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The Effect of Globalization in a Semi Endogenous Growth Model with Firm Heterogeneity, Endogenous International Spillover, and Trade*

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Abstract

We construct a semi endogenous growth model with firm heterogeneity, endogenous international spillover, and international trade and investigate the effects of further exposure to trade on R&D difficulty and welfare. Further exposure has ambiguous effects on R&D difficulty, increases when the sunk cost for foreign market is strictly greater than for domestic market and intertemporal spillover is sufficiently large, and decreases when the sunk costs for both markets are the same or the intertemporal spillover is small. We find unambiguously positive effect on welfare because the positive effects of the rises in the weighted average of productivity and the reduction in R&D costs through international spillovers strictly dominates the negative effects of increases in R&D costs through greater competition.

JEL Classication: F12, F15, O30, O33

Keywords: heterogenous firms, endogenous international spillover, semi endogenous growth model

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Abstract

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1. Introduction

Gains from trade have always been one of the important topics in international trade, and subject of many empirical and theoretical studies. International trade affects the economy through many channels[2]. First, new varieties imported from abroad increased welfare by 2.6 % of GDP between 1972 and 2001 (see Broda and Weinstein, 2006). Second, as trade reallocates resources from the less productive to the more productive exporting or non-exporting firms by shutting down the less productive firms and increasing exports, industrial productivity rises see Bernard, Jensen, and Schott, 2006)[3]. Finally, imports convey international knowledge spillover among the trade partners in the R&D sector. Put differently, the amount of international spillover is

[2] See Feenstra (2010) and Melitz and Trefler (2012) for a survey of gains from trade.
[3] Melitz (2003) construct a monopolistic competition model with firm heterogeneity which is consistent with this empirical evidence.

endogenous, not exogenous see Coe and Helpman, 1995). Following these empirical papers, Baldwin and Robert-Nicoud (2008) and Unel (2010) investigate the influence of globalization on growth rates and welfare in a model with firm heterogeneity, international trade, and endogenous international spillover. The effect of globalization on growth is ambiguous because there are conflicting positive and negative effects, caused by the increase and the reduction in R&D costs through greater competition and international spillover. The effect of globalization on welfare is also ambiguous because there are conflicting positive and negative effects represented by an ambiguous growth effects and an increases in the weighted average of productivity among firms. These papers do not derive parameter conditions for the gains from trade.

These papers have a strong scale effect that is inconsistent with the empirical evidence given by Jones (1995a, 1995b) which shows empirically that although R&D researchers in the OECD countries increased dramatically, the growth rate did not change between the 1960s and 1990; that is, the member of researchers did not affect the growth rate. Jones (1995 a) incorporates the diminishing returns to knowledge in the R&D sector into a first generation R&D growth model developed by Romer (1990), Segerstrom, Anant, and Dinopoulos (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), and constructe a semi-endogenous growth model. Many related papers construct semi-endogenous growth models with firm heterogeneity but have an exogenous international spillover, which is inconsistent with the empirical research by Coe and Helpman (1995). Gustafsson and Segerstrom (2010) analyze the effect of globalization on R&D difficulty (the number of varieties produced in each country) and welfare in a semi-endogenous growth model with firm heterogeneity, international trade, and exogenous international spillover. The effect of further exposure to trade is negative on R&D difficulty due to a rise in R&D costs caused by greater competition, and the effect on welfare is ambiguous because there are conflicting effects of rises in R&D costs and in the the weighted average of productivity. Dinopoulos and Unel (2011) analyze the effect of globalization on growth rates and welfare in a fully endogenous growth model with firm heterogeneity, international trade, and exogenous international spillover. Fukuda (2012) analyzes the effect of opening trade on R&D difficulty and welfare in a semi-endogenous growth model with firm heterogeneity and international trade, and no scale effect but exogenous international spillover. The effect of exposure to trade is ambiguous on R&D difficulty because R&D costs fall through exogenous international spillover and rise from greater competition. Though the weighted average of productivity among the production firms rises the ambiguous effect on R&D costs leaves the net effect on welfare ambiguous.

