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Environmental Outsourcing

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Abstract

Recent years have witnessed 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. We find evidence of an 'environmental outsourcing' effect although this is mitigated by transport costs and other factors related to dirty good production.

Key words: Environmental regulations, trade, outsourcing

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

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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 (Antweiler *et al.* 2001, Cole and Elliott 2003 and Frankel and Rose 2005). 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). Evidence remains decidedly mixed.

In this paper we address an aspect of the PHH that has been ignored within the trade-environment literature to date which is 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 reference to the possibility that firms may outsource the pollution intensive parts of their production process as a means of avoiding stringent domestic regulations. While such international outsourcing would influence, and be included within, net export pattern changes which have been examined at industry-level in the previous literature, 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. The specific focus in this paper is therefore on firm-level outsourcing.

While 'environmental outsourcing' has not been addressed to date, a small literature has now emerged which examines whether or not the US has 'offshored' its pollution in recent years (Kahn 2003, Cole 2004 and Levinson 2010). It should be noted that offshoring captures all firm activity undertaken abroad. This includes 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 (as opposed to domestic outsourcing where parts are sourced from firms based in the same country).[1] 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.

Hence, we believe that this is the first paper to consider the link between outsourcing and the environment and believe it provides an ideal and clear 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

[1] For the remainder of this paper we use the term outsourcing to mean international outsourcing.

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 as a result of the pollution that results from the increase in transport of goods around the world even if the environmental costs and benefits in the home and foreign country cancel out.[2] 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 the 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 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. A caveat is that of "outsourcing overshooting" where a firm

[2] For example, citizens in the country that loses the pollution intensive production process are likely to experience positive health benefits with a corresponding negative health effect in the receiving country.

begins by outsourcing just the dirty part of production and during the learning process decides to move the entire firm.

The remainder of the paper is structured as follows: Section 2 provides theoretical considerations and Section 3 provides our model. Section 4 outlines our empirical methodology and data while Sections 5 and 6 provide empirical results and conclusions, respectively.

2. Theoretical considerations

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 behaviour 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 were motivated in part by the empirical studies on firm size, productivity and export behaviour 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 often finding a positive correlation. These papers include 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 number of papers use similar firm-level data to our own to consider the relationship between productivity and outsourcing (see e.g. Wakasugi *et al*. 2008 and Tomiura 2005, 2007 and 2008, 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 undertake investment in abatement technology. The key features of our model are marginal cost differences due to different labor productivities across firms. As a result profits differ across firms with productive firms making greater profits. In our model firms face a trade-off between incurring abatement costs when domestically producing all production stages of the production process and the costs of outsourcing the dirty stage of the production process which are the transport costs for re-import and some fixed beachhead costs associated with finding a suitable foreign producer.

However, our simple model has several key differences to the standard heterogeneous-firm trade models. First, for simplicity we assume a small open economy (Home) and the rest of the world (multiple Foreign countries) and all firms are exporters due to an assumption of no export costs and hence we make no distinction between local producers and exporters; second, we assume no entry or exit, no dynamic effects (no growth), and no R&D investment stage before operation. The environment is introduced by the 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 production processes by paying outsourcing fixed costs and trade costs associated with importing the intermediate product or dirty production for final product assembly in the Home country.

3. The Model

In this section we present our heterogeneous-firm model with environmental regulations and the possibility of outsourcing dirty production within a Dixit-Stiglitz monopolistic competition framework. Firms are heterogeneous in labor productivity. In equilibrium we have two types of firm. First, domestic 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, outsourcing firms that now import the dirty intermediate stage of the production process to ensure that total emissions are below the regulation threshold which mitigates 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 that outsourcing.

Basic model

Suppose we have M sectors, $m=1 \ldots M$. 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 (a "blueprint") and requires "*a*" units of labor as a variable cost.[3] Associated with each firm's original blueprint, "a" becomes firm specific and takes different values across firms. Thus labor productivity is given as *1/a* and differs across firms (heterogeneous productivity). Each firm has a firm-specific marginal cost (labor requirement). Thus firm *j*'s marginal costs are given as wage rate, *w*, multiplied by firm-specific labor requirements, a_j. Note that *w* is a national or sectoral variable but *a* is firm specific. To be precise we assume *a* is *a priori* exogenously distributed from 0 to 1, subject to a probability density function denoted by *f(a)*.

