Intraindustry Trade and the Environment:
Is There a Selection Effect?

Sarma Aralas[1] and John Hoehn[2]

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA, CAES, & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010

---

[1] Ph.D. Candidate, Department of Agricultural, Food and Resource Economics, Michigan State University, East Lansing, MI 48824. Email: aralassa@msu.edu. Tel: (517) 316-6884, (517) 355-9813

[2] Faculty, Department of Agricultural, Food and Resource Economics, Michigan State University, East Lansing, MI 48824. Email: hoehn@msu.edu. Tel: (517) 353-6735 Fax: (517) 432-1800

1. Introduction

Environmental concerns are at center stage of current global debates on issues ranging from climate change to natural resource conservation. Anthropogenic sources of environmental degradation include development activities undertaken to increase economic growth and welfare. In the late twentieth century, industrialization characterizes the developmental paths of countries seeking to modernize and to raise per capita incomes. Countries that engage in international trade expand their potential beyond domestic borders to reach a global and richer market. As globalization becomes an important aspect of economic development, countries with accelerated growths in dirty industries are viewed as contributing to the deterioration of environmental problems such as global warming, deforestation and resource depletion. Globalization, it is argued, leads to the expansion of pollution-intensive production which causes harm to the environment.

While it is widely recognized that international trade raises economic welfare, the question that remain is if production is pollution intensive, does international trade necessarily lead to detrimental effects on the environment? Is there evidence to suggest that trade is beneficial or harmful to the environment? Investigations into the trade-environment linkage have mainly sought to address the heatedly debated question of whether dirty trade contributes to increasing pollution levels and thus negate the benefits of cross-border exchanges of goods. While free trade may increase consumptive welfare, there is yet a definite answer as to whether globalization and the environmental cost of dirty production can lead to net welfare gains. From the seminal work by Grossman and Krueger (1991) to the more recent study by Antweiler et al. (2001), the answer to the question of whether trade is good or bad for the environment remain elusive. Thus far, empirical findings provide mix evidence, and in many cases depends on the nature of pollutants being studied (see Shafik 1994; Harbaugh et al. 2002; Antweiler et al. 2001; Cole and Elliot 2003; Broda and Weinstein 2006).

Notably, the majority of empirical studies investigating the impact of trade on the environment are based on the traditional theory of trade. On the other hand, international trade theory suggests that trade may be driven by not only factors that lead to comparative advantage that is based on cross-country differentials in factor endowments, but that trade may also be driven by preferences for variety in goods and scale economies in production. Hence, if economic theory suggests that traditional, inter-industry trade is distinct from "new", intra-industry trade, can the environmental impact of intra-industry trade be shown to be distinct from the environmental impact of inter-industry trade?

In their study, Antweiler et al. (2001) formally decomposes the environmental impact of trade using the Heckscher-Ohlin type model into the three kinds of environmental effect, namely, the scale, technique and selection effects. While there are studies based on "new" trade theory that investigate the environment-trade relationships (see for example, Gurtzgen and Rauscher 2000), presently there has not been any study that formally shows the explicit impact of intra-industry trade on environmental quality. Further, although intra-industry trade explains a significant volume of trade patterns, there is currently no empirical study that investigates the impact of new trade on domestic local pollutants. This paper aims to fill the gap in the literature by showing that that the environmental impact of trade in differentiated goods or "new" trade can be formally decomposed into specific effects in a manner that parallels the decomposition of the effects of traditional trade on the environment. Further, we argue that if countries engage in both inter- and intra-industry trade[3], the empirical assessment of how international trade affects environmental quality should account for the impact of both types of trade. There has not been a study that assesses the full impact of trade under the assumption that countries engage in both intra- and inter-industry trade.

In this paper, we propose a pollution model of trade based on new trade assumptions that market structure is monopolistic competition and that trade is driven by increasing returns in production. We show that the environmental impact of trade in differentiated goods can be explicitly decomposed into scale, technique and selection effects. We test the predictions of our model for countries that engage in both intra- and inter-industry trade using pollution data from countries in the Organization for Economic Co-operation and Development (OECD), spanning the recent years 1995-2004. Three types of pollutants

---

[3] The World Bank (2009) calculates and makes available data on Intra-industry Trade (IIT) Index and the Revealed Comparative Advantage (RCA) Index. The IIT index can be computed for any country and is generally computed for the manufactured goods traded Standard Industrial Trade Classification (SITC) three-digit level.

are considered, namely, sulfur oxides (SOx), nitrogen oxides (NOx) and volatile organic compounds (VOC). Estimating equations are based on the predictions of two main theoretical frameworks. In addition, we examine the effect of openness to trade on emissions level. The full impact of international trade on the environment is estimated as the sum of the magnitudes of four environmental effects[4], that is, as the aggregation of the responses to the scale, technique, selection and composition effects. We control for the selection effect as an important variable that describes the data generating process of a trade-environment relationship for countries engaged in both intra- and inter-industry trade. In this manner, our model addresses the omitted variable problem in estimation.

The contribution of this paper includes the following. First, in the next section of this paper we develop a trade-environment framework that shows the explicit decomposition of the impact of new trade on pollution levels. The environmental impact of intra-industry trade is made distinct and is differentiated from the environmental impact of inter-industry trade. Second, our framework shows how trade in differentiated, dirty goods generates trade-induced scale, technique and selection effects. Third, our empirical findings show the following: one, trade in differentiated goods leads to a positive scale effect, a negative technique effect, and a positive selection effect; and two, the total impact of international trade on environmental quality is the sum of the magnitudes of trade-induced scale, technique, selection and composition effects. Fourth, our analysis finds evidence to suggest that the selection effect is an important and relevant variable whose omission causes misspecification of the estimation of data. Finally, our findings show results that suggest responses that describe the underlying assumptions of trade that is intra-industry.

The remainder of this paper is organized as follows. Section 2 presents a pollution model of trade under the assumptions market is monopolistically competitive and that technology is increasing returns to scale. Section 3 presents concepts and hypotheses. Section 4 derives the reduced form and estimating

---

[4] The empirical study by Antweiler et al. (2001) investigated three environmental effects, namely the scale, technique and composition effects using the framework based on the traditional theory of trade.

equations for the econometric analysis. Section 5 discusses the empirical strategy. Section 6 presents results, section 7 is discussion and section 8 concludes.

2. Theory

2.1 The Model

The analysis in this section proceeds by characterizing the closed economy equilibrium followed by the open economy equilibrium. We develop a model of pollution based on the neo-Chamberlinian-Krugman type model of monopolistic competition and trade. We extend the Dixit-Stiglitz-Krugman (1979) trade model by incorporating pollution externality to examine the impact of trade on environmental quality. The economy is composed of consumers, firms, and a regulatory authority. Market structure is monopolistically competitive and production technology yields increasing returns to scale. Firms produce differentiated goods which generate pollution as a by-product, that is, pollution is a joint output of production. Firms have identical technologies and produce goods with a large number of potential product varieties. Because of economies of scale, each firm produces one type of product. Producers are identical except in the design of their products. Firms are able to differentiate their products without incurring additional costs. A large number of goods are produced such that there is negligible effect of the price of any one good on the demand of another; hence, one firm’s behavior is independent of the other, that is, there is no strategic interdependence between firms. Labor is the only factor of production that is inelastically supplied in a competitive labor market. Income in the economy comes from wage earnings. There are instantaneous adjustments to changes in variables, and there is perfect information. Finally, countries are identical in size, technology and preference, and there is zero transportation cost.

2.3.1 Demand

There is L number of consumers with identical preferences in the economy. The utility function takes the symmetric, additively separable form where love of variety is assumed with respect to consumption of goods. Consumers do not derive utility from leisure. Each consumer receives positive utility from consuming c_i, the consumption of the *i*th good, but obtains negative utility (disutility) from pollution, z_i. Products are horizontally differentiated and enter the utility function symmetrically. Social damage from pollution comes from the disutility imposed on consumers. Consumers take pollution as given. Thus, the consumer maximizes utility only with respect to the consumption of goods. The utility function is as follows:

$$(2.1) \qquad U = \sum_{i=1}^{n} v(c_i) - \sum_{i=1}^{n} z_i \qquad v^{'} > o, \quad v^{''} < 0, \quad u' > 0$$

Let the representative consumer maximizes utility with respect to c_i subject to a budget constraint. Total income, y, is equal to wage, w, earned by the individual. Therefore the consumer's maximization problem is as follows:

$$\underset{\{c_i\}}{Max} \quad U = \sum_{i=1}^{n} v(c_i) - \sum_{i=1}^{n} z_i \qquad \text{subject to} \quad y = w$$

where $y = \sum_{i=1}^{n} p_i c_i$, and p_i denotes the price of the ith good. Then, the first order condition for consumer utility maximization is:

$$(2.2) \qquad v'(c_i) = \lambda p_i \qquad i = 1, ..., n$$

where λ is the Lagrange multiplier and the marginal utility of income.

If the number of varieties is large such that the budget share of each variety is small, the impact of price on the marginal utility of income may be ignored. In that case, the effect of a change in price implies that the elasticity of demand for variety i is the following (see Krugman 1979):

$$(2.3) \qquad \eta_i = \frac{-dc_i}{dp_i} \cdot \frac{p_i}{c_i} = -\left(\frac{v'}{c_i v''} \right) > 0$$

Following Krugman (1979), it is assumed that

$$(2.4) \qquad \frac{d\eta_i}{dc_i} < 0$$

so that elasticity is increasing as we move up along the demand curve and consumption is falling.

2.3.2 Production

Firms have identical technologies where labor is a linear function of output and takes a particular functional form (Krugman 1979). There is increasing return to scale that is internal to firms with positive initial fixed costs, constant marginal costs and thus declining average costs.

Output, q_i, is an increasing function of labor, l_i, such that:

$$l_i = \alpha + \beta q_i \qquad \alpha > 0,\ \beta > 0 \tag{2.5}$$

where α is the fixed cost of production. Firms generate pollution jointly and symmetrically with the production of goods. For simplicity, assume pollution is generated in constant proportion to output production. Pollutants in the model are local in their manner of dispersion and are uniformly released into the environment. There is a regulatory authority which imposes emission tax to internalize the negative pollution externality. In this paper, emission tax is determined exogenously. In response to the implementation of environmental regulation, firms undertake emission abatement to avoid costly emission tax payments. Resources for abatement are drawn from the output that firms produce. Therefore, firms allocate a portion of output towards abatement activity and allocate the remaining portion for goods consumption in the market.