The objective of this paper is to construct a semi-endogenous growth model with firm heterogeneity, international trade, and endogenous international spillover consistent with the empirical results cited, and to investigate the effect of globalization on R&D difficulty and welfare. The effect of reduction of iceberg costs on R&D difficulty is ambiguous. This is because the positive effects of reduction in R&D costs through endogenous international spillover may be offset by the negative effect of an increase in R&D costs by more competition through importing. But the effect of greater exposure to international trade on welfare is unambiguously positive. This is because the positive effects of endogenous international spillover and the rise in the weighted average of productivity among the active firms more than offsets the negative effect of an increase in R&D costs caused by more competition through importing from abroad.

The rest of the paper is organized as follows: In section 2, we describe and explain the model. In section 3, we offer our concluding remarks.

2. The Model

2.1 Basic model structure

There are two symmetric countries. Each consumer supplies inelastically one unit of labor in each period. Labor is the only production factor, grows at the rate of population growth and serves as the numeraire. There are monopolistically competitive goods and perfectly competitive R&D sectors. In the former sector, the firms are heterogeneous with regard to marginal cost, which is drawn from a Pareto distribution. To enter each a market, each firm has to incur a sunk cost for drawing a marginal cost, and then chooses entering by incurring the sunk cost for each market. Exporters face iceberg costs as well. Thus, each firm is classified as a production firms (exporting and domestic firms) or a shutdown firms. In the R&D sector, there are diminishing returns to knowledge and the growth rate in a steady state is pinned down by parameters, as in Jones (1995 a). We follow Baldwin and Robert-Nicoud (2008) and Unel (2010) who assume endogenous international spillovers consistent with Coe and Helpman (1995) and who assume an exogenous domestic knowledge spillover in autarky and there are endogenous international knowledge spillovers as well in the open economy.

2.2. Consumer

The consumer is a representative agent. Each consumer supplies inelastically one unit of labor in each time period. The total amount of labor supplied equals the size of the population. Thus, labor supply can be denoted by $L_t = L_0 e^{nt}$, where n denotes the population growth rate. The consumer earns incomes from his or her assets and labor, and chooses the path of consumption expenditure and assets so as to maximize the sum of his or her discounted value of utility. The intertemporal utility function is given by $u(c_t) = \int_0^{\infty} \log c_t e^{-(\rho-n)t} \mathrm{d}t$, where c_t is a per capita consumption index which depends on the consumption of a continuum of varieties, given by $c_t = \left(\int_{\Omega_t} (x_{Lt}(i))^{\frac{\sigma-1}{\sigma}} \mathrm{d}i + \int_{\Omega_t} (x_{Et}(i))^{\frac{\sigma-1}{\sigma}} \mathrm{d}i\right)^{\frac{\sigma}{\sigma-1}}, \sigma > 1,$ where Ω_t is the set of varieties that can be consumed, $x_{Lt}(i)$ ($x_{Et}(i)$) the individual demand for the i-th variety produced domestically (produced abroad and exported), and ρ the individual's subjective discount rate. The per capita inter-temporal budget constraint is $\dot{s}_t = r_t s_t + w_t - e_t$, where s_t is the per capita assets, r_t the rate of return on assets, w_t the wage, and e_t the per capita expenditure. Solving the dynamic optimization problem implies that $\frac{\dot{e}_t}{e_t} = r_t - \rho$. Static optimization yields the demand for each variety, given by $x_t(i) = \frac{p_j(i)^{-\sigma}}{(P_t)^{1-\sigma}} e_t L_t,\ j = L, E,$ where $P_t = \left(\int_{i\in\Omega} [p_L(i)]^{1-\sigma} \mathrm{d}i + \int_{i\in\Omega} [p_E(i)]^{1-\sigma} \mathrm{d}i\right)^{\frac{1}{1-\sigma}}$ is the price index, $p_L(i)$ the price of varieties produced domestically, and $p_E(i)$ the price of the varieties produced abroad and exported.