Figure 1 shows the cumulative density function of *f(a)* in terms of *a* denoted as F(a). In addition, each firm has a pollution intensive production process, which incurs abatement costs to reduce emissions to satisfy government regulations. As long as firms produce all stages of the production process domestically then they are required to pay abatement costs. Abatement costs are *D* units of labor per unit of output which are the marginal abatement costs (MAC) and *A* unit of labor per firm (fixed abatement costs), thus total abatement costs (TAC) are written as $wA_m + wD_m x_{mj}$ and per-unit (average) abatement costs are derived as $\frac{wA_m}{x_j} + wD_m$. For simplicity suppose *D* and *A* are identical across firms but differ across sectors. In reality pollution intensive sectors are more likely to be

[3] Our two-factor model employs Martin and Rogers (1995) and adopts their cost function. Same as in their model our model does not allow for entry and exit because the capital endowment is limited and one unit of capital creates one firm. Like in their short-run equilibrium, we do not take into account firm relocation for simplicity.

strictly regulated or require higher abatement costs and thus have larger D and/or larger A. Importantly, as labor productivity is higher and thus output (firm size) is larger, TAC always increases but per-unit abatement costs decrease.

[Figure 1 about here]

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 is variable costs and the third one is abatement costs. This simple model does not involve an endogenous firm distribution, and thus we assume away any dynamic factors such as entry/exit, R&D investment before operation, survival rate of firms and economic growth. This simplification allows us to focus on the relationship between labor productivity (size), environmental regulations and outsourcing.

Initial equilibrium (abatement firms)

We allow for an open economy (Home) to trade with Foreign countries (s=1…S) but focus on the Home economy. Utility maximization results in the CES demand function. Consumption of the variety produced by firm j in sector m in Home 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 (≥ 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 across foreign countries. Likewise, the representative foreign country s's consumption of the variety produced by Home firm j 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 import varieties from Home, the second is from other Foreign countries (S-1 countries) and the third is 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 lower productivity (a_j) firms charge lower prices and have higher demand for their product. The operating profit, which is the capital reward, and the output for a representative firm (in Home) can be obtained by utilizing (2), (3) and (4) to give:

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

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

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

Two important features are central to the following analysis. First, all firms earn positive operating profits when abatement costs are moderate.[4] 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 the largest producers. Thus more productive (smaller a) firms sell more domestically and export more.[5] Likewise, the less labor intensive and relatively more capital intensive (i.e. smaller labor requirement a_j) firms are more profitable. Here more precisely we define the capital-labor ratio as the ratio of capital rewards to all wage payments including abatement costs:

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

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[4] For simplicity, the model has a condition to ensure no exit. 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 into account abatement costs, we need to prevent sufficiently high abatement costs so as to keep all firms operating. To guarantee positive profits for all firms and no exit, we need to assume small or moderate abatement costs, i.e. small or moderate *A* and *D* so as to satisfy: $\pi_m(1) = \left(B_m + \sum_{s=1}^{S} \phi B_m^s \right) \frac{\gamma^{1-\sigma}\theta_m}{\sigma} \left((1 + D_m) w \right)^{1-\sigma} - wA_m > 0$.

[5] $\text{export} = \left(\sum_{s=1}^{S} \phi B_m^s \right) \theta_m p_{mj}^{1-\sigma} = \left(\sum_{s=1}^{S} \phi B_m^s \right) \theta_m \gamma^{1-\sigma} \left((a_j + D_m) w \right)^{1-\sigma}$

Differentiating this expression we get $\frac{dKL}{da_j} < 0.$. Thus we have $\frac{d\pi}{dKL} > 0.$

Now we consider firm-level pollution. We assume a pollution intensive process emits a large volume of pollution but with the abatement investment specified above pollution is reduced to a satisfy government regulations. One unit of production for abatement firms emits Z units of pollution.[6] Thus, total emissions for firm j, $G(x_{mj})$, are simply written as:

$$G(x_{mj}) = Zx_{mj} = Z\left(B_m + \sum_{s=1}^{S} \phi B_m^s\right)\theta_m \gamma^{-\sigma}\left((a_j + D_m)w\right)^{-\sigma}$$

Total emissions increase with firm size and productivity is higher (smaller *a*) as shown in Figure 2. Total abatement costs are therefore given by:

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

As $\sigma>1$, emissions are reversely proportional to a_j. Hence, larger (higher labor productivity, small a_j) firms have higher emissions and thus incur greater TACs.

