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Matthew A. COLE

Robert J.R. ELLIOTT

Toshihiro OKUBO

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Research Institute for Economics and Business Administration

Kobe University

2-1 Rokkodai, Nada, Kobe 657-8501 JAPAN

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Matthew A. Cole[1], Robert J.R. Elliott[1] and Toshihiro Okubo[2]
[1]Department of Economics, University of Birmingham, UK
[2]Research Institute for Economics and Business Administration, Kobe University, Japan

Abstract

In recent years there has been a dramatic increase in the number of firms shifting stages of their production processes overseas. In this paper we investigate whether firms outsource the dirtier stages of production to minimise domestic environmental regulation costs – a process broadly consistent with the pollution haven hypothesis. We develop a theoretical model of environmental outsourcing that focuses on the roles played by firm size and productivity, transport costs and environmental regulations. We test the model's predictions using a firm-level data set for Japan and do find evidence of an 'environmental outsourcing' effect.

JEL: F18, F23, L51, L60, Q56, R3

Keywords: Environmental regulations, trade, outsourcing, outsourcing, firm-level.

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1. Introduction

The complex relationship between international trade and the environment has been thoroughly investigated in recent years often with differing conclusions drawn (Antweiler *et al.* 2001, Cole and Elliott 2003, Frankel and Rose 2005 and Lovely and Popp 2011). Central to the debate in the popular press is the concern that stringent environmental regulations in developed countries damage the competitiveness of firms. If true, it is claimed that the result will be pollution 'leakage' as pollution intensive firms either physically relocate to low regulation economies or are simply displaced by similar firms in low regulation countries. A large number of studies have examined this proposition, commonly referred to as the Pollution Haven Hypothesis (PHH), either by studying foreign direct investment (FDI) patterns (see e.g. Eskelund and Harrison 2003 and Cole *et al.* 2006) or net trade patterns (see e.g. Ederington *et al.* 2005). The findings of this literature are decidedly mixed. [1]

In this paper we address an aspect of the PHH that has been ignored within the trade-environment literature to date, the notion of outsourcing; that is the increasing tendency of firms to subcontract parts of their production process to other firms that are often based overseas. Outsourcing has received considerable attention in the trade literature with studies such as Feenstra and Hanson (1999) and (2006), Grossman and Helpman (2005), Grossman *et al.* (2005), Hsieh and Woo (2005) and Tomiura (2007) typically focusing on the potential positive impact of outsourcing on domestic firm productivity. However, neither this literature, nor the trade-environment literature, has made

[1] A related literature looks directly at the impact of environmental regulations on productivity (see for example Aiken *et al.* 2009 and Greenstone *et al.* 2011).

reference to the possibility that firms may outsource the pollution intensive parts of their production process as a means of avoiding stringent domestic regulations.[2]

There are several reasons why it may be helpful to examine the impact of regulation costs on outsourcing as opposed to net trade or FDI patterns. First, with regard to net trade patterns, it is clear that international outourcing would influence, and be included within, such net trade patterns and these patterns have been examined at industry-level in the previous literature (see for example Ederington *et al*. 2005). However, it is quite likely that the specific impact of a firm's outsourcing would be highly diluted within an industry's overall net export figures. If outsourcing turns out to be a direct mechanism through which firms respond to changes in regulation costs then this may be missed if the focus is on overall trade patterns at the level of the industry, perhaps explaining the relatively weak evidence of pollution have effects provided by the net trade literature. With regard to FDI, a number of attempts have been made to theoretically explain the various factors that may make a firm choose between outsourcing and FDI. Attention has typically focused on the roles played by incomplete contracts, the thickness of markets, the cost base of the firm and strategic considerations more generally (Grossman and Helpman 2003 and Spencer 2005). Regarding the latter, Leahy and Montagna (2009) go as far as to argue that *ex ante* identical firms may choose

[2] The international trade literature regularly refers to the concept of 'offshoring' (e.g. Grossman and Rossi 2008) and several recent papers have attempted to address whether the US is 'offshoring', or displacing, its pollution (Kahn 2003 and Levinson 2010). It should be noted that such offshoring captures all firm activity undertaken abroad and hence the offshoring of pollution refers to pollution emanating from all of these activities. These activities include FDI, joint ventures and arms length trade with affiliates and non-affiliates. International outsourcing however refers only to arms length trade between firms where parts of the production process are undertaken by unrelated firms abroad. Outsourcing is therefore a much more precise concept than offshoring. The studies that do look at US offshoring also do so at the level of the industry rather than the firm and all seem to find no evidence that the US has been systematically offshoring pollution.

different internationalization options (i.e. FDI or outsourcing) purely as a result of strategic considerations. To some extent this literature is in its infancy, with little by way of strong empirical evidence to support the various assertions as to how firms choose between these different avenues of internationalization. Given this uncertainty, and the presence of increasing trends of both FDI and outsourcing, there seems no reason to necessarily assume that firms' environmental regulation costs will necessarily affect their decisions whether or not to undertake FDI in the same way as the decision to undertake international outsourcing. While several studies have examined the impact of such costs on FDI flows, none has yet examined the impact on outsourcing. The specific focus in this paper is therefore on firm-level international outsourcing and the theoretical and empirical mechanisms through which it may be influenced by environmental regulation costs.[3]

We therefore believe this to be the first paper to consider the link between outsourcing and the environment and believe it provides a clean mechanism for indentifying pollution haven consistent effects. To introduce the concept of environmental outsourcing we first build a model of outsourcing with heterogeneous firms that concentrates on the roles played by firm size and productivity, transport costs and environmental regulations. We then test the model's predictions using Japanese firm-level data. Japan provides an excellent setting in which to test our model given the considerable levels of outsourcing and FDI undertaken by Japan in recent years. Significant parts of the Japanese supply chain now occur overseas, particularly in China and other developing Asian economies. The Japanese economy is also increasingly dependent on imports of intermediate

[3] While firms may undertake domestic or international outsourcing, our focus is on international outsourcing given the fact that regulatory differences between Japan and many developing economies are likely to be much greater than any regulatory differences within Japan. For the remainder of the paper we use the term outsourcing to refer to international outsourcing (although we do consider domestic outsourcing in our sensitivity analysis).

goods. Our analysis of over 12,000 Japanese firms reveals evidence to support the existence of environmental outsourcing and hence provides evidence consistent with a pollution haven effect although transport costs remain a significant deterrent to this process.

This paper has potentially important policy implications. First, the net effect of environmental outsourcing is likely to be detrimental to the global environment if production that formerly occurred within the highly regulated Japanese economy now occurs in countries with less stringent regulations where production techniques are less clean. However, even if the environmental costs and benefits in the home and foreign country cancel out, outsourcing is still likely to lead to a net increase in pollution due to the increase in the transportation of goods around the world.

It is clear that any equitable climate change policy will need to address outsourcing as a possible transmission mechanism for pollution 'leakage'. For example, the Chinese government may object to pressure from the West to reduce emissions if a proportion of these emissions are as a result of supplying dirty intermediate goods to Western firms especially if the final product is then exported back to China. It is important that we understand these potentially complex trading relationships when designing climate change policy.

More positively, the implications for a country of increasing environmental regulations may be less severe than first thought. Instead of firms relocating or closing down in light of an increase in environmental regulations firms may simply adjust to a change in their cost structure and outsource. Whilst this will involve job losses in the intermediate good production there may be more high skilled jobs created in the headquarters or other domestic plants following an increase in overall production and profitability. Indirectly, these new jobs could be considered as part of the much heralded 'green jobs' revolution.

The remainder of the paper is structured as follows: Section 2 provides some theoretical considerations and presents our model. Section 3 outlines our empirical methodology and data while Sections 4 and 5 provide empirical results and conclusions respectively.