2.3 Innovation

We next explain firm behavior. For firms to enter the market, they have to pay the sunk cost of variety creation $b_{It} F_I$, where $b_{It} \equiv \frac{1}{(m_t)^{\phi}[1+(B_E/B_L)^k]^{\phi}}$ represents the unit labor requirement for knowledge creation, $(\frac{B_E}{B_L})^k (m_t)^{\phi}$ the international knowledge spillover, m_t the number of varieties produced, and $\phi < 1$ the measure of intertemporal knowledge spillover[4]. These assumptions follow Baldwin and Robert-Nicoud (2008). This assumption is consistent with the empirical findings of Coe and Helpman (1995). As time passes by, R&D researchers learn to generate knowledge more efficiently, and the unit labor requirement will be lower. Then they find the unit labor requirement for manufacturing from a Pareto distribution, given by $G(B) = (\frac{B}{\bar{B}})^k$, where $1 + k - \sigma > 0$. To enter the market, each firm has to pay the domestic and exporting sunk costs, given by $b_{It}F_L$ and $b_{It}F_E$, respectively. For one unit of good entering the domestic and exporting markets, 1 and τ units of goods, respectively, must be transported. Firms with unit labor requirement $B > B_L$ exit the market immediately. Firms with unit labor requirement $B_E < B < B_L$ enter the domestic market. Firms with unit labor requirement $B < B_E$ enter the both markets.

2.4 Product Market

If a firm with unit labor requirement B enters the market, the firm earns profits $\pi_{Lt}(B) = p_{Lt}(B)x_{Lt}(B) - Bx_{Lt}(B)$. The profit-maximizing price is given by $p_{Lt}(B) = \frac{\sigma B}{\sigma-1}$. Thus, the profit function can be given by $\pi_{Lt}(B) = \frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}B^{1-\sigma}e_tL_t}{(P_t)^{1-\sigma}}$. Given consumer expenditure and the price index, the profit function monotonically decreases according to the level of the unit labor requirement for manufacturing. For a firm to export one unit of a good, the firm must produce $\tau > 1$ units, and the profit-maximizing price would be $p_{Et}(B) = \frac{\tau\sigma B}{\sigma-1}$. Thus, the profit function for exporting is given by $\pi_{Et}(B) = \frac{\tau^{1-\sigma}\sigma^{-\sigma}(\sigma-1)^{\sigma-1}B^{1-\sigma}e_tL_t}{(P_t)^{1-\sigma}}$. A consumer has two methods to accumulate assets: firm shares and riskless bonds. The rate of return on the former type of assets depends on dividends and capital loss (gain). The latter type comes from the interest. In equilibrium, the two rates of return are equalized. Thus, the following no-arbitrage condition holds: $\frac{\pi_{jt}(B)}{V_{jt}(B)} + \frac{\dot{V}_{jt}(B)}{V_{jt}(B)} = r_t,\ j = L, E$. This equation determines the value of a firm serving the market as a function of the level of its unit labor requirement. The cost associated with serving the domestic market is $b_{It}F_L$. Thus, the local cutoff B_L is determined as follows:

[4] Unel (2010) assume that international knowledge spillover depends on the value of total trade relative to the value of intermediate goods produce domestically.

$$V_{Lt}(B_L) = \frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}(B_L)^{1-\sigma}e_tL_t}{(P_t)^{1-\sigma}(r_t+\phi g)} = b_{It}F_L, \tag{1}$$

where $g \equiv \frac{\dot{m}_t}{m_t}$. Similarly, there exists a foreign cutoff B_E satisfying

$$V_{Et}(B_E) = \frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}(B_E)^{1-\sigma}e_tL_t}{(P_t)^{1-\sigma}(r_t+\phi g)} = b_{It}F_E. \tag{2}$$

Using the two cut off conditions (1) and (2), we obtain the cutoff ratio as a function of the iceberg costs and the ratio of the second stage sunk costs $\frac{B_E}{B_L} = \left(\frac{\tau^{1-\sigma}F_L}{F_E}\right)^{\frac{1}{\sigma-1}} < 1$. We follow Helpman, Melitz, and Rubinstein (2008), Burstein and Melitz (forthcoming), and Dinopoulos and Unel (2011, 2012) in that $F_E \geq F_L$.