[Figure 2 about here]

Outsourcing

We now allow firms to outsource part of the production process which will result in a fall in emissions and hence the avoidance of abatement costs. If firms outsource their emission intensive

[6]The government regulations set Z per output a priori. To satisfy Z, firms pay abatement costs. Once firms pay abatement costs, their per-unit emissions are reduced to Z.

production process to a foreign country, which for simplicity is assumed to have no environmental regulations, then they can move the pollution intensive production process outside 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 in Home. 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 lower than Home, $w^* < w$ and [3] fixed costs such as business/management costs or search/supervision costs at the headquarters, O_m that are associated with outsourcing when the firm imports the outsourced production from the foreign country that we label beachhead costs. When the benefits of outsourcing [1] exceed the costs [2] and [3], then a firm decides to outsource and vice versa.

To be precise, outsourcing incurs two types of cost, per-unit intermediate import costs of $\tau_m w^*$ (> 1) and fixed costs O_m. For simplicity, intermediate import costs boil down to the trade costs of the imports of intermediate products and the wage in foreign outsourcing countries.[7] By outsourcing the pollution intensive process of any production line, firms can produce without pollution intensive process (variable) costs and without paying abatement costs. In addition, the removal of the pollution intensive process decreases the labor requirements *D*. Thus, the marginal costs for outsourcing firms are $\tau_m w^* + a_j w$. Labor productivity increases (i.e. marginal costs decrease) with outsourcing, $\tau_m w^* + a_j w < (a_j + D_m) w$ and is supported by much empirical evidence that suggests outsourcing significantly enhances firm (labor) productivity (Egger and Egger 2006, Amiti and Wei

[7] 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.

2005 and 2009). On the other hand, outsourcing needs more additional fixed costs such as supervising costs for many reasons (e.g. incomplete contract for outsourcing and more transaction costs). To be more precise we assume $O_m > A_m$. This indicates that although lowering marginal costs due to lower foreign wages and small trade costs, outsourcing involves fairly high supervision costs to initiate foreign outsourcing and to enforce contracts due for example to asymmetric information.

Profits and outputs for outsourcing firms are given by:

$$\pi_m^o(a_j) = (B + \sum_{s=1}^{S} \phi B^s) \frac{\theta_m \gamma^{1-\sigma}}{\sigma} (\tau_m w^* + a_j w)^{1-\sigma} - wO_m \text{ and } x_m^o(a_j) = (B + \sum_{s=1}^{S} \phi B^s) \gamma^{-\sigma} (\tau_m w^* + a_j w)^{-\sigma} \quad (6)$$

Note that profit and production remain inversely proportional to a_j and proportional to labor productivity as is the case for the non-outsourcing abatement firms discussed above.

Two types of firms

There are cut-off levels of a_j between abatement and outsourcing firms and we denote these cut-offs 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 as to choose higher profits. Using (5) and (6), the profit gap between outsourcing firms and abatement firms is given as:

$$\pi_m^O(a_j) - \pi_m(a_j) = (B + \sum_{s=1}^{S} \phi B^s) \frac{\gamma^{1-\sigma} \theta_m}{\sigma} ((a_j w + \tau_m w^*)^{1-\sigma} - (a_j w + D_m w)^{1-\sigma}) - (wO_m - wA_m). \quad (7)$$

The cutoff a_o is determined by $\pi_m^O(a_0) - \pi_m(a_0) = 0$.[8] As shown in Figure 3, if $a_o > a_j$ ($a_o < a_j$), firms are outsourcing firms (non-outsourcing abatement firms). We can now derive some key outcomes.