Pollution emission, z_i, is the difference between potential pollution, z^F, and pollution abated, z^A. Emission per unit of output or emission intensity denoted e_i, is z_i / q_i. Hence, the following equation specifies the relationship between emission and emission per unit output:

$$z_i = e_i q_i \tag{2.6}$$

If each firm allocates q_i^a of units of output into abatement, then net output is:

$$q_i^{net} = q_i (1 - \theta_i) \tag{2.7}$$

where $\theta_i = q_i^a / q_i$ is the fraction of output allocated towards emission control.

Since individual consumers are the workers in production, total labor force in the economy is L. Then, supply of output is equal to demand given by the following relationship:

(2.8) $$(1-\theta_i)q_i = Lc_i \qquad 0<\theta<1$$

where $\left(1-\theta_i\right)$ is the fraction of output allocated towards consumption.

We specify a functional form for emission per unit to describe the relationship between pollution emission and output[5] such that emission per unit or emission intensity, e_i, takes the following form:

(2.9)[6] $$e_i = (1-\theta_i)^{\delta} \qquad \text{where} \quad 0<\theta<1$$

The parameter δ measures the responsiveness of a change in emission levels due to a change in the fraction of output allocated towards consumption. The elasticity is assumed to be positive, which means that pollution is emitted in increasing proportion relative to the production of pollution-intensive or dirty goods. If δ is less than one, then this implies that the percentage change in emission is less than a percentage change in the fraction of output produced for consumption purpose. Generally, in pollution-intensive industries such as manufacturing and agriculture, pollution is emitted at an increasing rate as greater amount of resources are allocated towards the production of dirty goods. Therefore, for the functional form specified above, the assumption that δ may be greater than one is reasonable and has a basis in the practical sense.

The pollution tax, τ, is taken to be high enough so that firms choose to undertake abatement activity. Denoting π as profit, the profit function is the firm's revenue less labor cost, pollution taxes and abatement cost such that:

(2.10) $$\pi_i = p_i(1-\theta_i)q_i - w\alpha - w\beta q_i - \tau z_i$$

---

[5] This approach allows for the explicit decomposition of the effects of intra-industry trade on environmental quality. It is also consistent with the approach of specifying a particular production technology in the Krugman (1979/1980) model.

[6] This particular functional form for emission per unit differs from the emissions function of Antweiler, Copeland and Taylor (2001). This form implies that emission release is released in increasing proportion relative to the production of dirty goods, which is consistent with pollution-intensive industries including the agricultural sector.

Since all firms are identical, symmetry across firms implies that $p = p_i$, $q = q_i$, $\theta = \theta_i$ and $z = z_i$ for all $i.$ Henceforth, subscripts are suppressed.

2.3.3 Autarky Equilibrium

The first order conditions for profit maximization with respect to q implies:

$$p'\left(1-\theta\right)^2 q + p\left(1-\theta\right) - w\beta - \tau(1-\theta)^{\delta} = 0 \tag{2.11}$$

By simplification and by substitution for the elasticity of demand, the following equation is obtained:

$$p\left(1-\frac{1}{\eta}\right) = \frac{w\beta}{\left(1-\theta\right)} + \tau\left(1-\theta\right)^{\delta-1} \tag{2.12}$$

where η is the price elasticity of demand. Equation (2.12) shows marginal revenue, the term on the left hand side, is equal to marginal cost, the term on the right hand side. Marginal cost is the sum of (i) the marginal cost of production from the incremental use of labor normalized by the fraction of output/resource allocated towards goods' consumption and (ii) the marginal cost of emission per unit normalized by the consumption fraction.

The first order conditions for profit maximization with respect to θ is:

$$-qp'\left(1-\theta\right)q - qp + \tau\delta\left(1-\theta\right)^{\delta-1} q = 0 \tag{2.13}$$

Substituting for the elasticity of demand and simplifying, equation (2.13) can be rewritten as the following:

$$p\left(1-\frac{1}{\eta}\right) = \delta\tau\left(1-\theta\right)^{\delta-1} \tag{2.13'}$$

Equation (2.13') shows that marginal revenue is equal to the marginal cost of per unit emission normalized by per unit consumption and multiplied by the factor $\delta.$ The parameter δ is the elasticity of emission per unit with respect to per unit consumption. The equation implies that the marginal revenue obtained from the incremental sale of consumption goods is equal to the opportunity cost of resources used to generate emission per unit. In this model, output is used as resources for two purposes, one, as consumption goods for the product market, and two, as resources in abating emissions. Thus, in other words, equation (2.13') shows that the cost of foregone emissions multiplied by a factor of δ exactly equals the revenue that can be obtained were resources allocated away from abatement and into goods production for the purpose of consumption. Second order conditions for profit maximizations can be shown to be fulfilled. Then, assuming an interior solution, the first order conditions can be solved for the fraction of output allocated towards abatement as:

(2.14) $$\theta = 1 - \left(\frac{w\beta}{\tau\left(\delta - 1\right)} \right)^{\frac{1}{\delta}}$$

Equation (2.14) shows it is decreasing in wage $w,$ the labor coefficient $\beta,$ and in the marginal cost of goods production, $w\beta.$ Consistent with theory, the fraction of output allocated towards abatement is increasing in emissions tax, τ . This means that a more stringent environmental policy leads to higher level of abatement activity undertaken by the firm. The equation also shows that the abatement fraction of output is increasing in the elasticity of per unit emissions with respect to per unit consumption, $\delta.$ The more elastic emission intensity is to a change in the allocation of output towards consumption, the greater the allocation of output towards abatement. This implies that higher emission intensity from an expansion of the scale of production necessarily leads the firm to undertake higher abatement levels as the firm attempts to exert greater control over the production of emission. This is consistent with the abatement theory that firms choose to reduce emission levels that is jointly generated with the expansion of production to avoid higher emission tax cost.

Since the fraction of output used for abatement is a value that is between zero and one, equation (2.14) implies the following:

(2.15) $$0 \le \left(\frac{w\beta}{\tau\left(\delta - 1\right)} \right)^{\frac{1}{\delta}} \le 1$$

Equation (2.15) implies that for the condition to hold and be meaningful, it is required that $\left(\delta-1\right)\neq 0$, that is, $\delta>1$. Then, as mentioned in the foregoing, $\delta>1$ implies that pollution is emitted at an increasing rate as greater amount of resources are allocated towards the production of dirty goods.

By substitution of equation (2.14) into equation (2.9), emission per unit output can be written as:

$$e=\left(\frac{w\beta}{\tau\left(\delta-1\right)}\right) \tag{2.16}$$

Equation (2.16) shows that emission intensity decreases with more stringent environmental policy, but increases with an increase in the marginal cost of production of output. Therefore, a more stringent policy implies that firms strive to reduce emissions level and undertake greater abatement to pursue this goal. This results in lower emission intensity per unit output. On the other hand, higher marginal cost of production implies that there is an expansion of production which leads to an increase in emission intensity.

The equilibrium pricing rule is obtained by substituting equation (2.14) into (2.12) to obtain the following:

$$p\left(1-\frac{1}{\eta}\right)=\left(w\beta\right)\left(\frac{w\beta}{\tau\left(\delta-1\right)}\right)^{-\frac{1}{\delta}}\left(\frac{\delta}{\left(\delta-1\right)}\right) \tag{2.17}$$

Equation (2.17) shows that in the model with pollution externality, product price is determined not only by the marginal cost of production, but it is also determined by emission tax rate and the emission intensity of production.

By substituting for the value of θ and e, we rewrite equation (2.17) as:

$$p=\left(1-\frac{1}{\eta}\right)^{-1}\left(w\beta\right)e^{-\frac{1}{\delta}}\left(\frac{\delta}{\left(\delta-1\right)}\right) \tag{2.17'}$$

Equation (2.17') indicates that given the emission elasticity parameter and the elasticity of demand for variety, the pricing rule is a function of emissions per unit output such that it is decreasing in emission intensity. This implies the higher the emissions intensity, the lower the price of market goods. One explanation for the lower price is that there is a trade-off between emission control and allocating goods for consumption. Greater emission intensity implies there is less abatement which in turn implies that there is greater allocation of output for the purpose of consumption. Therefore, holding every other factor equal, a greater supply of goods induces a lower product price in the market.

Equation (2.17) is one of the two equilibrium conditions that determine the equilibrium consumption level of product varieties and the price level for the firm. We designate equation (2.17) as the PE line[7]. We rewrite the PE line as:

$$\frac{p}{w}=\left(1-\frac{1}{\eta}\right)^{-1}\left(\frac{w\beta}{\tau\left(\delta-1\right)}\right)^{-\frac{1}{\delta}}\beta\left(\frac{\delta}{\left(\delta-1\right)}\right) \tag{2.18}$$

The other equilibrium condition is the zero profit condition. Free entry with positive profits requires that firms earn zero profit in the long run. In this model, the zero profit condition is given by the following:

$$p(1-\theta)q-w\alpha-w\beta q-\tau(1-\theta)^{\delta}q=0 \tag{2.19}$$

Divide equation (2.19) by net output, $\left(1-\theta\right)q,$ and the wage rate, w, then substitute total consumption $\left(Lc\right)$ for quantity supplied. Then, by equation (2.14) and rearranging, the following equation is obtained:

$$\frac{p}{w}=\left(\frac{\tau}{w}\right)^{\frac{1}{\delta}}\left(\frac{\alpha}{Lc}\left(\frac{\beta}{\left(\delta-1\right)}\right)^{-\frac{1}{\delta}}+\delta\left(\frac{\beta}{\left(\delta-1\right)}\right)^{\frac{\delta-1}{\delta}}\right) \tag{2.20}$$

Equation (2.20) is the equilibrium condition where price equals the average of the sum of labor cost and emission cost. Designate this line as the ZE line.

Equations (2.18) and (2.20) form two equations that can be solved for the two unknowns, $\frac{p}{w}$, and consumption, $c,$ or alternatively, to solve for quantity of output, $q.$ In this model of pollution

---

[7] Tis curve is similar to the PP line in Krugman (1979), but in our pollution model, the PE line is a function of emission tax rate.

externality, we solve for the quantity of output instead of consumption for the reason that output is the more relevant variable in analyzing changes in emission levels[8]. Then, given an emission tax rate and fixed parameters in the system, we can graph equations (2.18) and (2.20) in the price and output space as the PE and the ZE curves respectively. This is shown in Figure 2.1. As in Krugman (1979), we assume that $d\eta_i / dc_i < 0$. In a model of pollution, the PE line that represents equation (2.18) is shown to be upward sloping, and the ZE line that represents equation (2.20) is downward sloping.

The relationship between the PE and ZE lines with respect to output level is shown in equations (2.21) and (2.22) as the following. Taking the total differentiation of the PE line with respect to output yields the result in equation (2.21).