2. Theoretical Considerations and Model

To our knowledge this is the first paper to theoretically model firm-level environmental outsourcing. The current international trade literature models a relationship between export behavior and productivity in the presence of firm heterogeneity, so-called heterogeneous-firm trade models (see e.g. Melitz, 2003 and Helpman *et al.* 2004). The recent proliferation of trade models based on heterogeneous firms was motivated in part by the empirical studies on firm size, productivity and export behavior by Tybout and Westbrook (1995), Bernard and Jensen (1995, 1999), Bernard *et al.* (2003), Aw *et al.* (2000), Pavcnik (2002) and Eaton *et al.* (2004).

The recent trade literature has begun to pay more attention to outsourcing. Grossman and Helpman (2002 and 2005) and Antras (2003) use the incomplete contract model of Grossman and Hart (1986) to model global outsourcing and intra-firm trade. The main issue relates to firm boundaries and the decision to outsource versus the decision to integrate foreign intermediate production processes within overall production processes.

Empirically, the main contribution to date has been to consider the relationship between outsourcing and productivity, with a positive correlation often found. Research includes Egger and

Egger (2006) for a sectoral analysis in the EU, Amiti and Wei (2005, 2009) for service sector offshoring in US and Daveri and Jona-Lasinio (2008) for the case of Italy. For Japan, a body of research has emerged that uses similar firm-level data to our own to consider the relationship between productivity and outsourcing (see e.g. Tomiura 2005, 2007 and 2008, Wakasugi *et al.* 2008 and Hijzen *et al.* 2010).

In this paper our focus is on whether firms facing stringent environmental regulations outsource production to foreign countries or simply maintain domestic production but pay the abatement costs associated with the resulting pollution. A key feature of our model is marginal cost differences due to different labor productivities across firms with the result that more productive firms make greater profits. In our model firms face a trade-off between incurring abatement costs when all stages of the production process are undertaken domestically and the costs of outsourcing a dirty stage of the production process which are the transport costs for the re-import of the intermediate good and some fixed costs associated with finding a suitable foreign producer and maintaining and supervising this arms length activity.

Our focus is on the characteristics of outsourcing firms in the presence of environmental regulations. In contrast to previous studies we are not therefore concerned about issues relating to the impact of trade liberalisation on entry or exit; productivity issues; or issues relating to the number of exporters and the effects on profits. Thus our model is intentionally simple in order to highlight outsourcing when firms are heterogeneous. First, for simplicity we assume a small open economy (Home) and the rest of the world where all firms are exporters with the assumption of no export fixed costs. Hence, we make no distinction between local producers (non-exporters) and exporters; second, we assume no entry or exit (no non-producers), no dynamic effects (no growth), and no R&D

investment stage before operation. The environment is introduced by an assumption that abatement costs are incurred by a firm in response to government regulation in the Home country. Finally, we assume that firms can outsource any part of their production processes by paying an outsourcing fixed cost and trade costs associated with importing the intermediate dirty product for final product assembly in the Home country. The key results of our simple model persist even if we abandon these simplifications and add more factors to be closer to Melitz (2003) and Helpman, Melitz and Yeaple (2004).

Our model is a heterogeneous-firm model with environmental regulations and outsourcing within a Dixit-Stiglitz monopolistic competition framework. Firms are heterogeneous in labor productivity. In equilibrium we have two types of firm. First, firms that emit pollution as a by-product of the production process and are required to pay abatement costs in order to meet government set environmental regulations (abatement firms). Second, firms that outsource part of the production process to mitigate the need to pay abatement costs (outsourcing firms).

Our model explains why and how firms could potentially outsource their dirty production stage and the competing factors that make domestic production with abatement costs more attractive than outsourcing.

Basic model

Suppose we have M sectors, $m = 1 \ldots M$ where each sector, m, has a number of varieties, i. The demand side of our model has a representative consumer who has the following utility function:

$$U = \prod^{M} C_m^{\theta_m} \text{, where } C_m = \left(\int_{i \in \Theta} c^{1-1/\sigma} di \right)^{1/(1-1/\sigma)}, \qquad \sigma > 1 \quad 1 > \theta_m > 0 \tag{1}$$

which is a Cobb-Douglas function across sectors and is a CES function across varieties in each sector, *m*. θ_m is expenditure share on sector *m* goods, c_i is consumption of the variety *i* and Θ is the set of all varieties consumed. σ denotes the constant elasticity of substitution between any two varieties.

Firm heterogeneity comes only from the supply side. Labor and capital (human or physical) are the only two factors of production. Each firm requires one unit of capital fixed costs and requires *a* units of labor as a variable cost.[4] As variable *a* is firm specific it follows that labor productivity, given as *1/a,* differs across firms (heterogeneous productivity). Hence, each firm has a firm-specific marginal cost (labor requirement). For a firm *j*, the marginal costs are given as the wage rate, *w*, multiplied by a firm-specific labor requirement, a_j. Note that *w* is measured at the national or sectoral level whilst *a* is firm specific. Assume *a* is *a priori* exogenously distributed subject to a probability density function.

To introduce the environment into the model we assume that each firm has a pollution intensive production process which incurs an abatement cost in order to satisfy government regulations. As long as firms domestically operate all stages of the production process then they are required to pay abatement costs which are defined as *D* units of labor per unit of output (marginal abatement costs) and *A* unit of labor per firm (fixed abatement costs). Thus, total abatement costs (TAC) can be written as $wA_m + wD_m x_{mj}$. Average (per-unit) abatement costs are hence $\frac{wA_m}{x_{mj}} + wD_m$, where x_{mj} is

[4] Our two-factor model adopts the cost function of Martin and Rogers (1995). In keeping with Martin and Rogers our model does not allow for entry and exit because the capital endowment is limited and one unit of capital creates one firm. As a result of the entry and exit assumption all pure profits can be considered as capital returns.

output for firm *j*. For simplicity suppose *D* and *A* are identical across firms but differ across sectors although in reality pollution intensive sectors are more likely to be strictly regulated or require the payment of higher abatement costs and hence will have larger *D* and/or larger *A*. The implication of our model is that as labor productivity increases so does output so that TAC increases while per-unit abatement costs decrease.

In sum, total costs including abatement costs for firm *j* in sector *m* are given by $TC_{mj} = \pi_j + wa_j x_{mj} + w(A_m + D_m x_{mj})$, where the first term is fixed costs, requiring one unit of capital and thus π_j denotes the (per-firm) capital reward, the second term encompasses the variable costs while the final term relates to the abatement costs incurred. As this is a simple model we abstract from an endogenous firm distribution, thus assuming away any dynamic factors such as entry and exit, R&D investment before operation, the survival rate of firms and economic growth. This simplification allows us to focus on the relationship between labor productivity (size), environmental regulations and outsourcing.

Abatement firms

Assume a small open economy (Home) that trades with a range of Foreign countries ($s = 1 \ldots S$). Our focus is on the Home economy. Utility maximization results in a CES demand function. Consumption of the variety produced by firm *j* in sector *m* in the Home country is given by:

$$c_{mj} = \frac{p_{mj}{}^{-\sigma} \theta_m E}{P_m{}^{1-\sigma}}; \quad P_m \equiv \left(\int_{i\in\Theta} p_{mi}^{1-\sigma} di + \sum_{s=1}^{S} \phi \int_{h_s\in\Theta} p_{mh}^{1-\sigma} dh_s \right)^{1/(1-\sigma)}, \ \phi \equiv t^{1-\sigma} \tag{2}$$

where E is the total expenditure on all varieties and P is the CES price index, where i is varieties produced domestically and h_s are the (imported) varieties produced in a Foreign country s. Trade costs, $t\,(\geq 1)$, are of the traditional iceberg type. The freeness of trade, ϕ, is defined as $\phi \equiv t^{1-\sigma}$. This implies that free trade, t = 1, can be expressed as ϕ = 1 whereas ϕ = 0 represents autarchy (t = ∞). Without loss of generality we assume identical trade costs for each foreign country. Likewise, the consumption of the variety produced by Home firm j by a representative firm s is given by:

$$c_{mj}^{s} = \frac{(tp_{mj})^{-\sigma}\theta_m E^s}{(P_m^s)^{1-\sigma}}; \quad P_m^s \equiv \left(\phi\int_{i\in\Theta} p_{mi}^{1-\sigma}di + \sum^{S-1}\phi\int_{h\in\Theta} p_{mh}^{1-\sigma}dh + \int_{h_s\in\Theta} p_{mh_s}^{1-\sigma}dh_s \right)^{1/(1-\sigma)} \tag{3}$$

where E^s is total expenditure and P_m^s is the CES price index in country s, where the first term is the number of imported varieties into a Foreign country s from Home, the second term refers to imports from other Foreign countries (S-1 countries) and the third term refers to domestically produced products. Dixit-Stglitz monopolistic competition implies (consumer) prices in the Home and a representative Foreign country s for firm j with labor requirement a_j produced in Home are given by:

$$p_{mj} = \frac{(a_j + D_m)w}{1-1/\sigma} \quad \text{and} \quad p_{mj}^s = tp_{mj} = \frac{t(a_j + D_m)w}{1-1/\sigma} \tag{4}$$