2.5 Innovation Incentives

A firm does not know its own productivity before entering the market, and decides whether to enter or not by weighing its ex-ante value and the expected R&D sunk cost. Due to free entry and exit, and the constant returns to scale technology in R&D, the free-entry condition is

$$\frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}\Delta e_tL_t}{(P_t)^{1-\sigma}(r_t+\phi g)} = b_{It}\bar{F}. \tag{3}$$

The left-hand side of (3) is the expected excess benefit from creating a new variety and the right-hand side of (3) is the expected cost for creating a new variety; $\Delta \equiv \int_0^{B_L} B^{1-\sigma}\frac{g(B)\mathrm{dB}}{G(B_L)} + \tau^{1-\sigma}\int_0^{B_E} B^{1-\sigma}\frac{g(B)\mathrm{dB}}{G(B_L)} = \frac{k(B_L)^{1-\sigma}\Phi}{1+k-\sigma}$ is the weighted average of productivity, $\bar{F} \equiv \frac{F_I}{G(B_L)} + \int_0^{B_L} F_L\frac{g(B)\mathrm{dB}}{G(B_L)} + \int_0^{B_E} F_E\frac{g(B)\mathrm{dB}}{G(B_L)} = F_I\left(\frac{\bar{B}}{B_L}\right)^k + F_L\Phi$ is the expected cost of a producing firm's creating a new variety, and $\Phi \equiv 1 + \tau^{-k}\left(\frac{F_E}{F_L}\right)^{\frac{\sigma-1-k}{\sigma-1}}$ measures increase in R&D costs owing to globalization or the rise in competition due to importing. The first term of R&D cost is the cost of choosing the unit labor requirement for manufacturing equal to or less than the cutoff domestic market level. The second term of the last equation is the beachhead cost for the domestic market and the final term of the last equation is the sunk beach head cost for the foreign market.

The production function for a new variety is given by $\dot{m}_t = \frac{L_R}{b_{It}\bar{F}}$, where L_R represents the R&D researchers. R&D technology can be written as $\frac{\dot{m}_t}{m_t} = \frac{(\chi)^{\phi}}{z_t\bar{F}}\frac{L_R}{L_t}$, where $z_t \equiv \frac{(m_t)^{1-\phi}}{L_t}$ is the R&D difficulty and $\chi \equiv 1 + \tau^{-k}\left(\frac{F_E}{F_L}\right)^{\frac{k}{\sigma-1}} > \Phi$ measures the degree of endogenous international spillover. In the steady-state equilibrium, the growth rate of variety depends only on exogenous parameters, given by $g = \frac{n}{1-\phi}$ as in Jones (1995, a).

2.6 Full Employment Condition

The labor market is perfectly competitive, and it is used for R&D or manufacturing and the full employment condition is $L_t = L_R + L_x$ where $L_x = \int_0^{B_L} Bx_L(B)\, m_t \frac{g(B)\mathrm{dB}}{G(B_L)} + \tau\int_0^{B_E} Bx_E(B) m_t \frac{g(B)\mathrm{dB}}{G(B_L)}$ is the labor used for manufacturing. The price index is given by $(P_t)^{1-\sigma} = m_t\left(\sum_{j=L,E}\int_0^{B_j} P_{jt}(B)^{1-\sigma}\frac{g(B)\mathrm{dB}}{G(B_L)}\right) = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} m_t\Delta,\ \ j = L, E.$

2.7 Solving the Steady State

Substituting the free-entry condition, costs for creating a new variety, the weighted average of the unit labor requirement of production firms, and the Pareto distribution into the local cut-off condition yields the unique solution of the local market cutoff level, determined by $\frac{1+k-\sigma}{k\Phi} = \frac{F_L}{F_I\left(\frac{\bar{B}}{B_L}\right)^k + F_L\Phi}$. The closed-form solution of the local cut-off level is given by

$$B_L = \left(\frac{(1+k-\sigma)F_I}{(\sigma-1)F_L}\right)^{\frac{1}{k}} \Phi^{\frac{-1}{k}}\bar{B}. \tag{4}$$