(2.21)
$$\frac{d\left(PE\right)}{dq} = \left\{ -\left(1-\left(\eta\left(c\right)\right)^{-1}\right)^{-2} \left(\eta\left(c\right)\right)^{-2} \frac{\partial \eta}{\partial c} \cdot \frac{\partial c}{\partial q} \right\}$$

Thus, the PE line is upward sloping since $\frac{\partial n}{\partial c} < 0$ and $\frac{\partial c}{\partial q} > 0$.

Taking the total differentiation of the ZE line with respect to output yields:

(2.22)
$$\frac{d\left(ZE\right)}{dq} = -\alpha q^{-2} \mathrm{M}^{-1}$$

where
$$\mathrm{M} = \left(\frac{w\beta}{\tau\left(\delta - 1\right)} \right)^{\frac{1}{\delta}} \quad .$$

Therefore, the ZE line is downward sloping. Figure 1 shows the diagrammatic representation of the relationship between the PE and ZE lines and the level of output.

---

[8] This contrasts with the Krugman (1979) trade model which solved for consumption level, and not output level.

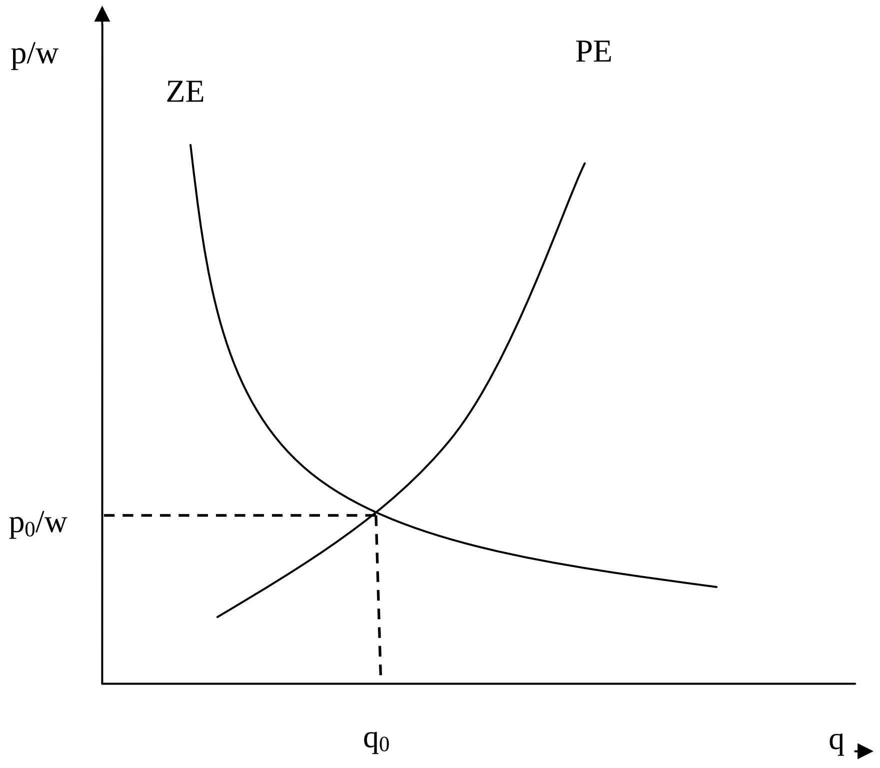

Figure 1: The PE line and the ZE line.

We solve for the number of product varieties using the full employment equation. Then, by equations (2.8) and (2.14), and assuming symmetry, the following is obtained:

$$L = \sum_{i=1}^{n} \left(\alpha + \beta q_i\right) = n\left(\alpha + \beta q\right)$$

(2.22) *or*

$$L = n\left(\alpha + \frac{\beta L c}{\left(1-\theta\right)}\right) = n\left(\alpha + \frac{\beta L c}{\left(\frac{w\beta}{\tau\left(\delta-1\right)}\right)^{\frac{1}{\delta}}}\right)$$

Solve for n such that:

(2.23) $$n = \frac{L}{(\alpha + \beta q)}, \quad n = \frac{1}{\alpha L^{-1} + \beta c \left(\frac{w\beta}{\tau(\delta - 1)} \right)^{-\frac{1}{\delta}}}$$

The number of product varieties is a function of total labor, consumption level, the wage rate, emission tax rate and other predetermined variables. For a given level of consumption, an increase in the labor force increases the number of product varieties. On the other hand, an increase in emission tax rate decreases the number of product varieties.

2.3.4 Decomposition of Impact: Scale, Technique and Selection Effects

In this subsection, I show the decomposition of the impact of pollution-intensive production on total emission. The derivation of the scale, technique and selection effect is shown as the following. Equation (2.6) can be written as:

(2.24) $$z_i = e_i q_i \Rightarrow \sum_{i=1}^{n} z_i = \sum_{i=1}^{n} e_i q_i = \sum_{i=1}^{n} e_i \left(Lc_i / (1 - \theta_i) \right)$$

In the closed economy, total labor L, is fixed, and with symmetry across firms, these imply:

(2.25) $$\begin{gathered} \sum_{i=1}^{n} z_i = \sum_{i}^{n} e_i q_i \Rightarrow nz = n \cdot e \cdot q \\ and \\ \sum_{i=1}^{n} z_i = L \sum_{i}^{n} e_i c_i \big/ (1 - \theta_i) \Rightarrow nz = L \cdot n \cdot ec \big/ (1 - \theta) \end{gathered}$$

Letting $nz = Z$ (total pollution), and rewriting equation (2.25) in differential form (hats denote percent change) yields[9]:

(2.26) $$\begin{gathered} \hat{Z} = \hat{n} + \hat{e} + \hat{q} \\ or \\ \hat{Z} = \hat{n} + \hat{L} + \hat{c} + \hat{e} - \left(1 \overset{\wedge}{-} \theta\right) \end{gathered}$$

---

[9] See Appendix A for more detailed derivation.

Thus, equation (2.26) shows that the impact of economic factors on pollution can be decomposed into the *selection*, *scale,* and *technique effects* in the following way:

(2.26.1) Selection effect, $\hat{n}$

(2.26.2) Scale effect, $\hat{S} = \hat{q}$ or $\hat{S} = \hat{L} + \hat{c} - \widehat{\left(1-\theta\right)}$

(2.26.3) Technique effect, $\hat{e}$

In a model of monopolistic competition and increasing returns, the impact of the production of dirty goods generates three types of effects, namely the scale, technique and selection effects. Holding other determinants constant, the environmental effects of production are described as the following. The scale effect refers to how a change in the scale of the economy results in a change in emissions level; the technique effect refers to the effect of how emission intensity affects emissions level; and the selection effect refers to how a change in the number of product varieties changes the levels of pollution emission. Thus, equation (2.26) shows that growth in total emissions level depends on the growth of the scale of the economy, the growth in emission intensity of production, and the growth in the number of firms or equivalently, in the number of product varieties.

The current model distinguishes the environmental impact of trade driven by the demand aspect of the economy from the environmental impact of trade driven by the supply or production aspect of the economy. While the production of dirty goods in a perfectly competitive market with constant returns to scale technology can be decomposed into scale, technique and composition effects (Antweiler et al. 2001), equation (2.26) shows that the difference between a model under new trade framework from that under traditional trade framework is that the former yields a selection effect while the latter yields a composition effect.

Further, equation (2.26) implies that under new trade theory, the environmental impact of trade can be broken down into finer structural decomposition. Note that under monopolistic competition, growth of the scale effect can be further decomposed into the effects of growth in the factor of production, labor, L, growth in the demand or consumption of products, c, and growth in the fraction of output allocated towards consumption and exports, $(1-\theta)$. This differentiates the scale effect in the current model from the scale effect as defined in traditional models in current literature. While the new trade framework offers a more detailed decomposition, it is noted that in empirical investigations, difficulty may arise in differentiating the effects of "new" trade variables from "traditional" trade variables in the data. To facilitate the empirical measurements of variables, we condense the intra-industry trade decomposition of the scale and technique effects to parallel the conventional decomposition of inter-industry trade, hence establishing a link between the new trade theory and traditional trade theory in the environmental context. We also note that although parallel decompositions are desirable, it is not necessary. The environmental impact of trade under new trade theory can be decomposed in a defined representation that can be explicitly separated from the environmental decomposition under the traditional trade theory.

The decomposition of the impact of dirty production shows that the total impact of trade on emission level is the sum of the magnitude of each of the scale, technique and selection effects. The relative effects of the scale, technique and selection effect to each other determine whether dirty production will raise or lower total emission in the economy. Similarly, the impact of intra-industry trade on the environment is the sum of the trade-induced scale, technique and selection effects.

2.5 Trade and Pollution

In this section, we consider the effect of intra-industry trade on the environment for two countries with identical preferences, technologies and factor endowments. Note that in a Heckscher-Ohlin world, there is no reason to trade when countries are identical in terms of factor abundance. The relationship between the price level and the consumption level of product variety is used to describe the impact of trade in differentiated goods on environmental quality.

Theoretically, in the integrated world economy, openness to trade influences L, the size of labor (Krugman 1979, 1980). While the change in consumption resulting from openness to trade captures the impact of intra-industry trade on the economy through a shift in the zero-profit curve, in contrast, the impact of free trade on the quantity of output is not directly obtained through a shift in the zero-profit curve when L changes. The effect of trade on L can be seen in the following way. Rewrite the ZE curve as the ZZ line:

$$\text{(2.35)} \qquad ZZ: \quad \frac{p}{w} = L^{-1}\frac{\alpha}{c} + \varpi^{-1}\mathrm{B}$$

$$\text{where} \qquad \varpi = \left(\frac{(w\beta)}{\tau(\delta-1)}\right)^{\frac{1}{\delta}} \quad and \quad \mathrm{B} = \beta\left(\frac{\delta}{(\delta-1)}\right)$$

Then, the slope of the ZZ line (with respect to consumption) is:

$$\frac{\left(\frac{p}{w}\right)}{dc} = -c^{-2}\frac{\alpha}{L} < 0$$

Thus the ZZ curve is downward sloping. Taking the derivative of the ZZ line with respect to labor, L:

$$\frac{\partial(ZZ)}{\partial L} = \frac{\partial\left(\frac{p}{w}\right)}{\partial L} = -L^{-2}\frac{\alpha}{c} < 0$$

A change in the labor population shifts the ZZ curve in a negative direction.