We note that higher productivity (lower a_j) firms charge lower prices and have a higher demand for their product. The operating profit, which is the capital reward, and the output for a representative firm (in the Home country) can be obtained by utilizing (2), (3) and (4) to give:

$$\pi_m(a_j) = \left(B_m + \sum_{s=1}^{S}\phi B_m^s \right)\frac{\theta_m}{\sigma} p_{mj}^{1-\sigma} - wA_m = \left(B_m + \sum_{s=1}^{S}\phi B_m^s \right)\frac{\theta_m}{\sigma}\gamma^{1-\sigma}\left((a_j + D_m)w\right)^{1-\sigma} - wA_m \tag{5}$$

where;

$$B_m \equiv \frac{E}{P_m^{1-\sigma}}, \quad B_m^s \equiv \frac{E^s}{(P_m^s)^{1-\sigma}}, \quad \gamma \equiv \frac{1}{1-1/\sigma}$$

and

$$x_m(a_j) = \left(B_m + \sum_{s=1}^{S} \phi B_m^s \right) \theta_m p_{mj}^{-\sigma} = \left(B_m + \sum_{s=1}^{S} \phi B_m^s \right) \theta_m \gamma^{-\sigma} \left((a_j + D_m) w \right)^{-\sigma} \tag{6}$$

Two important features are central to the following analysis. First, all firms earn positive operating profits when abatement costs are moderate.[5] Second, the highest labor productivity firms with a_j=0, i.e. the firms with the lowest labor requirement and thus low marginal cost and lowest price, are the most profitable and are hence the largest producers. Thus more productive (smaller *a*) firms sell more domestically and export more.[6] Likewise, less labor intensive and relatively more capital intensive firms are more profitable (i.e. smaller labor requirement a_j).

We define the capital-labor ratio as the ratio of capital rewards to all wage payments including abatement costs:

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[5] Remember that the model has a condition to ensure no entry or exit. Even without abatement costs, all firms can always operate and thus no exit occurs because the least productive firms always make positive pure profits. However, once we take abatement costs into account, to guarantee positive profits for all firms we need to assume that abatement costs *A* and *D* satisfy: $\pi_m(1) = \left(B_m + \sum_{s=1}^{S} \phi B_m^s \right) \frac{\gamma^{1-\sigma}\theta_m}{\sigma} \left((1+D_m) w \right)^{1-\sigma} - wA_m > 0$.

[6] The level of exports is given by; $\text{export} = \left(\sum_{s=1}^{S} \phi B_m^s \right) \theta_m p_{mj}^{1-\sigma} = \left(\sum_{s=1}^{S} \phi B_m^s \right) \theta_m \gamma^{1-\sigma} \left((a_j + D_m) w \right)^{1-\sigma}$

$$KL(a_j) \equiv \frac{\pi(a_j)}{w(a_j + D_m)x_j + wA_m} = \frac{\left(B_m + \sum_{s=1}^{S} \phi B_m^s\right)\frac{\theta_m \gamma^{1-\sigma}}{\sigma}\left((a_j + D_m)w\right)^{1-\sigma} - wA_m}{\left(B_m + \sum_{s=1}^{S} \phi B_m^s\right)\frac{\theta_m \gamma^{1-\sigma}}{\sigma}\left((a_j + D_m)w\right)^{1-\sigma} + wA_m} \tag{7}$$

Differentiating equation (7) we get $\frac{dKL}{da_j} < 0$. Hence, $\frac{d\pi}{dKL} > 0$.

Now we consider firm-level pollution. We assume that a given stage of the production process emits a level of pollution and, in the face of government regulation, firms have to pay abatement costs. We assume that for abatement firms, one unit of production emits z units of pollution.[7] Thus, total emissions for firm j, $G(x_{mj})$, can be written simply as $G(x_{mj}) = zx_{mj}$

Hence, total emissions increase with firm size and productivity. Total abatement costs are therefore given by:

$$TAC_m(a_j) = w(A_m + D_m x_{mj}) = wA_m + wD_m\left(B_m + \sum_{s=1}^{S} \phi B_m^s\right)\theta_m \gamma^{-\sigma}\left((a_j + D_m)w\right)^{-\sigma} \tag{8}$$

As $\sigma>1$, emissions are inversely proportional to a_j. Hence, larger firms have higher emissions and thus incur greater TACs.

[7] The government regulations set z per unit of output *a priori*. To satisfy z, firms pay abatement costs which when paid reduces z to zero.

Outsourcing firms

We now allow firms to outsource part of the production process which will reduce emissions and hence allow the firm to avoid the payment of abatement costs. If firms outsource their emission intensive production process to a foreign country, which for simplicity is assumed to have no environmental regulations, then the pollution intensive production process is relocated outside of the firm. As a result, outsourcing firms are no longer subject to [1] abatement costs associated with a pollution intensive production process, i.e. $D=0$ and $A=0$ and wages w for domestic production. However, in the absence of abatement expenditure and pollution production, the firm incurs, [2] trade costs from foreign outsourcing $\tau_m > 1$ and a foreign wage which we assume is lower than Home, $w^* < w$ and [3] fixed costs related to the costs associated with the monitoring and supervision of the foreign supplier, O_m. When the benefits of outsourcing [1] exceed the costs [2] and [3] then a firm will decide to outsource.

To be precise, outsourcing incurs two types of cost, per-unit intermediate import costs of $\tau_m w^*$ (> 1) and a fixed cost O_m. For simplicity, import costs consist of the trade costs associated with importing intermediate products and the wage in the foreign countries.[8] By outsourcing the dirtiest part of the production process firms can avoid the production costs associated with this part of production costs (a decrease in the labor requirements D) and avoid having to pay the corresponding abatement costs. Thus, the marginal costs for outsourcing firms are $\tau_m w^* + a_j w$. Labor productivity increases (i.e. marginal costs decrease) with outsourcing,

[8] Without loss of generality we assume the wage in the foreign country is normalized to unity and intermediate goods are produced under perfect competition and constant return to scale in the foreign country.

$\tau_m w^* + a_j w < (a_j + D_m)w$ and is supported by the empirical evidence that suggests outsourcing significantly enhances firm (labor) productivity (Egger and Egger 2006, Amiti and Wei 2005 and 2009). On the other hand, outsourcing requires additional fixed supervisory costs. To be more precise we assume that $O_m > A_m$. Hence, although marginal costs are lower due to lower foreign wages and what we assume to be relatively low trade costs, outsourcing can involve fairly high supervision costs.

Profits and output for outsourcing firms are given by:

$$\pi_m^o(a_j) = (B + \sum_{s=1}^{S} \phi B^s) \frac{\theta_m \gamma^{1-\sigma}}{\sigma} (\tau_m w^* + a_j w)^{1-\sigma} - wO_m \tag{9}$$

and

$$x_m^o(a_j) = (B + \sum_{s=1}^{S} \phi B^s) \gamma^{-\sigma} (\tau_m w^* + a_j w)^{-\sigma} \tag{10}$$

Note that profit and production decreases in a_j and are thus positively related to labor productivity as is the case for the non-outsourcing abatement firms discussed above.