The domestic market cutoff level is the same as with the exogenous international spillover economy type given by Baldwin and Robert-Nicoud (2008) and Gustafsson and Segerstrom (2010). We follow the explanation given by Furusawa and Konishi (2012). A decrease in the iceberg cost leads to more competition due to imports from abroad, and leads to a lower demand for each variety and higher demand for labor due to numeraire. Thus, a variety with lower productivity cannot serve the domestic market.

We now turn to derive the closed-form solutions for per capita expenditure and R&D difficulty. We obtain the first relationship between per capita expenditure and R&D difficulty from full employment, which becomes becomes $1 = \frac{\sigma-1}{\sigma} e + \frac{gkF_L\Phi}{1+k-\sigma} \frac{z}{\chi^{\phi}}$. The full employment condition is represented by line a with negative slope line that starts in the positive in (e, z) plane, because an increase in e implies a larger number of manufacturing firms and a lower value of z a smaller number of researchers to maintain the equality. We obtain the second relationship between per capita expenditure and R&D difficulty from the free-entry condition $\frac{e}{\sigma(\rho+\phi g)} = \frac{kF_L\Phi}{1+k-\sigma} \frac{z}{\chi^{\phi}}$. The free-entry condition is an upward sloping curve that starts at the origin of the (e, z) plane, because an increase in e implies a larger benefit from creating a new variety and associated costs. Using these conditions, the closed-form solutions of per capita expenditure and R&D difficulty are given by $e = \frac{\sigma(\rho+\phi g)}{g+(\sigma-1)(\rho+\phi g)}$ and $z = \frac{(1+k-\sigma)\chi^{\phi}}{kF_L[g+(\sigma-1)(\rho+\phi g)]\Phi}$, respectively. In this model, the unit cost of knowledge creation depends negatively on the amount of imports due to endogenous international spillover. It affects the labor devoted to R&D activity and the costs for creating a new variety in the free-entry condition by exactly the same amount. Thus, labor allocation is the same as in the the exogenous international spillover case analyzed by Gustafsson and Segerstrom (2010). Thus, per capita expenditure does not depend on the iceberg cost.

2.8 Comparative Statistics

We next explain R&D difficulty and the labor allocation following further trade liberalization. We first examine its effect on R&D difficulty. We obtain higher R&D knowledge spillover from a foreign country and an increase in R&D cost by increasing the value of firms, which in turn increases the cost of creating a new variety through decreasing the domestic cutoff level and increasing the exporting cutoff level to satisfy cutoff conditions. The condition for an increase in R&D difficulty by further exposure to trade is given by

$$1 > \phi \geq \frac{\left(\frac{F_E}{F_L}\right)^{\frac{\sigma-1-2k}{\sigma-1}} + \tau^{-k}\left(\frac{F_E}{F_L}\right)^{\frac{\sigma-1-k}{\sigma-1}}}{1 + \tau^{-k}\left(\frac{F_E}{F_L}\right)^{\frac{\sigma-1-k}{\sigma-1}}}$$

where $\sigma - 1 - 2k < 0$. R&D difficulty increases by further exposure to international trade when the intertemporal spillover is large and the sunk cost for the foreign market is strictly greater than that for the domestic market and decreases when the intertemporal spillover is sufficiently low or the sunk cost for the domestic market is equal to that for the foreign market. This is because there is a positive effect through international spillover, which depends on intertemporal spillover and a negative effect of an increase in R&D cost through changes in cutoff points, which does not depend on intertemporal spillover. This result differs from that in an exogenous international spillover case analyzed by Gustafsson and Segerstrom (2010), where further exposure to international trade raises the R&D cost and leads to lower R&D difficulty.