Figure 2 shows the ZZ and PE curves in the price-consumption space. When two identical countries trade in differentiated, pollution-intensive goods, it is as if there is an increase in labor supply. The ZZ curve shifts downward and to the left to yield both a fall in the price level and a fall in the consumption of a variety of goods. The fall in consumption leads to the exit of firms that earn negative profits when they cannot compete with foreign firms or products. Surviving firms expand production as they take advantage of economies of scale. As price level falls from p_0/w to p_1/w, there is a gain in real income which contributes to a higher level of economic welfare. Thus, the effect of trade on the structural factors of the economy with pollution is similar to the effect of trade in an economy without pollution. There is however, a distinguishing difference of the impact of trade between the two economies. In a model where dirty goods are produced, openness to trade influences structural factors which lead to changes in the environmental aspect of the economy. When countries engage in the trade of dirty goods where trade acts as if there is an increase the supply of labor, competition from abroad causes some firms in the domestic country to exit the industry.

Consequently, the number of firms in the open economy is lower than the number of firms in autarky. Holding everything else constant, a smaller number of firms will generate less emission into the environment. This is the trade-induced selection effect. Surviving firms increase output as they expand production to take advantage of economies of scale. All other factors equal, a larger scale of production generates greater level of pollution emission. This is the trade-induced scale effect. As output level rises with the opening of trade, the price level falls, and real income rises. Since environmental quality is a normal good, higher income level promotes stricter environmental policy. A higher emission tax rate leads to greater emission

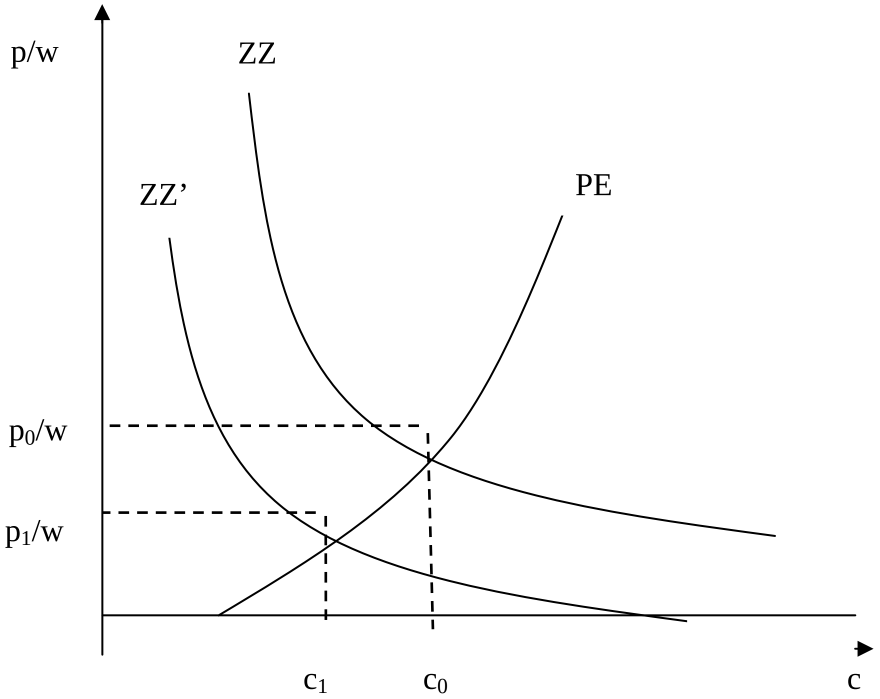

Figure 2: With the opening of trade, it is as if there is an increase in the amount of labor available for production. Consequently, the ZZ curve shifts down and to the left, where quantity of consumption decreases from c_0 to c_1 and the price level drops from p_0/w to p_1/w. Thus, the gains from trade are achieved through two sources: one, from the decline in the price level, and two, from the increase in the number of varieties due to imports. However, since goods are dirty, intra-industry trade affects the emission level in the economy.

control and thus lower emission intensity. This is the trade-induced technique effect. Thus, when production entails pollution externality, intra-industry trade generates three kinds of environmental effects which are, namely, one, the trade-induced environmental scale effect due to the expansion of production and economies of scale; two, the trade-induced environmental selection effect due to the entry and exit of firms resulting from competition from abroad; and three, the trade-induced environmental technique effect due to a fall in emission intensity when environmental regulations becomes more stringent as income level rises.

The foregoing analysis of the impact of trade on the environment can be stated more formally as the following:

PROPOSITION: *Consider two identical economies engaged in intra-industry trade. Then, under the conditions of monopolistic competition market structure and increasing returns to scale technology, free trade implies there are three trade-induced environmental effects: a positive scale effect, a negative selection effect, and a negative technique effect. The impact of trade on total emission is the sum of the trade-induced scale, selection, and technique effects. The magnitude and direction of each effect determine the overall impact of intra-industry trade on environmental quality.*

PROOF:

Equation (2.24) is:

(2.24) $$\hat{Z} = \hat{n} + \hat{e} + \hat{q}$$

Equation (2.24) shows that the overall impact of free trade on domestic emission is the sum of the scale, selection and technique effects. If trade in differentiated good expands the firm's production of goods, while the total number of firms has fallen and emission intensity is unchanged, then the scale effect may or may not overwhelm the selection and technique effect so that total emission level may rise or fall. In the case where trade and economies of scale allow the firm to expand production to the extent that increased production generates an overwhelming increase in emission, total domestic emission level may rise even though there are now fewer firms in the economy. On the other hand, if trade and economies and scale allow the firm to expand production but only to small extent such that the trade-induced reduction in the number of firms are enough to offset the increase in the scale effect of pollution, then total emission in the open economy may fall. The two alternative cases mentioned above assume that there is either very little or no technique effect.

In the case where trade allows expansion of production such that income rises high enough to provide incentive for the regulatory authority to raise the stringency of pollution policy, then firms may undertake greater abatement level. Therefore, in the case where the technique and selection effect may overwhelm the scale effect, trade is good for the environment as it results in a fall in domestic emissions level.

Since there are various alternative possibilities of the combinations of the trade-induced scale, technique and selection effects for the open economy, this suggests that the question of whether the impact of intra-industry trade on the environment will raise or lower the total level of emission is an empirical one. I will further explore the implications of the pollution model of intra-industry trade by testing the predictions of the model in an empirical analysis in a subsequent chapter.

3. Concepts and hypotheses

3.1 Concepts

In this section we present concepts and hypotheses in our empirical analysis. New trade theory suggests intra- industry trade generates three environmental effects, namely, the scale, technique and selection effects. Traditional trade theory generates three environmental effects, namely the scale, technique and composition effects (see Antweiler et al. 2001 for a formal decomposition). In this paper, we distinguish the scale effect of intra-industry trade from the scale effect of inter-industry trade. The former arises from the growth or expansion in the production of differentiated goods while the latter arises from the expansion of the production of inter-industry goods. Notably, this distinction cannot be discerned in the data when the scale effect is measured as the value of gross domestic product (GDP) since GDP reflects the value of total national production of all goods. The analysis in this paper recognizes that the scale effect constitutes the effects from both the production of differentiated and the production of homogeneous goods. The second environmental effect included as an explanatory variable in the current analysis is the technique effect. In this paper, the technique effect is defined as the effect of a change in emission intensity on environmental quality, holding the scale, selection and composition effects constant. The two major ways to generate the technique effect are, one, from the technique effect is related to the level of abatement and two, from the cross-country diffusion of efficient abatement techniques. The technique effect arising from international trade occurs not only for inter-industry trade goods but also for intra-industry goods. The response to policy requirements applies in any, or both industries engaged in the production of differentiated or homogeneous goods. The third environmental effect and explanatory variable in the current analysis is the selection effect. We define the selection effect as the change in the level of emissions due to a change in the number of firms engaged in the production of differentiated products, holding the scale and technique effects constant. Everything else equal, including the scale effect, fewer numbers of firms leads to lower levels of emission. Theoretically, free trade implies foreign competition leads to a decrease in the number of domestic firms as consumers choose to consume both domestic and foreign products under a constrained budget (Krugman 1979). A trade-induced selection effect implies that holding all other factors constant, the fall in the number of firms will lead to a fall in aggregate emissions level. The fourth environmental variable included as an explanatory variable is the composition effect. Grossman and Krueger (1991 define the composition effect as the change in the composition of sectors due to trade liberalization derived from two sources, one, from the competitive advantage in environmental regulation in the pollution-intensive sector, and two, from comparative advantage in cross-country differentials in factor abundance and technology in pollution-intensive activities. In this paper, we define the composition effect as the change in emissions level due to a change in factor intensity, holding the scale, technique and selection effects constant[10].

A final variable of interest is the trade intensity variable which measures openness to trade and the degree of trade liberation. It is used in interaction forms to measure the responses to trade-induced scale, technique, selection and composition effects and to measure the effect of free trade and trade liberalization on environmental quality.

3.2 Research Hypotheses

We propose the following hypotheses about the trade-environment relationship to describe the impact of both intra- and inter-industry on environmental quality.

Hypothesis 1: A positive scale effect contributes positively to the level of emissions.

Hypothesis 2: A negative technique effect contributes negatively to the level of emissions.

Hypothesis 3: A negative selection effect contributes negatively to the level of emission

Hypothesis 4: The composition effect is positively related to the level of emissions.

Hypothesis 5: The level of emissions is decreasing in trade intensity or openness to trade.

---

[10] This definition is similar to Antweiler et al. (2001).

4. Reduced Form Equations

The private demand for pollution is given by equation (19) while the supply of pollution is given by equation (28). The equation can be decomposed into its primitive determinants and by combining the supply and demand for pollution generates a parsimonious reduced form equation given by:

$$(30)\qquad \hat{Z} = \Pi_1\hat{n} + \Pi_2\hat{S} + \Pi_3\hat{w} + \Pi_4\hat{n}^* + \Pi_5\hat{p}^* + \Pi_6\hat{L} + \Pi_7\hat{\rho} + \Pi_8\hat{\beta} + \Pi_9\hat{\delta} + \Pi_{10}\hat{\varphi} + \Pi_{11}\hat{\alpha}$$

Equation (30) relates emission levels to economic variables. Total emissions is influenced by the number of domestic firms (n), the level of output produced for the purpose of consumption (S), wage which is net income (w), the factor of production in the economy $\left(L\right)$, imported product varieties (n^*), the world price level ($\hat{p}^*$), the preference parameter (ρ), the productivity of labor parameter (β), the elasticity of emission with respect to the fraction of output allocated towards consumption (δ), the marginal disutility of pollution (φ), and fixed cost (α).