Two types of firms

We assume that there is a cut-off level of a_j after which an abatement firm will begin to outsource which we denote as a_o. For $\pi_m^O(a_o) = \pi_m(a_o)$ the cut-off level between abatement and outsourcing firms a_o is determined so a firm will choose higher profits. Using (5) and (9), the profit gap between outsourcing firms and abatement firms is given as:

$$\pi_m^O(a_j) - \pi_m(a_j) = (B + \sum_{s=1}^{S} \phi B^s) \frac{\gamma^{1-\sigma}\theta_m}{\sigma}((a_j w + \tau_m w^*)^{1-\sigma} - (a_j w + D_m w)^{1-\sigma}) - (wO_m - wA_m) . \quad (11)$$

The cut-off a_o is determined by $\pi_m^O(a_0) - \pi_m(a_0) = 0$.[9] We can now derive some key outcomes and testable hypotheses.

First, considering size we show that differentiating (11) we get $\frac{\partial(\pi^O - \pi)}{\partial a_j} < 0$ which indicates that as firms become larger they are more likely to outsource. [10] Since large firms are more likely to export we also expect a positive relationship between exporting status and outsourcing. Second, in terms of the capital-labor ratio, the capital intensity of a firm is increasing as a_j falls. Hence, we get $\frac{\partial(\pi^O - \pi)}{\partial KL} > 0$ inferring that capital (or R&D) intensive firms are more likely to outsource. With reference to environmental regulations (our key variable) we can show that $\frac{\partial(\pi^O - \pi)}{\partial A_m} > 0$ and $\frac{\partial(\pi^O - \pi)}{\partial D_m} > 0$ so that more stringent regulations incur higher (total and/or marginal) abatement costs meaning that a firm is more likely to outsource. Relating to transport costs we can demonstrate that $\frac{\partial(\pi^O - \pi)}{\partial \tau_m} < 0$ which means that higher trade costs associated with the import of the intermediate product reduces the incentive to outsource. Finally we consider wages and show that $\frac{\partial(\pi^O - \pi)}{\partial w} > 0$ so that given our assumption that *D* is not large (see footnote 5) we expect that

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[9] In our model $(\tau_m w^* + a_j w)^{1-\sigma} > (a_j w + D_m w)^{1-\sigma}$ always holds as long as $O_m > A_m$ and $\pi^O - \pi = 0$ holds for a certain *a*. If $O_m < A_m$ then all firms outsource because $\pi^O - \pi^A > 0$. To keep our case interesting we assume that $O_m > A_m$.

[10] In more detail: $\frac{\partial(\pi^O - \pi)}{\partial a_j} = \frac{\gamma^{1-\sigma}\theta_m E}{\sigma P^{1-\sigma}}(1-\sigma)w\{(a_j w + \tau w^*)^{-\sigma} - (a_j w + D_m w)^{-\sigma}\} < 0$ because $(a_j + D_m)w > a_j w + \tau w^*$ and $\sigma > 1$.

the higher the wage in the Home country the more likely firms are to outsource. Note that the marginal change in *A*, *D*, τ and *w* happens only in the Home country. The model assumes that there are a large number of foreign countries and thus the marginal change in *A*, *D*, τ and *w* in Home never affects the price indices in *B* and B^S in $\pi^O - \pi$.

To illustrate the relationship between outsourcing and abatement figure 1 plots profit in terms of productivity *1/a* and illustrates how the cut-off allows us to distinguish between our two types of firm.

4. Data and Methodology

In the empirical section of this paper we utilize a firm-level dataset entitled *Kigyou Katsudou Kihon Chousa Houkokusho* (The Results of the Basic Survey of Japanese Business Structure and Activities) from the Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry (MITI). This dataset provides information on over 22,000 Japanese firms for the years 1996 to 2000 although our variables of interest are available for only 12,335 firms for 1998 and 1999. To be eligible for inclusion in the survey firms must have more than 50 employees and capital of more than 30 million Yen. Firms are then selected to be representative. The dataset provides detailed information on the activities of each firm including whether or not they outsource activities overseas. Crucially, the dataset also includes information on firms' environmental activities discussed in more detail below.

To investigate which firm level characteristics are correlated with the decision to outsource we express the odds, or likelihood, that a firm undertakes outsourcing as the ratio of the probability that outsourcing will be undertaken (Pr) to the probability that it will not be undertaken (1-Pr). We estimate a logistic transformation of this ratio, the logit of Pr, defined as:

$$\text{logit}\left[\Pr\left(OUTSOURCE\right)=1\right]=\log\left(\frac{\Pr}{1-\Pr}\right) \tag{12}$$

Since we are particularly interested in the role played by environmental regulation and transport costs, our equation to be estimated is of the form:

$$\text{logit}\left[\Pr\left(OUTSOURCE_i\right)=1\right]=\alpha+\delta_j+\lambda ER_i+\beta TRANS_i+\theta TARIFF_j+\varsigma' Z_i+\varepsilon_i \tag{13}$$

where *OUTSOURCE* is a dummy variable equal to 1 if a firm undertakes overseas outsourcing and 0 otherwise, *ER* is a measure of environmental regulation, *TRANS* is transport costs, *TARIFF* is tariff revenues as a share of imports, *Z* is a vector of other firm characteristics and δ is an industry specific dummy variable and subscripts *i* and *j* denote firm and industry, respectively.[11] Industry controls are included for two reasons. First, our model is a multi-sector model in which firms may differ across sectors in terms of their abatement costs. To be consistent with our theoretical model we therefore need to control for such differences. Second, the industry dummies are intended to capture other unobserved industry-level factors that may influence the decision to outsource. While most determinants of outsourcing are expected to be firm specific and are controlled for in vector *Z*,

[11] Although our dataset does provide the level of outsourcing undertaken by each firm, our interest is in the decision whether or not to outsource and the factors that influence this decision. We have therefore converted the level of outsourcing into a simple dummy variable equal to 1 if a firm undertakes any outsourcing and 0 otherwise. In a sensitivity analysis we report results based on the level of outsourcing and they are consistent with the main reported results. Unfortunately, our dataset does not provide the country that each firm outsourced to but simply the total value of overseas outsourcing. Note also that our outsource variable is unable to indicate which part of the production process is outsourced.

some such factors may be industry specific, for example an industry as a whole may require expensive skilled labor. To reduce contemporaneous correlation, explanatory variables are reported in 1998 while the dependent variable is reported in 1999. Since our specification includes firm and industry level variables we cluster our standard errors by our industry classification to adjust them for unobserved industry attributes (Moulton 1990).

The challenge in a study of this kind is to find a firm-level measure of environmental regulation costs. While no direct measures of such costs are available our dataset does provide information on firms' environmental activities which, the previous literature tells us, are likely to be highly correlated with firms' abatement costs.[12] The survey from which our data emanate requires firms to answer seven questions relating to their environmental activities as listed below:

Q1. Does your firm explicitly refer to consideration of the natural environment in your management policy?

Q2. Does your firm have a specific environmental action plan to reduce environmental damage?

Q3. Does your firm produce an environmental report that is publicly available?

Q4. Does your firm re-use waste products and utilize recycled products and equipment where possible?

Q5. Has your firm developed technology to increase the degree of recycling?

Q6. Has your firm utilized equipment and technology to reduce energy use?

Q7. Has your firm developed technology to reduce energy use?