[Figure 3 about here]

By differentiating (7) we get $\frac{\partial(\pi^O - \pi)}{\partial a_j} < 0$.[9] This indicates that as firms become larger (smaller *a*), they are more likely to outsource, and *vice versa*. This immediately induces the result that firms with larger exports are more likely to outsource because larger firms have more exports as shown above. Since the capital-labor intensity ratio, KL, as defined above, is higher as a_j is smaller, we get $\frac{\partial(\pi^O - \pi)}{\partial KL} > 0$. This means that capital intensive firms are more likely to outsource. Likewise $\frac{\partial(\pi^O - \pi)}{\partial A_m} > 0$ and $\frac{\partial(\pi^O - \pi)}{\partial D_m} > 0$. This indicates that more stringent regulations incur higher (total and/or marginal) abatement costs meaning that a firm is more likely to outsource. Next, $\frac{\partial(\pi^O - \pi)}{\partial \tau_m} < 0$, which means that higher trade costs for outsourcing reduce the incentive to outsource. Finally, $\frac{\partial(\pi^O - \pi)}{\partial w} < 0$ due to our assumption that *D* is not large (see footnote 3). Thus, the higher the wage in the Home country the more likely firms are to outsource.

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8 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 $\pi^O - \pi^A = 0$ 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 $O_m > A_m$.

9 $\frac{\partial(\pi^O - \pi^A)}{\partial a_j} = \frac{\gamma^{1-\sigma}\theta_m E}{\sigma P^{1-\sigma}}(1-\sigma)w\{(a_j w + \tau w^*)^{-\sigma} - (a_j w + D_m w)^{-\sigma}\} < 0$ because $(a_j + D_m)w > a_j w + \tau w^*$ and $\sigma > 1$.

Fundamentally, we have two types of firms; higher productivity firms that outsource and lower productivity firms that incur abatement expenditure at Home. Figure 3 plots profit in terms of productivity *1/a*.

Several testable predictions can be derived from our simple model: [1] more stringent regulations means higher abatement costs (TAC and/or MAC) which increases the likelihood that firms will outsource. [2] lower trade costs (transport costs and tariffs) make outsourcing more likely. [3] more productive firms will outsource (hence larger firms will outsource). [4] firms with larger exports are more likely to outsource. [5] more (human or physical) capital intensive firms are more productive and thus more likely to outsource (hence higher physical capital per worker or R&D intensive firms will outsource) and finally [6] higher wage rates in the Home country promotes foreign outsourcing. The next section tests these theoretical predictions with data for a unique sample of Japanese firms in 1998 and 1999.

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:[10]

$$\text{logit}\left[\Pr(OUTSOURCE)=1\right]=\log\left(\frac{\Pr}{1-\Pr}\right) \qquad (8)$$

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

$$\text{logit}\left[\Pr(OUTSOURCE_i)=1\right]=\alpha+\delta_j+\lambda ER_i+\beta TRANS_i+\varsigma' Z_i+\varepsilon_i \qquad (9)$$

where *OUTSOURCE* is a dummy variable equal to 1 if a firm undertakes overseas outsourcing, *ER* is a measure of environmental regulation, *TRANS* is transport costs, *Z* is a vector of other firm characteristics and δ is an industry specific dummy variable. To reduce contemporaneous correlation, explanatory variables are reported in 1998 while the dependent variable is reported in 1999.

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

[10] Our dependent variable takes the form of a dummy variable since our interest is the decision whether or not to outsource and the factors that influence this decision. For reasons of space we have not reported estimations based on the *degree* of outsourcing but they were consistent with the reported results.

firms' environmental activities which, the previous literature tells us, are likely to be highly correlated with firms' abatement costs. 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 *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).[11] 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

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

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.[12] In sum, it does appear highly 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. These are defined in Appendix Table 1.

[Table 1 about here]

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 its inputs if it did decide to outsource them.[13] Second, *TARIFF* to control for the impact of domestic tariffs on imports measured as tariff revenue in Yen as a share of imports. 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

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[12] 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.

[13] 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.

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.

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. 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 all variables while Appendix 2 provides summary statistics.[14] Appendix 3 compares the mean values of our explanatory variables for firms that outsource and those that do not. It can be seen that outsourcing firms are, on average, larger than non-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. Appendix 4 compares the responses to the environmental questions of outsourcing and non-outsourcing firms. 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.

