lahiri (University of Essex and Osaka)
11:20-12:15	Wolfgang Mayer (University of Cincinnati) “Endogenous Corrections of Economic Policies under Majority Voting” Discussant: Motoshige Ito (University of Tokyo)
	Closing Address Kaz Miyagiwa, Co-organizer (Kobe University)

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