Previous studies have shown that the firms most likely to adopt environmental management type practices such as those above are typically those firms that generate more pollution per unit of output and hence have higher abatement costs per unit of output (see e.g. Cole *et al.* 2005 and Cole

[12] Although some firm-level abatement cost data are available for Japan, the firms in the sample do not match those in our sample, nor do they provide sufficient industry coverage to provide industry-level observations.

et al. 2006). Indeed, if we rank the 115 industries in which our firms reside in terms of the proportion of firms who answered 'yes' to at least one of these seven questions we find that the results conform to our expectations. Table 1 provides the top 10 industries in this ranking and compares them to the top 10 (again out of 115) US industries in terms of pollution abatement costs per unit of value added, based on data reported in Cole and Elliott (2005).[13]

[Table 1 about here]

Although Japan and the US use different industry classifications, which prevents a direct comparison of each industry, it is clear that the majority of the US industries with the highest pollution abatement costs per unit of value added are the same industries that appear in the Japanese ranking. Industries common to each ranking include Petroleum, Non-Ferrous Metals, Chemicals, Paper & Pulp, Chemicals, Iron & Steel, and Plastics & Rubber. Similarly, a ranking of UK industries by pollution intensity and by environmental operating expenditure per unit of value added by Cole and Elliott (2007) reveals a very close correlation with the industries listed in Table 1.[14] In sum, it does appear likely that differences in firms' responses to the seven environmental variables do provide us with information regarding differences in the environmental regulation costs that they are likely to face. For our empirical analysis we create six different variables from the responses to these questions which we define in Table 2.

[Table 2 about here]

[13] Ranking our industries in terms of other combinations of the seven questions provides almost identical rankings.

[14] The Japanese industries with the *least* number of firms answering the environmental questions are also very similar to US and UK industries with the least pollution abatement costs per unit of value added and include industries such as Clothing and Publishing.

In our sensitivity analysis we utilize the US pollution abatement operating expenditure per unit of value added (PAOC) referred to above and, using a specially constructed concordance between US SIC industry codes and Japanese industry codes, we create industry-level observations for Japan. While it is clearly far from ideal to use US abatement costs as a proxy for Japanese costs, the findings of Cole and Elliott (2005) and (2007) and others indicate that the ranking of industries in terms of abatement costs per unit of value added are very similar across countries, at least for those countries for whom data are reported (e.g. US and UK). It is therefore likely that Japanese and US industry-level abatement costs will be broadly similar, in an ordinal sense at least.

To measure the theoretical cost of outsourcing we include two variables. First, transport costs (*TRANS*), expressed as a percentage of total sales, to capture the likely cost to the firm of importing intermediate inputs if it did decide to outsource them.[15] Second, *TARIFF* is included to control for the impact of domestic tariffs on imports, measured as tariff revenue in Yen as a share of imports at the industry level. We also include a range of control variables based on the theoretical framework outlined in Section 3. In line with the theoretical predictions of our model, since large firms may be more likely to outsource than smaller firms, we include the number of workers (*SIZE*) to capture the scale effect (which corresponds to productivity in the model). *WAGE* captures wages per worker as a measure of workforce quality. Capital per worker (*KL*) is included to control for the capital intensity of a sector.

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[15] We acknowledge that a firm's transport costs will be a function of both the weight of the product being shipped and the distance that the product has to travel and are likely to relate to the firm's final product rather than intermediate inputs. Nevertheless, if we assume that the weight of intermediate inputs are correlated with the weight of the final product, and if the final products of firms are shipped similar distances, then transport costs are likely to provide some indication of the potential cost to the firm of importing intermediate inputs.

We also include the value of each firm's exports (*EXP*) and research and development (*R&D*) expenditure measured as research and development expenditure as a percentage of sales. Finally, we include advertising expenditure as a percentage of sales (*ADV*). This variable is included to proxy the public profile of a company and hence the level of public scrutiny that a company is likely to experience from various stakeholders and non-governmental organizations.

A key econometric concern is that of simultaneity bias between regulation costs and outsourcing. Whilst the cost of environmental regulations may cause firms to outsource their production it could also be argued that outsourcing could itself impact upon those regulation costs for two reaons. First, if a country is concerned about job losses associated with outsourcing, governments may reduce environmental regulation costs in certain sensitive industries. Second, once a firm does outsource a part of its production process its regulation costs are likely to fall. While we utilize lagged explanatory variables to attempt to mitigate this endogeneity problem, it should also be borne in mind that both of these simultaneity arguments suggest a negative relationship between outsourcing and regulation costs, in contrast to the positive relationship predicted by our model. This therefore suggests that the estimated coefficients on our environmental regulation variables are likely to be conservative estimates of the true impact of regulations on outsourcing (having been mitigated by the negative effect of outsourcing on regulation costs).

Appendix 1 provides definitions of our non-environmental variables while Appendix 2 provides summary statistics and compares the mean values of our variables for firms that outsource and those that do not. [16] Appendix 2 revels that outsourcing firms are, on average, larger than non-

[16] Appendix 2 indicates, for example, that the mean of the OUTSOURCE dummy is 0.061 implying that 6.1% of the firms in our sample undertake international outsourcing. Similarly, 26% of firms answered 'yes' to the environmental

outsourcing firms, as predicted by our theory, and face lower transport costs. Outsourcing firms also have higher capital-labor ratios, pay higher wages, have a larger share of exports in total sales and have greater R&D and advertising expenditure as a share of sales. In all cases, outsourcing firms appear to undertake a greater degree of environmental management and hence, we would argue, are likely to face greater pollution abatement costs per unit of value added.

4. Results

In Table 3 we report the odds ratios emanating from our estimation of equation (13) but have subtracted one from each odds ratio to ease interpretation. The environmental variable is the *ENVdumall* measure, defined as a dummy variable equal to one if a firm answers 'yes' to any of the seven environmental questions and zero otherwise. All models include our environmental and transport cost measures and firm size, with additional explanatory variables added incrementally. In all models we find the odds ratio (minus 1) of *ENVdumall* and *SIZE* to be positive and that of *TRANS* to be negative, and both are statistically significant. Taking the example of model (6), this implies that a firm that answers 'yes' to one of the environmental questions is 5.3% more likely to outsource than a firm that does not. In contrast, a 1 unit increase in transport costs as a share of sales *reduces* the likelihood of a firm outsourcing by 27%. To put this in context, the mean value of transport costs as a share of sales across all firms is 2.41 and hence a 1 unit increase represents a

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question 1, 2 or 3, 43% answered 'yes' to the questions 4, 5, 6 or 7 and 57% answered 'yes' to at least one of the questions 1 to 7.

large proportional change. Therefore, to express this another way, if *TRANS* increased by 10% for the mean firm in the sample, the likelihood of that firm outsourcing would decrease by 6.6%. [17]

Firm size is statistically significant in all models and increases the likelihood of outsourcing. In model (6) we find that an increase in *SIZE* (the number of workers) by one hundred workers increases the likelihood of the firm outsourcing by 1.4%. Wage is also statistically significant in all models in which it is included and again increases the likelihood of outsourcing. An increase in the annual average wage of a firm by one million Yen increases the likelihood of outsourcing by 9.4%.[18] To express this differently, if the wage level increased by 10% for the mean firm in the sample, the likelihood of outsourcing would increase by 4.6%.[19]

In terms of the other variables, we find no statistically significant relationship between tariffs and outsourcing. However, the level of exports and the share of R&D expenditure all increase the likelihood of outsourcing in a statistically significant manner. The capital-labor ratio consistently reduces the likelihood of outsourcing, although this relationship is not statistically significant. While our model highlighted the role of physical or human capital in influencing outsourcing, our empirical results suggest that the latter, perhaps captured by our R&D variable, is the more important of the two in this context.

In Table 4 we check the sensitivity of our results by testing our alternative environmental measures. Columns (1) to (6) include the alternative measures of ENVdum1, ENVdum2, ENVcount1,

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[17] 0.049 = 0.273*(2.41 * 0.1) where 0.273 is the odds ratio (minus 1) on *TRANS* and 2.41 is the in sample mean value of *TRANS*.

[18] 1 million Yen = US $12,000 approximately (exchange rate $1= 83 Yen, Feb 2011).