5. Results

In Table 2 we report the odds ratio emanating from our estimation of equation (8) but have subtracted one from each odds ratio to ease interpretation. The dependent variable is the *ENVdumall* environment 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, with additional explanatory variables added incrementally. In all models we find the odds ratio (minus 1) of *ENVdumall* to be positive and that of *TRANS* to be negative, and both are statistically significant. Taking the example of model (6),

[14] 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 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.

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% increase in transport costs as a share of sales *reduces* the likelihood of a firm outsourcing by 27%.

In terms of other variables, we find no statistically significant relationship between tariffs and outsourcing. However, firm size, the level of wages, 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 3 we check the robustness of *ENVdumall* by testing the five remaining environmental variables, as defined in Appendix Table 2. 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. These 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. Other results are consistent with those in Table 2.

We 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.

6. Conclusions

In this paper we develop a heterogeneous-firm model with environmental regulations and the possibility of outsourcing dirty production. In equilibrium we have two types of firm. First, firms with emissions above a given government set threshold that pay abatement costs (abatement firms). Second, outsourcing firms that outsource the dirty 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 pollution intensity and abatement costs per unit of value added of firms, we interpret this as meaning that pollution intensive, 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 massive 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.

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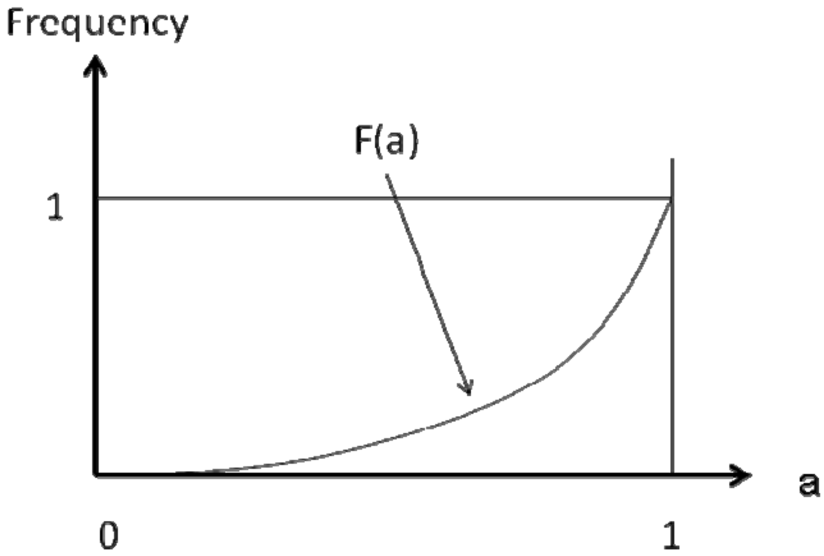