We next analyze the welfare effects caused by further exposure to international trade. For this, we represent welfare, given by

$$c_t = \frac{e}{P_t} = \frac{(\sigma - 1)e}{\sigma(m_t \Delta)} = \nu \chi^{\frac{k\phi}{k(\sigma-1)(1-\phi)}} \Phi^{\frac{\sigma-1-\phi(k+\sigma-1)}{k(\sigma-1)(1-\phi)}}$$

where $\nu \equiv \frac{(\sigma-1)(\rho+\phi g)[(1+k-\sigma)L_t]^{\frac{1}{(\sigma-1)(1-\phi)}}}{(\bar{B})[g+(\sigma-1)(\rho+\phi g)]^{1+\frac{1}{(\sigma-1)(1-\phi)}}} \left(\frac{k(\sigma-1)F_L}{(1+k-\sigma)^2 F_I}\right)^{\frac{1}{\sigma-1}}$.

We next represent the comparative globalization statics on welfare as follows:

$$-\frac{dc_t}{d\tau} > 0$$

$$\Leftrightarrow k\phi \left(\frac{F_E}{F_L}\right)^{\frac{k}{\sigma-1}} \left[1 - \left(\frac{F_E}{F_L}\right)^{\frac{\sigma-1-2k}{\sigma-1}}\right] + (\sigma - 1)(1 - \phi) \left[1 - \left(\frac{F_E}{F_L}\right)^{\frac{k}{\sigma-1}}\right] > 0$$

The globalization effects on welfare are positive because R&D difficulty is affected ambiguously but the weighted average of productivity among the active firms is affected positively, and the latter effect unambiguously outweighs the former effect when the former effect is negative. This result is different from that in an exogenous international spillover economy because in that case welfare may increase or decrease following globalization and the positive effect of increasing the weighted average of productivity may or may not be outweighed or not by the negative effect of decreases in R&D difficulty. The difference in these results depends both on the exogenous or endogenous international spillover and scale variant or invariant model. The effect of globalization on R&D difficulty is different from Gustafsson and Segerstrom (2010) because there are positive effects of increases in the weighted average of productivity among the production firms and negative effects of increases in R&D costs following trade liberalization in their models. The effect of globalization on welfare is also different from Gustafsson and Segerstrom (2010) because there are positive and negative effects of increases in the weighted average of productivity among the active firms and increases in R&D costs, and because the former effect is larger or smaller than the latter effect. The latter result is also different from Baldwin and Robert-Nicoud (2008) and Unel (2010) because the responses of welfare to globalization are ambiguous due to ambiguous effects of growth rate and increases in productivity among the production firms in Baldwin and Robert-Nicoud (2008) and Unel (2010). Moreover, they do not derive conditions for gains from trade.

3. Conclusions

We construct a growth model with firm heterogeneity, endogenous international spillover, international trade, and no scale effect. We investigate the effects on R&D difficulty and welfare following globalization. We find ambiguous effects on R&D difficulty, which increases when the sunk cost for the foreign market is strictly greater than that for the domestic market and the intertemporal spillover is sufficiently large, and decrease when sunk costs for both markets are the same or the intertemporal spillover is small. We also find an unambiguous positive effect on welfare because the positive effects of increases in the weighted average of productivity and reductions in R&D costs through international spillover strictly dominates the negative effect of increases in R&D costs through greater competition from imports. The former result is different from Gustafsson and Segerstrom (2010), who examine the effect of globalization on R&D difficulty and welfare in a semi-endogenous growth and exogenous international spillover model, because in their model there is only a negative effect of increases in R&D costs through greater competition. The latter result is different from Gustafsson and Segerstrom (2010) because globalization has an ambiguous effect on welfare due to conflicting effects: the negative effect of increases in R&D costs, which depends on the size of intertemporal spillovers, and the positive effect of increases in the weighted average of productivity among the active firms. Moreover, the second result is different from Baldwin and Robert-Nicoud (2008) and Bulent (2010), because there are ambiguous effects of growth rate and positive effects of increases in the weighted average of productivity among the active firms.

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