[19] 0.046 = 0.094*(4.855*0.1) where 0.094 is the odds ratio (minus 1) on *WAGE* and 4.855 is the mean level of wage in our sample.

ENVcount2 and ENVcountall alongside ENVdumall for means of comparison.[20] As a further test of our environmental variables we utilize the US pollution abatement operating expenditure per unit of value added (PAOC), referred to earlier, concorded to Japanese industry codes to create industry-level observations for Japan. Column (7) provides estimation results with this measure (denoted as USpaocva) included. As can clearly be seen, no matter how we define our environmental variable, it remains a positive and statistically significant determinant of the likelihood of outsourcing. The results in columns (1) to (6) suggest that firms that undertake these various environmental activities are between 2.1% and 4.2% more likely to outsource than firms that do not. The coefficient on USpaocva indicates that a 1 unit increase in pollution abatement costs as a share of value added increases the likelihood of outsourcing by 13.3%. To put this in context, if USpaocva increased by 10% for the mean firm in the sample, the likelihood of that firm outsourcing would increase by 11%.[21]

In column (8) of Table 4 we replace our discrete dependent variable with a variable measuring the level of outsourcing as a percentage of sales which we estimate using OLS. It can be seen that the coefficient on ENVdumall remains positive and statistically significant. Finally, column (9) returns to a discrete dependent variable, but this time capturing whether or not the firm undertakes *domestic*, as opposed to international, outsourcing. Since there is little variation in the stringency of regulations within Japan (relative to the international differences) we would not expect the decision

[20] These variables are defined in Table 2. We also performed a battery of sensitivity and robustness checks with various combinations of controls which did nothing to alter the general pattern of results. Space prevents us reporting them here.

[21] 0.11 = 0.133*(8.29*0.1) where 0.133 is the odds ratio (minus 1) on USpaocva and 8.29 is the mean level of USpaocva in our sample.

to domestically outsource to be influenced by a firm's regulation costs. Column (9) confirms this to be the case, with ENVdumall having a statistically insignificant effect on the domestic outsource decision.

To summarise, our empirical analysis provides compelling support for the predictions of our theoretical model by indicating that regulation costs, firm size, wages, and KL or R&D all increase the likelihood of a firm undertaking overseas outsourcing while transport costs reduce the likelihood of outsourcing.

5. Conclusions

In this paper we develop a heterogeneous-firm model with environmental regulations and the possibility of outsourcing. In equilibrium we have two types of firm. First, firms that produce domestically and pay abatement costs on the level of pollution emitted as part of the production process (abatement firms). Second, outsourcing firms that outsource part of their production process thereby reducing the need to pay abatement costs at home (outsourcing firms).

Using a sample of over 12,000 Japanese manufacturing firms, we then empirically test the implications of our model and find results to be supportive of the model's findings. First, firms that undertake environmental activities are more likely to outsource. Given the very close association between such activities and the likely abatement costs per unit of value added of firms, we interpret this as meaning that high regulation cost firms are more likely to outsource. Second, we find that trade costs, in the form of transport costs, decrease the likelihood of a firm outsourcing. This suggests that there is a tradeoff between paying transport costs and paying abatement costs locally.

An increase in regulations or a fall in transport costs will both affect the extent to which domestic firms outsource dirty production. Of our other variables we find that the likelihood of a firm outsourcing increases with the size of the firm. Other things being equal, large firms are more likely to outsource.

The results of this paper have potentially important implications and reveal another transmission mechanism by which domestic regulations may influence trade and production patterns. In addition to the relocation or displacement of the entire production processes of firms, we observe that it is possible for just parts of the production process to be relocated in response to increases in domestic regulations - leaving a large and profitable headquarters in the home country. In this sense, increases in environmental regulations can increase the health of local citizens without the large job losses associated with wholesale relocation or closure predicted by industry lobby groups. On the other hand, the existence of pollution haven consistent effects may lead to calls of exploitation from developing countries whose environment is being despoiled for the profit of foreign multinationals. This is a particular worry for large producers such as China and India and provides an additional level of complexity to multi-country negotiations on the environment. Failure to make progress in the future will be hampered by the knowledge that environmental outsourcing or 'dirty leakage' appears to exist, at least for the case of Japan.

References

Aiken, D., Fare, R., Grosskopf, S. and Pasurka, C.A. (2009), Pollution Abatement and Productivity Growth: Evidence from Germany, Japan, the Netherlands, and the United States. *Environmental and Resource Economics*, Vol. 44, pp. 11-28.

Amiti, M. and Wei, S.J. (2005), Fear of service outsourcing: is it justified?, *Economic Policy*, Vol. 20, 42, pp. 308-347.

Amiti, M. and Wei, S. J. (2009), Service Offshoring and Productivity: Evidence from the US, *World Economy*, Vol. 32, 2, pp. 203-220.

Antras, P. (2003), Firms, Contracts, and Trade Structure, *Quarterly Journal of Economics*, Vol.118, No.4, pp.1375-1418.

Antweiler, W., Copeland, B.R. and Taylor, M.S. (2001), Is Free Trade Good for the Environment? *American Economic Review*, Vol. 91, no. 4, pp. 877-908 (Sept).

Aw, B. Y., Chung, S. and Roberts, M. (2000), Productivity and Turnover in the Export Market: Micro Evidence from Taiwan and South Korea, *World Bank Economic Review* Vol. 14, pp. 65-90.

Bernard, A.B., Jensen, J.B., (1995), Exporters, jobs, and wages in US manufacturing, 1976-1987, *Brookings Papers on Economic Activity*, *Microeconomics*, pp. 67-119.

Bernard, A. B. and Jensen, B. (1999), Exceptional Exporter Performance: Cause, Effect, or Both? *Journal of International Economics*, Vol. 47, pp. 1-25.

Bernard, A.B., Eaton, J., Jensen, B. and Kortum, S. (2003), Plants and Productivity in International Trade, *American Economic Review,* Vol. 93, pp. 1268-90.

Cole, M.A. and Elliott, R.J.R. (2003), Determining the Trade-Environment Composition Effect: The Role of Capital, Labour and Environmental Regulations, *Journal of Environmental Economics and Management*, Vol. 46, 3, pp. 363-83.

Cole, M.A. and Elliott, R.J.R. (2005), FDI and the Capital Intensity of 'Dirty' Sectors: A Missing Piece of the Pollution Haven Puzzle, *Review of Development Economics*, Vol. 9, 4, pp.530-48.

Cole, M.A. and Elliott, R.J.R. (2007), Do Environmental Regulations Cost Jobs? An Industry-Level Analysis of the UK, *B.E. Journal of Economic Analysis and Policy*, Vol. 7, 1.

Cole, M.A., Elliott, R.J.R. and Fredriksson, P. (2006), Endogenous Pollution Havens: Does FDI Influence Environmental Regulations? *Scandinavian Journal of Economics*, Vol. 108, 1, pp. 157-178.

Cole, M.A., Elliott, R.J.R. and Shimamoto, K. (2005), Industrial Characteristics, Environmental Regulations and Air Pollution: An Analysis of the UK Manufacturing Sector, *Journal of Environmental Economics and Management*, Vol. 50, 1, pp.121-43.

Daveri, F. and Jona-Lasinio, C (2008), Off-shoring and Productivity Growth in the Italian

Manufacturing Industries, *Economic Studies*, Vol. 54, 3, pp. 414–450

Eaton, J., Kortum, S., Kramarz, F., (2004), Dissecting trade: firms, industries, and export destinations, *American Economic Review Papers and Proceedings* Vol. 94, pp. 150-154.

Ederington, J., Levinson, A. and Minier, J. (2005), Footloose and Pollution-Free, *Review of Economics and Statistics*, Vol.87 pp. 92-99

Egger, H. and Egger, P. (2006), International Outsourcing and the Productivity of Low-Skilled Labor in the EU, *Economic Inquiry*, Vol. 44, 1, pp. 98-108

Eskeland, G.S. and Harrison, A.E. (2003), Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis," *Journal of Development Economics,* Vol. 70, pp. 1-23.