Figure 1: Firm Distribution

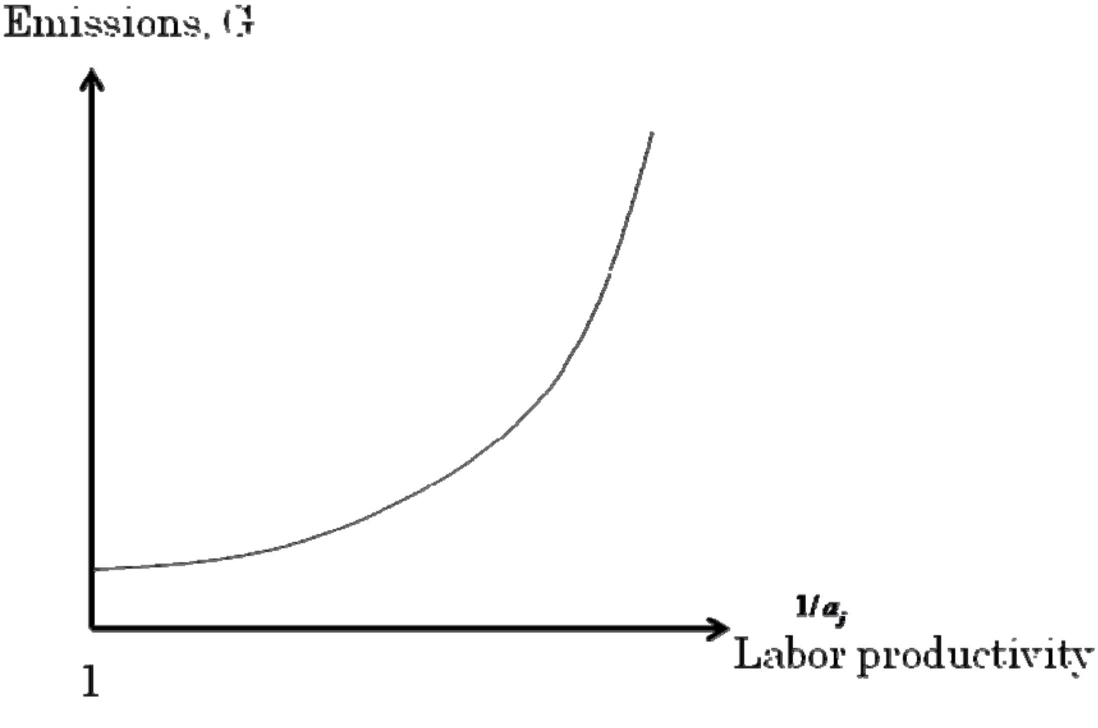


Figure 2: Emissions (initial equilibrium)

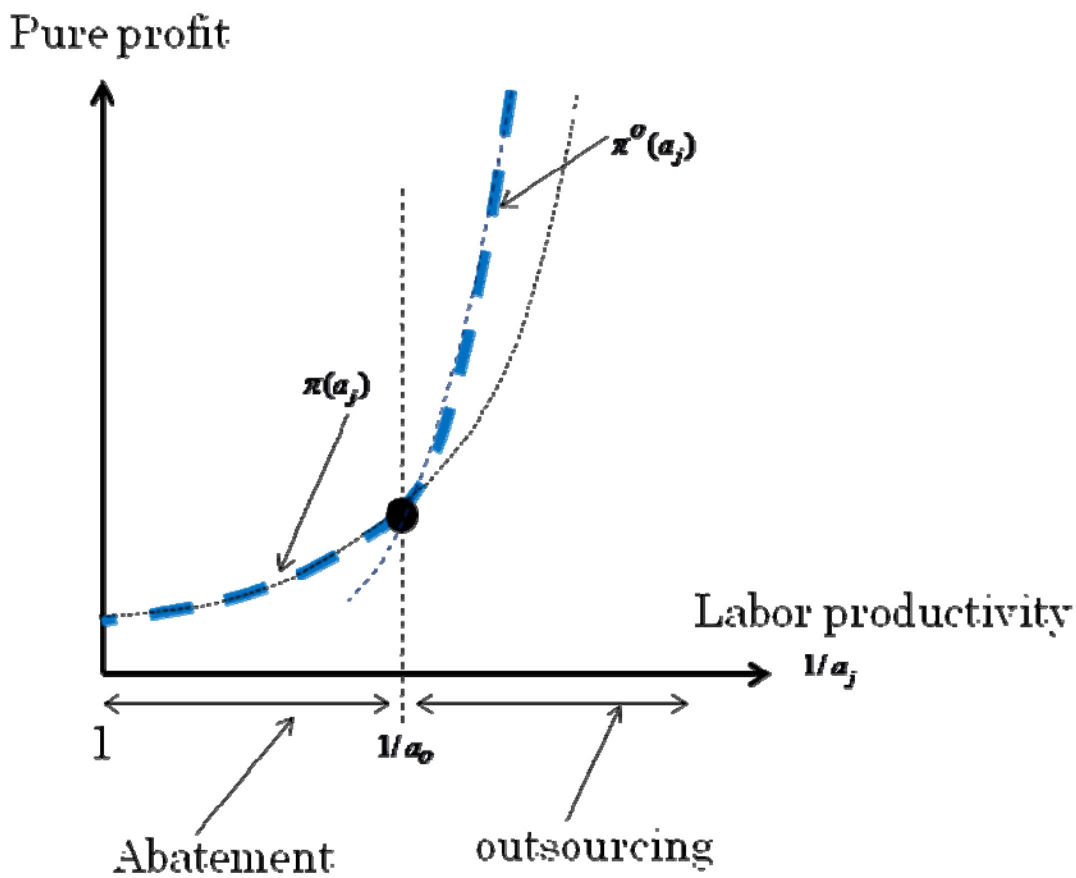


Figure 3: Outsourcing Equilibrium

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 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 doe not precisely match.