4.1 An Empirical Model of Inter-industry and Intra-industry Trade

OECD countries in the sample are assumed to engage in both intra- and inter-industry trade. This paper links the effects of intra-industry trade to the effects of inter-industry by integrating the reduced form variables shown in the Antweiler e al. (2001) with the reduced form variables described in the current intra-industry trade model. Hence, the empirical model is a function of four environmental effects, namely the scale, technique, composition, and selection effects. Note that the inter-industry and intra-industry models overlap in terms of the scale and technique effects and thus these effects will be represented by the same measures in the estimating equation. By controlling for the environmental effects of intra-industry trade, more precise estimation is obtained by preventing an omitted variable which if excluded, may produce biased estimates. Moreover, if the selection effect is a significant factor in the data generating process, then its inclusion implies an improvement over, if not a correction to, econometric specifications which analyzes the relationship between pollution and economic factors.

Combining the reduced form equation obtained in this section with the reduced form equation obtained in Antweiler et al. (2001) yields the following:

$$\begin{aligned}(31)\qquad &\hat{Z} = \Pi_1\hat{n} + \Pi_2\hat{S} + \Pi_3\hat{w} + \Pi_4\hat{n}^* + \Pi_5\hat{p}^* + \Pi_6\hat{L} + \Pi_7\hat{\rho} + \Pi_8\hat{\beta} + \Pi_9\hat{\delta} + \\ &\Pi_{10}\hat{\varphi} + \Pi_{11}\hat{\alpha} + \Pi_{12}\hat{p}^w + \Pi_{13}\hat{\kappa} + \Pi_{14}\hat{\omega} + \Pi_{15}\hat{\vartheta} + \Pi_{16}\hat{T}\end{aligned}$$

where p^W denotes world price, κ denotes capital intensity, ω denotes income, ϑ denotes trade friction, and T denotes country type[11].

The selection effect, denoted n, describes the change in emission level due to a change in the number of product varieties consumed, everything else constant. The scale effect is denoted S describes the change in emissions level due to a change in the scale of production, holding everything else equal. The technique effect is the change in emission levels due to a change in emission intensity, holding the scale, selection, composition effects and other factors constant. In equation (31), the technique effect is represented by a change in wage, w, which is net income in the intra-industry trade sector and in ω, which is income in the inter-industry trade sector. Since the realization of the technique effect from each trade sector is indistinguishable when measured as country-level income, we combine w and ω in equation (31) as total income, denoted y. The composition effect is the change in emissions level resulting from a change in the capital intensity used in the production. In equation (31), capital intensity is denoted as κ. Note that the preference for product varieties, ρ, the labor productivity, β, the elasticity of emission with respect to the fraction of output allocated towards consumption, δ, fixed cost, α, and the marginal disutility of pollution, φ, are fixed factors in the model. Measures and data for these country-specific effects namely, α, ρ, β, δ and φ, are not readily available, therefore they are considered as unobserved country parameters in the model.

We note that while the scale, technique, selection and composition factors are endogenous variables, emission levels are determined endogenously but recursively[12]. Thus, while the variables of

---

[11] Notations in the Antweiler et al. (2001) may differ from the ones used here.

scale, the number of firms, real income and pollution tax are set simultaneously in the model, emissions level is set recursively. In addition, we note that the interpretation of the empirical results in this paper will be based on the predictions of the intra-industry trade model which assumes non-homothetic utility functions as well as the CES framework of intra-industry trade. Literature on intra-industry trade suggests the following. One, the scale of production and the number of firms are fixed and openness of trade does not yield trade-induced scale and selection effect. This result is consistent with the assumption of a CES utility function. Two, and alternatively, trade generates changes in the scale of production and in the number of firms, which lead to trade-induced environmental scale and selection effects. This result is consistent with the assumption of a non- CES, non-homothetic utility function (see Krugman 1979).

5. Empirical Strategy

5.1 Measurement and Data Sources

The dependent variable in our estimating equations is the level of emission that prevails in the economy. Three types of air pollutant are used as separate measures of pollution emission, namely, sulfur oxides (SOx), nitrogen dioxide (NOx) and volatile organic compounds (VOC). SOx, NOx and VOC are measured in metric tonnes. Sulfur oxides (SOx) are produced mainly through the burning of fossil fuels and are the more widely regulated pollutant among the three pollutants. Nitrogen oxides (NOx) includes the highly reactive gasses nitrogen dioxide (NO_2), nitrous acid and nitric acid. NOx emissions are mainly regulated through air quality standards set by regulatory authorities. The third pollutant, volatile organic compounds (VOC) is emitted from the burning of coal, oil, gasoline, cleaners, paints and solvents. While outdoor VOC may be regulated, indoor VOC is may not be easily regulated due to the lack of authority in regulating indoor air quality and in collecting information on household products. The effects of SOx, NOx and VOC are local in nature, a characteristic that is consistent with the theoretical assumption in this study. Data on SOx, NOx and VOC is sourced from OECD Environmental Data for the years 1995-2004. We use the logarithmic transformation of each pollutant to provide a lognormal distribution of the annual

---

[12] Pollution itself does not cause any change in the factors that affect the reduced-form variables, that is, there is no simultaneity or feedback between the number of firms and emissions level. A change in emissions level does not cause second-order changes in the number of firms, or in the measures for the scale and technique effects.

country level data as recommended in previous work in this area (see WHO (1984) and Antweiler et al. (2001) on the appropriateness of lognormal distributions). Data on GDP, GNP in 2000 dollars and other macroeconomic variables is sourced from the Penn World Tables (PWT 6.2) as described by Summers, Heston and Aten (2006). Gross domestic product per square kilometer (GDP/km^2) measures the scale effect. We use gross national product per capita (GNP/L) earned both domestically and abroad[13] to measure the technique effect. To avoid high or perfect correlation between GDP and GNP, the difference between the two variables is used to separate the technique effect from the scale effect. Additionally, to prevent contemporaneous correlation with GDP, a three-year moving average of per capita GNP is lagged one period[14]. The selection effect of intra-industry trade is represented by the variable n. In theory, the selection effect comes from the change in the number of product varieties or the change in the number of firms engaged in the production of differentiated goods. Theory suggests the selection effect contributes to a positive (negative) change in pollution levels when there is a trade-induced expansion (contraction) of labor force which leads to an increase (decrease) in the number of domestic firms. Thus, the pollution-trade model suggests a definition of a selection effect that is best defined by firm-level production, that is, by the number of firms that are producing dirty products.[15] Accordingly, we use the number of listed domestic companies to represent the selection effect, sourced from the World Development Indicators (WDI). Consistent with other measures in the model, the measure for n is in intensive form, that is, it is the number of listed domestic companies per kilometer squared (Companies/ km^2). The composition effect is the change in emissions level due to a change in the capital intensity used in production, holding all other factors constant. As in the Antweiler et al. (2001) framework, capital is the factor of production used as input in the pollution-intensive industry. Since capital stock data was unavailable for the very recent years of interest 1995-2004, we construct a capital

---

[13] Antweiler et al. (2001) use income to measure the technique effect which is replicated in the current analysis.

[14] See Antweiler et al. (2001) where the same method is used.

[15] A literal approach of translating theory to data implies that the production of one firm comprises of a single variety. In reality, a firm may produce or export more than one variety in its product line. However, since the objective of the current model is to measure the firm's production of pollution emissions, then, for the purpose of estimating "n", it is sufficient to represent the selection effect by the number of firms engaged in the production of dirty goods or product varieties.

stock dataset with investment data sourced from WDI for the years 1995-2004 using the method outlined in Leamer (1984). Labor data is acquired from PWT so that capital intensity is the ratio of capital stock to labor force (K/L). Finally, openness to trade is measured by the variable trade intensity, the ratio of imports plus exports to GDP. Trade intensity data is sourced from PWT for the years 1995-2004.

5.2 Method

We use panel data method to estimate the empirical model which allows the analysis of both the spatial and temporal dimensions of units of observation. In this paper, both random and fixed effects estimations are reported. Further, in order to obtain panel-robust statistical inferences, the estimation corrects for both the correlation of model errors over time for given countries and for any heteroskedasticity across countries. A Sargan-Hansen test is performed to determine whether fixed effects are present.

Unobservable Variables

The parameter of the elasticity of emission intensity with respect to per unit consumption, the disutility of emissions parameter and the preference parameter are not observable in the data. They are considered as time-invariant country-specific effects represented by the unobserved heterogeneity, denoted as ς_k. Time-specific effects, denoted as ξ_t, include common-to-all-countries effects such as changes in the relative price of goods and changes in abatement technologies. Human and machine errors in reading pollutant concentrations constitute the idiosyncratic error, υ_{kt}. To account for the unobservables, an individual effects model for the error term u_{kt} is specified in the following equation:

$$u_{kt} = \xi_t + \varsigma_k + \upsilon_{kt} \tag{32}$$

where ξ_t is a time-specific effect, ς_k is a country specific effect, and υ_{kt} is an idiosyncratic measurement error for country k at time t. We include a set of unrestricted time dummies in the estimating equation to capture the effects of time specific, common-to-all-countries variables excluded in the model and left unobserved in the error term.

5.3 The Estimating Equation

Functional form: A linear representation of pollutant emissions in metric tonnes per squared kilometer at time t and country k is the following model:

$$Z_{kt}^{c} = \alpha_0 + \alpha_1 FIRM_{kt} + \alpha_2 SCALE_{kt} + \alpha_3 INC_{kt} + \alpha_4 (KL)_{kt} + \alpha_5 TI_{kt} + G_{kt}^{'}\beta + u_{kt} \tag{33}$$

where FIRM is the country specific number of listed companies per squared kilometer, COM/km^2, SCALE is country-specific GDP/km^2, INC is GNP/L, TI is trade intensity measured as the import-export ratio to GDP or (X+M)/GDP, and G contains country-specific variables and physical characteristics. Note that the world price and country-type variables are captured in the time-specific error term ξ_t, and unmeasured economic and physical variables such as the disutility of emissions parameter are captured in the country-specific error term ς_k.

To account for trade-induced environmental effects, we include interacted terms of the scale, technique, selection and composition effects with trade intensity to obtain the following linear model:

$$\begin{aligned} Z_{kt}^{c} &= \alpha_0 + \alpha_1 FIRM_{kt} + \alpha_2 SCALE_{kt} + \alpha_3 INC_{kt} + \alpha_4 (KL)_{kt} + \alpha_5 TI_{kt} + \\ &+\alpha_6 FIRM_{kt} \cdot TI_{kt} + \alpha_7 SCALE_{kt} \cdot TI_{kt} + \alpha_8 INC_{kt} \cdot TI_{kt} + \alpha_9 (KL)_{kt} \cdot TI_{kt} + G_{kt}^{'}\beta + u_{kt} \end{aligned} \tag{34}$$

where $FIRM \cdot TI$ is country k 's trade intensity interacted with the number of listed domestic companies per squared kilometer, $SCALE \cdot TI$ is country k 's trade intensity interacted with gross domestic product per squared kilometer, $INC \cdot TI$ is country k 's trade intensity interacted with real income per capita and $KL \cdot TI$ is country k 's trade intensity interacted with its capital-to-labor ratio. The vector G contains variables that describes country characteristic which includes population density, *POP*, country k 's real income measured relative to the world average denoted *REL.INC*, $FIRM.INC$ is country k 's number of listed domestic companies per squared kilometer interacted with real income, and time dummies that account for time-specific effects. Equation (34) is referred to as Model A in the analysis.