Feenstra, R.C. and Hanson, G.H. (1999), The Impact of Outsourcing and High Technology Capital and Wages: Estimates for the United States, 199-1990, *Quarterly Journal of Economics*, Vol. 114, 3, pp. 907-940.

Feenstra, R.C. and Hanson, G.H. (2006), Ownership and Control in Outsourcing to China, *Quarterly Journal of Economics*, Vol. 120, 2, pp. 85-120.

Frankel, J. A. and Rose, A. K. (2005), Is Trade Good or Bad for the Environment? Sorting Out the Causality, *The Review of Economics and Statistics*, Vol. 87, 1, 85-91.

Greenstone, M., List, J.A. and Syverson, C. (2011), The Effects of Environmental Regulation on the Competitiveness of US Manufacturing, Center for Economic Studies Working Paper CES 11-03.

Grossman, S. and Hart, O. (1986), The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration, *Journal of Political Economy*, Vol. 94, 4, pp. 691-719.

Grossman, G.M and Helpman, E. (2002), Integration versus Outsourcing in Industry Equilibrium, *Quarterly Journal of Economics*, 117(1), February, 85-120

Grossman, G.M. and Helpman, E. (2005), Outsourcing in a Global Economy, *Review of Economic Studies*, Vol. 72, pp. 135-159.

Grossman, G., Helpman, E. and Szeidel, A. (2005), Complementarities between Outsourcing and Foreign Sourcing, *American Economic Review*, Vol. 95, pp. 19-24.

Grossman, G. M., and Rossi-Hansberg, E. (2008), Trading Tasks: A Simple Theory of Offshoring. *American Economic Review*, Vol. 98, 5, pp. 1978–97.

Helpman, E, M. Melitz and S. Yeaple (2004), Export versus FDI with heterogeneous firms, *American Economic Review*, 94, 1, pp. 300-317.

Hijzen, A., Inui, T. and Todo, Y. (2010), Does Offshoring Pay? Firm-Level Evidence from Japan, *Economic Inquiry,* Vol. 48, 4, pp. 880-895.

Hsieh, C.T. and Woo, K.T. (2005), The Impact of Outsourcing to China on Hong Kong's Labour Market, *American Economic Review*, Vol. 95, 5, pp. 1673-1687.

Kahn, M. (2003), The Geography of U.S. pollution intensive trade: Evidence from 1959-1994, *Regional Science and Urban Economics*, Vol. 33, 4, pp. 383-400.

Leahy, D. and Montagna, C. (2009), Outsourcing Vs. FDI in Oligopoly Equilibrium. *Spatial Economic Analysis,* 4, 2, pp. 149-66.

Lovely, M. and Popp, D. (2011), Trade, Technology and the Environment: Does Access to Technology Promote Environmental Regulation? *Journal of Environmental Economics and Management*, 61, pp. 16-35.

Levinson, A. (2010), Offshoring Pollution: Is the US Increasingly Importing Pollution Intensive Production? *Review of Environmental Economics and Policy*, Vol. 4(1), Winter 2010, pp. 63-83.

Martin, P. and C.A. Rogers (1995), Industrial location and public infrastructure, *Journal of International Economics,* Vol. 39, 335–351.

Melitz, M.J. (2003), The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity, *Econometrica*, Vol. 71, 6, pp 1695-1725.

Moulton, B (1990), An illustration of a pitfall in estimating the effects of aggregate variables on micro units, *Review of Economics and Statistics*, Vol. 72, 2, pp. 334–338.

Pavcnik, N. (2002), Trade liberalization, exit, and productivity improvements: Evidence from Chilean plants, *Review of Economics Studies,* Vol. 69, pp. 245-76.

Spencer, B. (2005), International Outsourcing and Incomplete Contracts, NBER Working Paper No. 11418.

Tomiura, E, (2005), Foreign Outsourcing and Firm-level Characteristics: Evidence from Japanese Manufacturers, *Journal of the Japanese and International Economies*, Vol.19, pp. 255-271.

Tomiura, E, (2007), Foreign Outsourcing, Exporting, and FDI: A Productivity Comparison at the Firm Level, *Journal of International Economics*, Vol. 72, pp. 113-127.

Tomiura, E, (2008), Foreign outsourcing and the product cycle: evidence from micro data, *Applied Economics Letters*, Vol. 15, 13, pp. 1019-1022.

Tybout, J. R & M. D.Westbrook (1995), Trade liberalization and the dimensions of efficiency change in Mexican manufacturing industries, *Journal of International Economics*, Vol. 39, pp. 53-78.

Wakasugi, R., Ito, B. and Tomiura, E (2008), Offshoring and Trade in East Asia: A Statistical Analysis, *Asian Economic Papers*, Vol. 7, 3, pp. 101-124.

Figure 1. Outsourcing Equilibrium

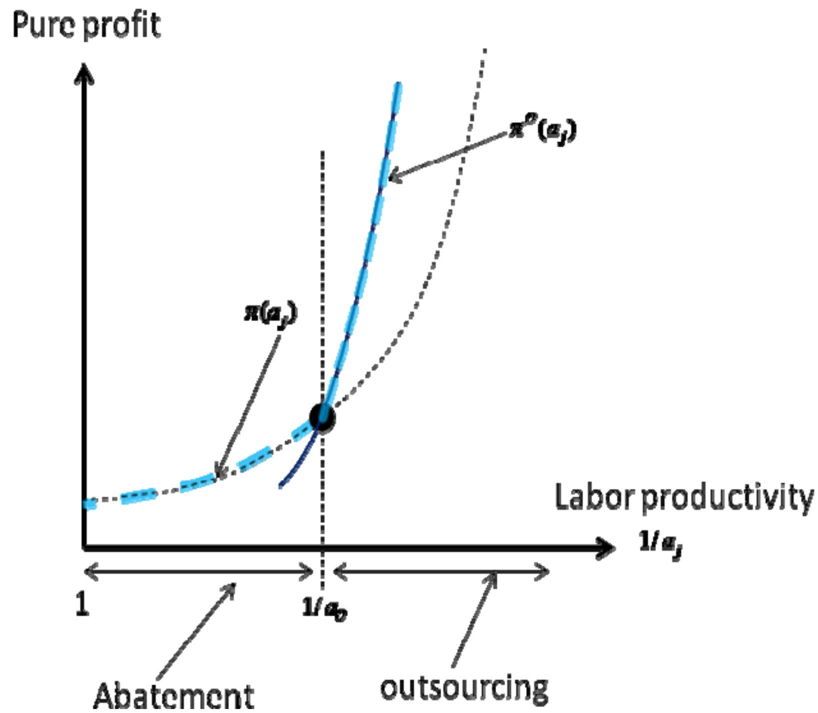

Table 1. The top 10 Japanese industries based on their responses to seven environmental questions compared with the top 10 US industries in terms of pollution abatement costs.

Japanese Industries		US Industries	
Industry	Percentage	Industry	PAOC
1. Rubber tires and inner tubes	100	1. Petroleum refining	12.3
2. Petroleum refineries	89.6	2. Primary smelting of non-ferrous metals	9.0
3. Chemical fertilisers	78.4	3.Pulp and paper	8.8
4. Non-ferrous metals	75.5	4.Secondary smelting of non-ferrous metals	6.7
5. Pulp and paper	74.2	5. Organic chemicals	6.0
6. Soap and detergents	74.1	6. Cement production	5.9
7. Chemical products	73.7	7. Paper mills	5.5
8. Other oil and coal products	70.8	8. Paperboard mills	4.9
9. Plastics and plastic products	70.2	9. Iron and steel	4.6
10. Iron and steel	67.7	10. Plastics and rubber	3.5

The Japanese industries stem from a ranking of 115 industries in terms of the percentage of firms in each industry answering ‘yes’ to at least one of seven environmental questions. The US industries stem from a ranking of 115 three-digit US SIC industries in terms of average pollution abatement operating costs (PAOC) per unit of value added (in thousands of 1990 US dollars) over the period 1989-1994 based on data reported in Cole and Elliott (2005). Note that Japan and the USA use different industry classifications and hence the titles of industries do not precisely match.