Table 2: 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***	0.673***	-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	0.0002***	0.0002***	0.0002***	0.0001***	0.0001***	0.0001***
	(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

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 3: Sensitivity Analysis.

	(1)	(2)		(3)	(4)	(5)
ENVdum1	0.032***					
	(3.0)					
ENVdum2		0.042***				
		(3.4)				
ENVdumall			0.053***			
			(4.8)			
ENVcount1				0.026***		
				(3.9)		
ENVcount2					0.029***	
					(4.9)	
ENVcountall						0.021***
						(5.8)
TRANS	-0.261***	-0.273***	-0.273***	-0.257***	-0.277***	-0.27***
	(5.3)	(5.5)	(5.6)	(5.3)	(5.8)	(5.7)
TARIFF	0.407	0.285	0.286	0.349	0.223	0.201
	(0.4)	(0.3)	(0.3)	(0.4)	(0.3)	(0.2)
SIZE	0.0001**	0.0001**	0.0001***	0.0001**	0.0001**	0.0001*
	(2.5)	(2.6)	(2.6)	(2.3)	(2.0)	(1.8)
WAGE	0.097***	0.097***	0.094***	0.094***	0.091***	0.087***
	(3.8)	(4.0)	(4.1)	(3.8)	(3.8)	(3.8)
KL	-0.291	-0.315	-0.314	-0.296	-0.365	-0.363
	(1.2)	(1.2)	(1.2)	(1.2)	(1.5)	(1.5)
EXPORTS	0.054***	0.054***	0.054***	0.054***	0.054***	0.054***
	(10.1)	(9.7)	(9.8)	(9.9)	(9.6)	(9.6)
R&D	0.080***	0.078***	0.078***	0.079***	0.077***	0.075***
	(3.9)	(3.8)	(3.8)	(3.8)	(3.6)	(3.6)
ADV	0.008	0.008	0.008	0.009	0.009	0.008
	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)
Observations	12335	12335	12335	12335	12335	12335

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.

Appendix 1: Data definitions and sources

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
TRANS	transport costs as a percentage of sales
TARIFF	Tariff revenue in Yen as a share of imports
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.