5.4 Alternative Functional Form

To account for the possibilities of nonlinearities in responses to the scale, technique and composition effects, an alternative specification by adding squared terms to the linear-in-variables representation of the model in equation (33) is considered. Non-homotheticities in production or consumption is one reason for a nonlinear response to the environmental effects. Differences in producer prices brought about by cross-country differences in income and in techniques of production may imply that the composition effect should be modeled as a nonlinear function of the capital intensity variable, K/L. These possibilities are consistent with assumptions under a traditional framework of trade. Therefore, to model nonlinear responses to the environmental effects, we include quadratic measures of the technique and composition effects. On the other hand, the CES model of pollution and intra-industry trade assumes homotheticity in consumption. This assumption suggests linearity in the response to the scale effect. Further, we maintain that the response to the selection effect is linear in the number of firms. The intra-industry trade framework assumes identical size, preference and production technology across countries. Hence, these imply similarities in income levels. If income levels are similar, then the response to the scale, technique effect and selection variables can be represented by linearity in the data of GDP, income and number of firms to reflect similarities in prices and techniques of production. To account for the aforementioned possibilities, the following functional form is designated as Models B:

$$\begin{aligned} Z^{c}_{kt} &= \alpha_0 + \alpha_1 FIRM_{kt} + \alpha_2 SCALE_{kt} + \alpha_3 INC_{kt} + \alpha_4 INC^{2}{}_{kt} + \alpha_5 (KL)_{kt} \\ &+ \alpha_6 (KL)^{2}{}_{kt} + \alpha_7 TI_{kt} + + \alpha_8 FIRM_{kt} \cdot TI_{kt} + \alpha_9 SCALE_{kt} \cdot TI_{kt} \\ &+ \alpha_{10} INC_{kt} \cdot TI_{kt} + \alpha_{11} (KL)_{kt} \cdot TI_{kt} + G^{'}_{kt} \beta + u_{kt} \end{aligned} \tag{35}$$

Models A and B sufficiently capture the essential responses to the environmental effects of production and of trade variables in parsimonious specifications.

6. Result

Tables 1, 2 and 3 present the results of fixed and random effect estimations for the dependent variables sulfur oxides (SOx), nitrogen oxides (NOx) and volatile organic compounds (VOC), respectively. For each estimation of the SOx, NOx and VOC equations, two econometric models are considered namely, Models A and B. Model A assumes linearity in all variables and Model B assumes non-linearities in the technique and composition effects variables. In the next section, sensitivity analysis of the estimations are presented in Tables 4, 5 and 6, each comprising of three estimating models namely, Model C, Model D and Model E.

Three main results in the analysis warrant attention. One, for each pollutant and for every econometric model A through E, F-tests statistics show that at the 1 percent level of significance, there is evidence to reject the null hypothesis that the variance due to cross-country differences is not different from zero. This result implies the presence of significant country-level effects. Hence, using pooled OLS estimator in the analyses will not be appropriate. Two, the correlation coefficients between the explanatory variables and unobserved country-level effects range from -0.95 to -0.97 in the fixed effects models of SOx, 0.64 to 0.69 in the fixed-effects models of NOx, and -0.51 to -0.57 in the VOC models. These results suggest high correlation between the regressors and the country level effects. On the other hand, statistically significant coefficient estimates obtained under fixed effects (FE) estimations and under random effects (RE) estimations are nearly identical. Hence, we use the Sargan-Hansen test for the appropriateness of using fixed effect (FE) estimator versus random effect (RE) estimator with cluster-robust standard errors. The Sargan-Hansen test statistics, shown in Tables 1 through 6, are statistically significant at the 1 percent level of significance which imply we can reject the null hypothesis that the additional orthogonality condition imposed by the RE estimator is valid. These results imply strong evidence to suggest that unobserved country-level heterogeneity is correlated with regressors in the models. Hence, in all models considered, there is evidence to suggest that estimates generated by FE estimators are consistent estimates whereas estimates generated in the RE models are not. Therefore, in describing the regression results in the following section, we focus only on estimates based on FE models.

Finally, the interaction terms of each of the environmental variable and the trade intensity variable use demeaned data which subtract the sample mean of each variable from its respective data values. Therefore, the interpretation of the coefficient estimates of the trade-induced scale, technique, selection and composition effects variables are made at the mean value of the trade intensity variable[16]. In other words, coefficient estimates of trade-induced environmental effects are calculated for the "average trading country" defined as the country whose level of trade intensity is equal to the sample mean.

6.1 *Sulfur Oxides* (SOx) *and the Selection, Scale, Technique and Composition Effects*

Table 1 shows that in the Models A and B for SOx, there evidence to support the hypotheses that there is a positive relationship between the selection effect variable and emissions of SOx, a positive relationship between the scale effect variable and SOx, a negative relationship between the income variable and SOx and a positive relationship between the capital intensity or composition effect variable and Sox. Estimates are statistically significant for the coefficients on the selection, scale, technique and composition effect variables at the conventional levels and they do not vary greatly in magnitudes between Model A and Model B. The coefficient estimates for the quadratic term of lagged per capita income in Model A and Model B are not statistically significant. There are two observations to make of the effect of income on SOx. First, OECD countries are comprised of mostly developed nations whose incomes per capita are greater than the per capita incomes of developing countries. The inverted-U shape of the Environmental Kuznets Curve (EKC) has a turning point of approximately $8,000 to $10,000 per capita income (Grossman and Krueger 1993) which is below the sample mean of per capita income of OECD countries in this analysis. For more affluent and developed economies, it is postulated that an increase in income leads to stricter environmental policy which then leads to lower emission intensity. Thus, in our sample of mostly high-income countries, the technique effect is manifested as a negative relationship between income per capita and emissions levels as indicated by the negative direction of the effect of income on SOx. A second observation is that the coefficient estimate of the level-form of INC is statistically significant but the coefficient estimate of the squared INC^2 is not statistically significant. The result that linearity in the income variable generates statistically significant estimates while non-linearity generates statistically insignificant estimates is consistent with the assumption of a homothetic utility function where the shares of income spent on consumption goods are constant. Further, our theory

---

[16] See Wooldridge (2003) pp. 194-195.

assumes a fixed fraction of output or resources is allocated towards abatement activity where pollution production is constant returns to scale. Thus, a change in the stringency of environmental policy implies a linear change in abatement levels. This provides an explanation of the statistically significant estimates of the technique effect in linear or level form of the income variable. Thus, the realization of income data seems to suggest that the assumption of homotheticity, consistent with intra-industry trade, is more relevant in capturing responses to the technique effect as opposed to an assumption of non-homotheticity.

The composition effect variable represented is by capital intensity. In Model A, which assumes linearity in all variables, the coefficient estimate of capital intensity is not statistically significant at the conventional levels. Interestingly, in both Models A and B, the coefficient estimates of the capital intensity variables measured in level forms are not statistically significant. A test of the joint significance of the variables capital intensity (K/L) and capital intensity-squared (K/L-squared) generates an F-test statistic that is statistically significant at the 1 percent significance level, indicating we can reject the null hypothesis that the model which excludes the variables K/L and K/L-squared is correctly specified relative to the full model. This result suggests that a quadratic functional form captures the responses to the composition effect on pollution, consistent with the assumption of non-homothetic production under the theoretical proposition that the impact of capital accumulation on the emission of SOx depends on the techniques of productions with the varying income levels across countries (see Antweiler et al. 2001).

The impact of freer trade or openness to trade on environmental quality is estimated by the effect of a change in the trade intensity variable on the change in emissions level. In both Models A and B, coefficient estimates on the trade intensity variables are statistically significant at less than 1 percent level of significance. This indicates evidence to suggest that a 1 unit change in the ratio of the volume of trade to GDP leads to approximately 2.6 percent decrease in the levels of SOx emissions. The negative direction of the effect of trade intensity on emissions level conforms to theoretical prediction which suggests that greater openness to trade or increased trade liberalization is beneficial to the environment.

We use a likelihood ratio (LR) test to evaluate the goodness of fit of the nested models A and B. Results show that the linear-in-variables and more restricted model A has lesser fit compared to the more general Model B. A significant LR-test statistic shows that the restrictions on Model A are rejected by the data. One explanation for this result is that for the countries in the sample, consumption or production is non-homothetic such that the response to the composition effect implies that capital accumulation generates non-linear effects on the composition of the economy. Hence, for the pollutant SOx, the specification test result indicates that greater emphasis should be given to estimates generated in Model B.

6.2 *Nitrogen Oxides* (NOx) *and the Selection, Scale, Technique and Composition Effects*

Table 2 shows the responses of changes in the selection, scale, technique and composition effects on the level of nitrogen oxides (NOx). Fixed effects estimations indicate that for the Models A and B, there is a positive relationship between the selection effect variable, represented by the number of listed companies per squared kilometer (Companies/ km^2), and the dependent variable, nitrogen oxides emissions (NOx). Statistically significant coefficient estimates of Companies/ km^2 at the 99-percent confidence levels provide strong evidence to suggest that, holding other factors constant, a 1 unit change in the number of domestic companies per squared kilometer leads to an approximately 25 percent change in the level of NOx per squared kilometer in Model A and approximately 29 percent in Model B. The direction of effect of the selection variable on emissions level is positive, consistent with the theoretical prediction that an increase in the number of firms leads to an increase in the level of emissions. On the other hand, coefficient estimates of the other environmental effects namely, the scale, technique and composition effects are statistically not significant in both models A and B. Similarly, estimates of the effects of trade intensity and other country-specific variables are not statistically significant where p-values indicate we fail to reject the null hypothesis at the conventional levels of significance. Interestingly, except for the coefficient estimate of interacted term between the selection effect variable and the trade intensity variable (that is, GDP/km^2 x TI), evidence suggests that all other coefficient estimates of interacted terms in the three models are statistically not different from zero. Meanwhile, the Relative Income variable in both models A and B is statistically significant at the 5 percent level of significance. These results seem to suggest that for the pollutant NOx, the scale of production, the emission intensity of pollution and the composition of capital to labor ratio do not affect emissions level. While the selection effect is robust in the two models, the neutrality of the scale, technique and composition effects may be explained by the proposition in new or intra-industry trade theory which assumes CES preferences. That is, the findings that, one, the selection effect is exists but that environmental scale effect and technique effects are absent. These results are consistent with evidence found in trade literature which supports a trade-selection effect but not a trade-scale effect (see Head and Rice 1999, 2001).