Table 2. Definitions of Environmental Variables

Variable name	Definition
ENVdum1	A dummy variable equal to 1 if a firm answers yes to questions 1, 2 or 3 and zero otherwise
ENVdum2	A dummy variable equal to 1 if a firm answers yes to questions 4, 5, 6 or 7 and zero otherwise
ENVdumall	A dummy variable equal to 1 if a firm answers yes to any of the questions and zero otherwise
ENVcount1	A variable that counts the number of positive answers to questions 1, 2 and 3.
ENVcount2	A variable that counts the number of positive answers to questions 4, 5, 6 and 7.
ENVcountall	A variable that counts the number of positive answers to all questions
USpaocva	Pollution abatement operating costs per unit of value added based on US industry-level data for 1994 from US Department of Commerce, *Pollution Abatement Costs and Expenditures*.

The Japanese variables are from *Kigyou Katsudou Kihon Chousa Houkokusho* (*The Results of the Basic Survey of Japanese Business Structure and Activities*) prepared by the Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry (MITI).

Table 3: Main Estimation Results

	(1)	(2)	(3)	(4)	(5)	(6)
ENVDUMall	0.062***	0.057***	0.057***	0.056***	0.053***	0.053***
	(5.9)	(5.3)	(5.3)	(5.0)	(4.8)	(4.8)
TRANS	-0.324***	-0.333***	-0.330***	-0.288***	-0.273***	-0.273***
	(6.3)	(6.2)	(6.2)	(6.0)	(5.6)	(5.6)
TARIFF	0.009	-0.171	-0.327	0.248	0.316	0.286
	(0.0)	(0.2)	(0.2)	(0.3)	(0.4)	(0.3)
SIZE	0.00023***	0.00020***	0.00021***	0.00016***	0.00014***	0.00014***
	(4.5)	(4.1)	(4.0)	(3.0)	(2.6)	(2.6)
WAGE		0.138***	0.146***	0.110***	0.094***	0.094***
		(5.1)	(4.9)	(4.4)	(4.1)	(4.1)
KL			-0.29	-0.34	-0.316	-0.314
			(1.0)	(1.3)	(1.2)	(1.2)
EXPORTS				0.058***	0.054***	0.054***
				(10.2)	(9.8)	(9.8)
R&D					0.078***	0.078***
					(3.8)	(3.8)
ADV						0.008
						(1.3)
Observations	12335	12335	12335	12335	12335	12335
Pseudo R^2	0.091	0.010	0.12	0.12	0.12	0.12

Robust z statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

The dependent variable is a dummy variable indicating whether the firm outsources or not. These results stem from the estimation of equation (8). Industry dummies included. For each variable we report the estimated odds ratios minus 1.

Table 4: Sensitivity Analysis (Robust z statistics in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ENVdum1	0.032***								
	(3.0)								
ENVdum2		0.042***							
		(3.4)							
ENVdumall			0.053***					0.065**	0.00021
			(4.8)					(2.0)	(0.8)
ENVcount1				0.026***					
				(3.9)					
ENVcount2					0.029***				
					(4.9)				
ENVcountall						0.021***			
						(5.8)			
USpaocva							0.13**		
							(2.0)		
TRANS	-0.261***	-0.273***	-0.273***	-0.257***	-0.277***	-0.27***	-0.27***	-0.083***	-0.20***
	(5.3)	(5.5)	(5.6)	(5.3)	(5.8)	(5.7)	(4.9)	(3.7)	(5.6)
TARIFF	0.407	0.285	0.286	0.349	0.223	0.201	0.14	-0.075	0.12
	(0.4)	(0.3)	(0.3)	(0.4)	(0.3)	(0.2)	(0.2)	(0.2)	(0.5)
SIZE	0.00014**	0.00014**	0.00014***	0.00013**	0.00011**	0.00010*	0.00015***	0.0044***	0.000084
	(2.5)	(2.6)	(2.6)	(2.3)	(2.0)	(1.8)	(2.7)	(3.5)	(1.3)
WAGE	0.097***	0.097***	0.094***	0.094***	0.091***	0.087***	0.095***	-0.093	0.13***
	(3.8)	(4.0)	(4.1)	(3.8)	(3.8)	(3.8)	(4.1)	(0.7)	(4.3)
KL	-0.291	-0.315	-0.314	-0.296	-0.365	-0.363	-0.039	-0.020	-0.49***
	(1.2)	(1.2)	(1.2)	(1.2)	(1.5)	(1.5)	(0.2)	(0.2)	(4.5)
EXPORTS	0.054***	0.054***	0.054***	0.054***	0.054***	0.054***	0.052***	0.043***	-0.0001
	(10.1)	(9.7)	(9.8)	(9.9)	(9.6)	(9.6)	(9.2)	(11.6)	(0.02)
R&D	0.080***	0.078***	0.078***	0.079***	0.077***	0.075***	0.081***	0.0024	0.045**
	(3.9)	(3.8)	(3.8)	(3.8)	(3.6)	(3.6)	(3.7)	(0.2)	(2.2)
ADV	0.008	0.008	0.008	0.009	0.009	0.008	0.0080	0.049	0.0057
	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)	(0.9)	(0.7)
Pseudo R^2	0.12	0.12	0.12	0.12	0.13	0.13	0.12	0.071	0.093

N = 12335. In columns (1) to (6) the dependent variable is a dummy variable indicating whether the firm outsources or not. In column (8) the dependent variable is a measure of outsourcing as a percentage of sales, estimated using OLS. In column (9) the dependent variable is a dummy variable indicating whether the firm *domestically* outsources or not. Industry dummies included. In columns (1) to (7) and (9) we report the estimated odds ratios minus 1.

Appendix 1: Data definitions and sources

Variable name	Definition
OUTSOURCE	A dummy variable equal to 1 if a firm undertakes any outsourcing and 0 otherwise
TRANS	transport costs as a share of sales
TARIFF	Tariff revenue in Yen as a share of imports, at industry level
SIZE	Employment, in workers
WAGE	Annual wage per worker in millions of Yen
KL	Physical capital stock per worker in hundreds of Yen
EXPORTS	Value of exports as a percentage of sales
R&D	Research and Development expenditure as a percentage of sales
ADV	Advertising expenditure as a percentage of sales.

All variables are from *Kigyou Katsudou Kihon Chousa Houkokusho* (*The Results of the Basic Survey of Japanese Business Structure and Activities*) prepared by the Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry (MITI).

Appendix 2. Summary Statistics

Variable	Mean Outsourcers	Mean Non-Outsourcers	Std. Dev.	Min.	Max.
ENVdum1	0.35	0.21	0.44	0	1
ENVdum2	0.53	0.35	0.50	0	1
ENVdumall	0.67	0.47	0.49	0	1
ENVcount1	0.52	0.26	0.63	0	3
ENVcount2	0.87	0.46	0.84	0	4
ENVcountall	1.39	0.71	1.18	0	7
OUTSOURCE	0.061		0.24	0	1
TRANS	1.73	2.45	1.30	0.79	6.33
TARIFF	0.05	0.04	0.11	0	0.71
SIZE	1249.84	353.27	1595.78	50	71154
WAGE	5.38	4.78	1.62	0.070	47.48
KL	0.13	0.12	0.25	0.000011	14.64
EXPORT	5.79	1.11	5.59	0	39.94
R&D	1.58	0.46	1.87	0	59.56
ADV	0.76	0.63	1.44	0	42.76
USpaocva	8.48	5.34	9.5	1.12	40.90

Note: For the ENVdum variables mean values provide the proportion of firms answering 'yes' to the different groups of environmental questions. For the ENVcount variables the mean values provide the average number of questions that firms answered 'yes' to within each group of questions. See Appendix Table 1 for more information