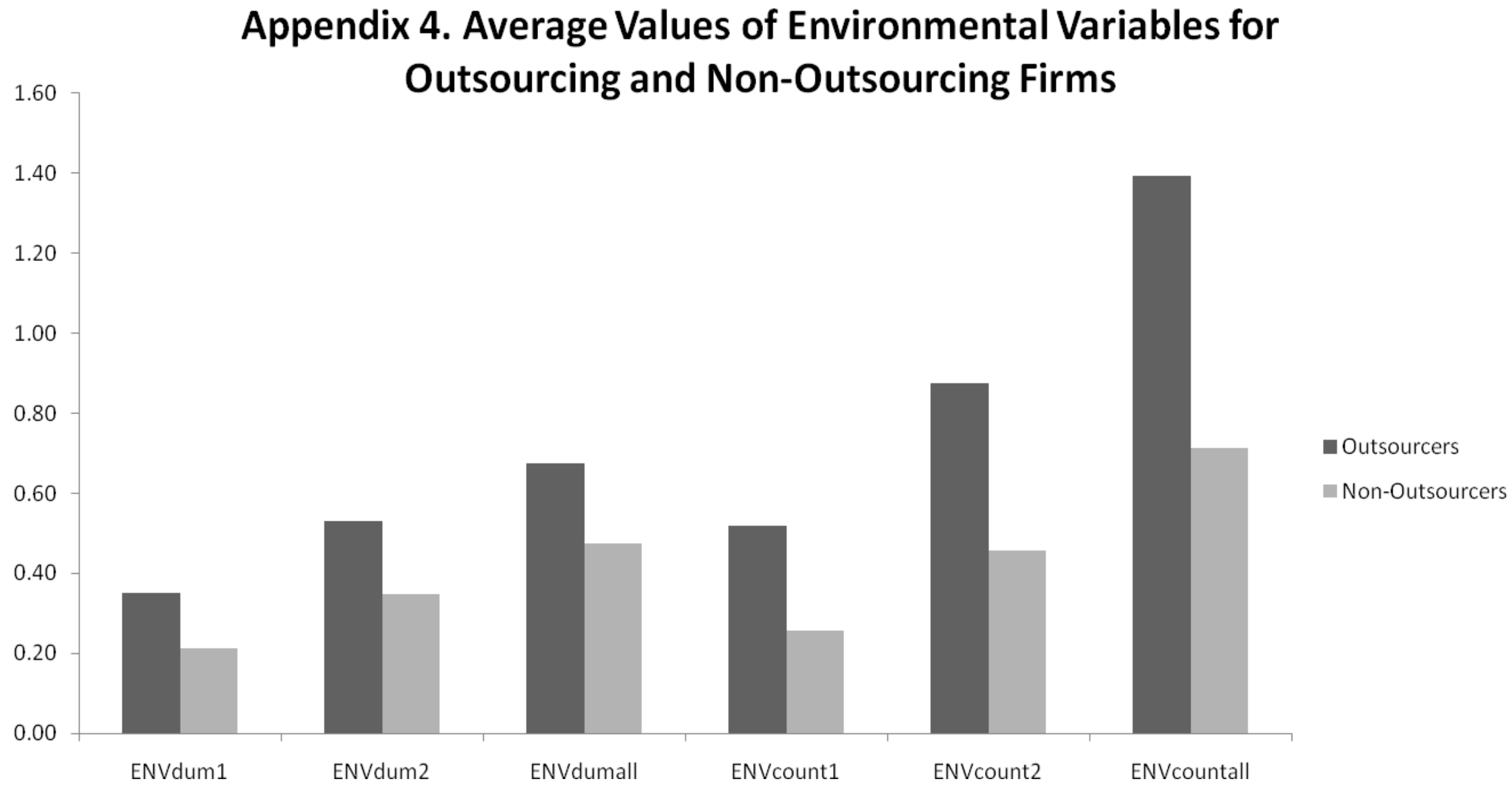
All variables are from *Kigyou Katsudou Kihon Chousa Houkokusho* (*The Results of the Basic Survey of Japanese Business Structure and Activities*) prepared by the Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry (MITI).

Appendix 2. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ENVdum1	12335	0.26	0.44	0	1
ENVdum2	12335	0.43	0.50	0	1
ENVdumall	12335	0.57	0.49	0	1
ENVcount1	12335	0.34	0.63	0	3
ENVcount2	12335	0.61	0.84	0	4
ENVcountall	12335	0.94	1.18	0	7
OUTSOURCE	12335	0.061	.24	0	1
TRANS	12335	2.39	1.30	0	7.30
TARIFF	12335	0.081	0.11	0	0.71
SIZE	12335	395.49	1595.78	50	71154
WAGE	12335	4.85	1.62	0.070	47.48
KL	12335	0.15	0.25	0.000011	14.64
EXPORT	12335	1.87	5.590548	0	39.94
R&D	12335	0.84	1.87	0	59.56
ADV	12335	0.43	1.44	0	42.76

Appendix 3. Mean Values of Explanatory Variables for Outsourcing and Non-Outsourcing Firms

Variable	Outsourcing	Non-Outsourcing
TRANS	1.67	1.81
TARIFF	0.05	0.04
SIZE	1249.84	353.27
WAGE	5.38	4.78
KL	0.13	0.12
EXPORTS	5.79	1.11
R&D	1.58	0.46
ADV	0.76	0.63



Note: For the ENVdum variables the Y axis provides the proportion of firms answering 'yes' to the different groups of environmental questions. For the ENVcount variables the Y axis provides the average number of questions that firms answered 'yes' to within each group of questions. See Appendix Tables 1 and 2 for more information.