6.3 *Volatile Organic Compounds (VOC) and Selection, Scale, Technique and Composition Effects*

Table 3 shows the estimates of the selection and scale effects which are statistically significant in Models A and B at the 1 percent level of significance. Both the selection and scale effects have positive relationship to the emissions level of volatile organic compounds (VOC). Estimates of the coefficients of the technique and composition effects in Models A and B are statistically not-significant at conventional levels. Thus, we fail to reject the null hypotheses that the coefficient estimates of the income (*INC*) and capital intensity (*K/L*) variables are equal to zero. One possible explanation for the absence of a technique effect is that a major proportion of VOC emissions may not be subjected to environmental regulation. Indoor VOCs, for example, are outside the purview of the regulatory authority; hence, regulation compliance is not enforceable. In the United States of America, sources of VOC emissions comes mainly from road vehicles, solvent use, fires and non-road equipment which in the year 2002 makes up seventy five percent of total VOC emissions (EPA 2009). The absence of a composition effect on VOC emissions may be explained by the possibility that the production of VOC is considered not capital-intensive, that is, shifts in the level of the use of capital in the VOC-intensive sectors have no effect on the levels of VOC emissions. The coefficient estimates of the openness to trade variables are statistically significant at the 5 percent level of significance in Models A and at the 10 percent level in Model B. There is evidence suggests that a 1 unit increase in trade intensity leads to 0.4 percent decrease in VOC emissions in Models A and B. These findings substantiate the prediction of a negative relationship between trade intensity and emissions level. The results are consistent with findings in the cases of SOx and NOx. Estimates for the trade-induced environmental effects, namely the trade-induced scale, technique, composition and selection effects are represented by the respective variables interacted with the trade-intensity variable. In the linear-in-variables Model A, with the exception of the selection effect, estimates of the trade-induced technique, composition and selection effects are statistically significant at the conventional level of significance. In Model B, the sole variable with statistically significant coefficient estimate is the trade-induced composition effect. These results suggest that the one common statistically significant trade-induced effect in the two models is the composition effect. However, when calculated for the average country in the sample, the composition effect does not lead to any change in the emissions level of VOC, which is consistent with the result of neutral linear-form composition effect in the models A and B.

6.4 Alternative Specification

In this section, we present three alternative econometric models to the main Model B to test the robustness of the results obtained in the previous section. The three alternative specifications are namely, Model C which specifies an estimating equation that is absent of the selection effect, Model D which does not include any interaction terms, and Model E which includes foreign direct investment (FDI).

Regressions of the Model C, which excludes the selection effect variable Companies/ km^2 generate mostly statistically insignificant estimates for the three pollutants SOX, NOx and VOC. For the pollutant SOx, fixed effects estimation of Model C shows one statistically significant coefficient estimate at the 1 percent level, namely for the variable trade intensity. In the cases of NOx and VOC, the sole significant estimate is for the variable population density. These results suggest that in excluding the selection variable, the estimation is not controlling for a theoretically relevant and important variable that belongs in the estimating equation. The omission of the selection variable leads to misspecification and omitted variable biases. The effects of misspecification and variable omission can be detected through the comparison of Model C with the main Model B. When the selection variable is added to Model C, thus generating the main model that is Model B, all other coefficient estimates of theoretically relevant variables namely, the scale, technique and composition variables which were previously not statistically significant now become statistically significant. In addition, the estimates have the correct signs in terms of the direction of effects on the dependent variables, hence conforming to theoretical predictions postulated in the inter-and intra-industry trade frameworks and as evidenced in past studies.

In Model D, interaction terms are dropped from the main model specification. These include interaction terms between the environmental effects variables and the trade intensity variable. In the SOx model, responses to the scale, technique selection and trade intensity effects are statistically significant at the conventional levels. The response to the composition effect is not statistically significant. In the case of NOx, coefficient estimates of the scale, selection and composition effects are statistically significant, but the coefficient estimate of the technique effect is not statistically significant. In the case of VOC, only the estimates of the scale, selection and relative income effects are statistically significant. Because Model D excludes the interaction terms, these results may be interpreted as estimates of the environmental effects on pollution in the autarky case. Hence, in model D, trade-induced effects are not estimated.

These findings suggest the following. One, there is evidence to substantiate the claim of the relevance of the including the selection effect in modeling the impact of economic production and trade on pollution levels for countries in the sample. Two, results provide evidence of the robustness of the earlier results in the previous models with respect to estimates of the environmental effects of scale, selection, technique, and composition.

Finally, in Model E, the trade variable foreign direct investment (FDI) is added to the main Model to investigate the environmental impact of the flow of factor movement across borders. Results show that for the pollutants SOx and NOx, adding the FDI variable worsens the R^2-statistic when compared to the main Model B. In the case of VOC, going from Model B to Model E finds the R^2-statistic increasing very slightly. Coefficient estimates of the effect of the FDI variable is statistically significant at the 1 percent level for SOx and at the 10 percent level for NOx, but it is not statistically significant at the conventional levels for VOC. Thus, in the SOx model, there is strong evidence to suggest that inward flow of foreign direct investment mitigate the emissions level of SOx. Estimates of the coefficients of selection effect variable, Companies/ km^2, are statistically significant for all three pollutants SOx, NOx and VOC at the 10, 5 and 1 percent levels of significance, respectively. These results show the robustness of the coefficient estimates for the selection effect variable.

7. Discussion

In a model of trade-and-environment, the impact of intra-industry trade on environmental quality can be decomposed into scale, selection and technique effects. Previous empirical studies based on the traditional trade framework shows that the environmental effects of inter-industry trade can be decomposed into scale, composition and technique effects. In the study by Antweiler et al. (2001), empirical evidence suggests the sum of the magnitudes of the coefficient estimates of the scale, composition and technique effects can be used to estimate the total impact of trade on emissions level.

Most, if not all countries engage in both intra- and inter-industry trade. The premise of the analysis in this paper is that international trade is composed of both types of trade, namely, trade in homogenous goods described by the theoretical framework of traditional trade, and trade in differentiated goods described by the framework of new trade theory. The selection effect distinguishes the impact of trade driven by market structure and increasing returns from the impact of trade that is driven by comparative advantage based on cross-country differences in factor abundance. If countries engage in the pollution-intensive production of homogenous and differentiated goods in an integrated economy, then an empirical estimation of the total impact of trade on the environment needs to account for a selection effect in addition to scale, technique and composition effects. In this paper, findings show there is strong evidence of the statistical significance of the selection effect in the trade-environment linkage.

Results show that the ex-ante prediction of an increasing relationship between the selection effect and emissions level is borne out in the data. Statistically significant coefficient estimates are found have positive signs, a result that is robust across the six empirical models and across all three pollutants, SOX, NOx and VOC. This result conforms to the prediction of a nonnegative trade-induced selection effect postulated by the intra-industry trade framework under the assumption of non-CES and non-homothetic utility function. A theoretical explanation is that, trade in differentiated goods induces a negative selection effect when openness to trade implies that competition from abroad leads to a reduction in the number of domestic firms or in the number of product varieties. Then, holding the scale and technique effects constant, a decrease in the number of firms leads to a decrease in emissions level. Further, firms in the intra-industry trade framework have identical technology, so that everything else equal, a fall in the number of firms implies a proportionate fall in emissions level. Hence, there is a linear and positive relationship between selection and emissions.

In the main Model B, statistically significant estimates of a positive relationship between the scale of production and emissions level conform to the theoretical predictions. In the SOx and VOC models, an increase (decrease) the level of activities raises (lowers) the emissions levels of sulfur oxides (SOx) and volatile organic compounds (VOC), ceteris paribus. In addition, findings show that responses to the scale effect variable are statistically significant under the functional form that specifies linearity in the scale variable. This result suggests that for countries in the sample, the assumption of homothetic production or consumption prevails over the assumption of non-homothetic functions. In the context of trade effects, since homotheticity is a feature consistent with trade in intra- rather than inter-industry goods, the evidence suggests that the realization of data is more consistent with trade driven by market structure and increasing returns rather than by cross-country differentials in factor endowments.

For the technique effect, negatively signed coefficient estimates are statistically significant for sulfur oxides (SOx). Estimates are not significant at the conventional levels for nitrogen oxides (NOx) and volatile organic compounds (VOC). This finding suggests that for SOx, there is evidence to support the hypothesis that emissions level decreases in abatement activities or in the stringency of environmental regulations. On the other hand, in the cases of NOx and VOC, one reason for the lack of evidence of the technique effect is that NOx and VOC are not subjected to strict environmental enforcement. VOC emission sources are mainly from transportation and indoor products. In contrast, sulfur oxides (SOx) emissions are subjected to rigorous environmental laws and standards at plant and firm sites and in the abating process which includes regulation on equipment requirements and production methods.

Findings also suggest that similar to the scale effect, the technique effect is statistically significant when measured as level-form income per capita but not statistically significant when measured in non-linear or quadratic form. This result provides evidence to suggest that the assumption of homothetic consumption is relevant for countries in the sample. The result is consistent with a CES utility function in a pollution model of intra-industry trade.

For the composition effect, there is evidence to support the prediction of a positive and increasing relationship between emissions level and capital intensity. Similar to the technique effect, the composition effect variable is statistically significant in the SOx models, but is not significant in the NOx and VOC models. One possible explanation for these findings is that SOx is generated in highly capital intensive production processes but that NOx and VOC emission are not dependent on capital-intensive production sectors. In the trade context, statistically significant coefficient estimates of the interacted terms between capital intensity and trade intensity (K/L x TI) provide strong evidence to suggest that trade-induced composition effects lead to increased SOx emissions. Interestingly, in contrast to the scale and technique effects, coefficient estimates of the composition effect variables are statistically significant in the quadratic or non-linear form but are not statistically significant in the level-form. This result conforms to the theoretical assumption of inter-industry trade where the impact of capital accumulation on pollution is linked to non-homothetic production or consumption, owing to income or production technique differentials across countries.

Estimates of the environmental effect of openness to trade or trade liberalization are statistically significant in the SOx and VOC models. In the SOx models, coefficient estimates of the trade intensity variable are consistently significant and negative in signs in the five models considered, Models A through E. In the VOC models, four out of the five model specifications show statistically significant trade intensity coefficient estimates. Therefore, these results suggest strong evidence for the prediction that greater openness to trade or greater trade liberalization leads to lower emissions level.

Finally, we note that the parsimonious model specifications adopted in the current analysis evidently captures the essential aspects of the trade-environment relationship postulated by theory. Statistically significant semi-elasticity estimates of variables do not differ in any great manner across the fixed effects and random effects estimations. Coefficient estimates are invariably found to be identical or nearly identical in their magnitudes. The signs or direction of effects of statistically significant variables are consistently identical across models and across estimators. Furthermore, and more importantly, statistically significant results conform to theoretical predictions and can be explained in terms of the underlying assumptions of the frameworks which form the basis of the econometric models specified. Findings are supportive of theoretical expectations consistent with intra-industry trade theory – this is not surprising considering our data describes countries that are known to engage in the trade of differentiated goods. But the findings also support theoretical predictions of inter-industry trade as evidenced in the estimates of the composition effect. Statistically significant capital intensity coefficients conform to the assumption that the trade-induced composition effect is generated by non-linearity in the techniques of production, brought about by income and price differentials across countries. This result is significant and interesting since new trade theory does not generate a composition effect.

8. Conclusion

International trade comprises of trade in homogenous and differentiated goods. Theory suggests the environmental effects of an integrated open economy can be explained by factors that drive inter-industry as well as intra-industry trade. In this paper, an analysis of panel data from OECD countries provides evidence of the following results. First, strong empirical evidence supports the hypotheses postulated by theory that emission levels are increasing in the scale of production, in emission intensity, in the number of firms, and in the composition of the economy. Second, in addition to the widely recognized scale, technique and composition effects, the selection effect needs to be controlled for in the estimation of the impact of trade on environmental quality. Statistically significant estimates of the selection effect are shown to be robust across six different model specifications and across three types of pollutant. Third, in consonant with the study by Antweiler et al. (2001), the findings in this paper show that responses to the scale, technique and composition effects are statistically significant for sulfur oxides (SOx). However, in contrast to findings in Antweiler et al. (2001), the results show that for the countries in the sample, estimates of the scale and technique effects can be explained by the assumptions of homothetic production or consumption, consistent with the intra-industry or new trade framework rather than with inter-industry or traditional trade framework. On the other hand, the estimates of the composition effect can be described by the assumption of non-homothetic production consistent with inter-industry trade framework – this result replicates the finding in Antweiler et al. (2001). Estimations of the scale, technique and composition effects for the pollutants nitrogen oxides (NOx) and volatile organic compounds (VOC) generate mix findings which can be explained by the inherent characteristics, processes and sources of the respective pollutants. Fourth, the analysis suggests that openness to trade or trade liberalization is beneficial to the environment in that there is strong evidence to indicate that greater openness to trade or increased liberalization of trade frictions leads to lower levels of emissions. This paper departs from previous work by showing that the estimation of the environmental impact of international trade need to account for a selection effect, a variable that help explain the total volume and integrated patterns of the exchange of goods across borders. The omission of a relevant variable can lead to specification error and biased estimates. The significance of unbiased estimation lies in the effect it has on resolving an important issue which may have implications on policy recommendations.

REFERENCES

Antweiler, Werner; Copeland, Brian R. and Taylor, M. Scott. "Is Free Trade Good for the Environment?" *The American Economic Review*, 2001, *91*(4), pp. 877-908.

Grossman, Gene and Krueger, Alan B. "Environmental Impacts of a North American Free Trade Agreement," *NBER Working Paper Series, No. 3914.* Cambridge, 1991.

Grossman, Gene and Krueger, Alan B. "Environmental Impacts of a North American Free Trade Agreement," P. M. Garber, *The U.S.-Mexico Free Trade Agreement.* Cambridge, MA: MIT Press, 1993, 13-56.

Krugman, P.R. "Increasing Returns, Monopolistic Competition, and International Trade." *Journal of international economics*, 1979, *9*(4), pp. 469-79.

Krugman, P.R. "Scale Economies, Product Differentiation, and the Pattern of Trade." *American Economic Review*, 1980, *70*(5), pp. 950-59.

Wooldridge, Jeffrey M. *Econometric Analysis of Cross Section and Panel Data*. Cambridge: MIT Press, 2002.

Wooldridge, Jeffrey M. *Introductory Econometrics: A Modern Approach*. Cincinnati: South-Western Thomson, 2006.

Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.2, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, September 2006.

World Bank's GGDC and the National Institute of Economic and Social Research, Manufacturing Productivity and Unit Labour Cost Database at http://www.ggdc.net/icop.html

Table 1: SOx, Models A and B

Dependent Variable: Log of Sulfur Oxides per sq km				
Estimation Method:	Fixed Effects		Random Effects	
Model Specification:	A (Levels Only)	B (Main)	A (Levels Only)	B (Main)
Variable/Column:	(1)	(2)	(4)	(5)
Companies/ km^2	0.501*	0.548**	0.587**	0.605**
	(0.277)	(0.260)	(0.248)	(0.251)
GDP/km^2	0.320**	0.318**	-0.124	0.108
	(0.129)	(0.125)	(0.121)	(0.120)
Lagged per capita income (INC)	-0.184**	-0.411**	-0.117*	-0.056
	(0.073)	(0.187)	(0.069)	(0.200)
Lagged per capita income squared		0.059		-0.013
		(0.044)		(0.046)
Capital abundance (K/L)	-0.333	0.066	-0.385***	-0.262
	(0.197)	(0.259)	(0.139)	(0.184)
(K/L) Squared		-0.036***		-0.010
		(0.013)		(0.011)
Trade Intensity (TI=X+M/GDP)	-0.026***	-0.026***	-0.021***	-0.021***
	(0.007)	(0.006)	(0.006)	(0.006)
Relative Income	0.009	0.009	0.009	0.010*
	(0.007)	(0.006)	(0.006)	(0.006)
Population Density	-0.333***	-0.379***	0.032	0.036
	(0.096)	(0.102)	(0.025)	(0.027)
TI x Companies/ km^2	-0.013**	-0.012**	-0.007	-0.006
	(0.005)	(0.005)	(0.005)	(0.005)
TI x GDP/ km^2	-0.0001	0.0002	-0.002*	-0.002*
	(0.002)	(0.002)	(0.001)	(0.0001)
TI x Per capita Income	-0.007**	-0.008***	-0.006***	-0.006***
	(0.003)	(0.002)	(0.002)	(0.002)
TI x (K/L)	-0.001	-0.0001	-0.001	-0.0009
	(0.002)	(0.002)	(0.002)	(0.002)
Companies x Per capita Income	-0.203*	-0.231**	0.181**	-0.197**
	(0.103)	(0.095)	(0.088)	(0.091)
Foreign Direct Investment				
Intercept	-0.689	-0.919	-4.714***	-5.117***
	(0.722)	(1.916)	(0.973)	(1.040)
Observations	211	211	211	211
Group	23	23	23	23
R^2 – within	0.7731	0.7826	0.7559	0.7603
R^2 – between	0.2290	0.2616	0.7785	0.7588
R^2 – overall	0.2109	0.2412	0.8054	0.7915
Sargan-Hansen Test/ χ^2 (df)			1608.75***	572.36***
LR test/ χ^2 (df)	8.93***			

***Significance at the 99-percent confidence level.
**Significance at the 95-percent confidence level.
*Significance at the 90-percent confidence level.
Note: Standard errors in parentheses are cluster-robust.

Table 2: NOx, Models A and B

Estimation Method:	Fixed Effects		Random Effects	
Model Specification:	A (Levels Only)	B (Main)	A (Levels Only)	B (Main)
Variable/Column:	(1)	(2)	(4)	(5)
Companies/ km^2	0.225**	0.257***	0.382***	0.374***
	(0.085)	(0.090)	(0.090)	(0.090)
GDP/km^2	0.107	0.087	0.110*	0.084
	(0.072)	(0.068)	(0.061)	(0.053)
Lagged per capita income	-0.060	-0.011	-0.047	0.034
	(0.049)	(0.114)	(0.040)	(0.089)
Lagged per capita income squared		-0.011		-0.019
		(0.021)		(0.019)
Capital abundance (K/L)	0.006	0.122	-0.048	0.070
	(0.067)	(0.084)	(0.045)	(0.065)
(K/L) Squared		-0.010		-0.009
		(0.006)		(0.006)
Trade Intensity (TI=X+M/GDP)	-0.004	-0.004	-0.002	-0.002
	(0.003)	(0.003)	(0.003)	(0.003)
Relative Income	-0.006**	-0.006**	0.002	0.0009
	(0.003)	(0.003)	(0.004)	(0.003)
Population Density	0.006	0.010	0.045***	0.052***
	(0.057)	(0.059)	(0.011)	(0.010)
TI x Companies/ km^2	-0.005**	-0.004	-0.001	-0.0005
	(0.002)	(0.003)	(0.002)	(0.002)
TI x GDP/ km^2	0.0002	0.0003	-0.0003	-0.0002
	(0.0008)	(0.001)	(0.0007)	(0.001)
TI x Per capita Income	-2.55e-06	-0.0004	-0.00002	-0.0002
	(0.002)	(0.002)	(0.001)	(0.001)
TI x (K/L)	-0.001	-0.0004	-0.0004	-0.0004
	(0.001)	(0.001)	(0.001)	(0.001)
Companies x Per capita Income	0.032	0.011	0.020	-0.005
	(0.035)	(0.035)	(0.026)	(0.027)
Foreign Direct Investment				
Intercept	-6.473***	-6.843***	-6.981***	-7.369***
	(0.784)	(0.848)	(0.382)	(0.336)
Observations	211	211	211	211
Group	23	23	23	23
R^2 – within	0.6035	0.6170	0.5745	0.6001
R^2 – between	0.6952	0.7047	0.7915	0.7833
R^2 – overall	0.7397	0.7685	0.8037	0.8007
Sargan-Hansen Test/ χ^2 (df)			2783.39***	3924.3***
LR Test/ χ^2 (df)	7.33**	0.02		

Table 3: VOC, Models A and B

Estimation Method:	Fixed Effects		Random Effects	
Model Specification:	A	B	A	B
	(Levels Only)	(Main)	(Levels Only)	(Main)
Variable/Column:	(1)	(2)	(4)	(5)
Companies/ km^2	0.497***	0.517***	0.520***	0.537***
	(0.054)	(0.063)	(0.055)	(0.065)
GDP/km^2	0.129***	0.112***	0.145***	0.131***
	(0.032)	(0.033)	(0.040)	(0.044)
(GDP/km^2) Squared				
Lagged per capita income	-0.008	0.086	0.0003	0.057
	(0.044)	(0.116)	(0.040)	(0.097)
Lagged per capita income squared		-0.019		-0.013
		(0.022)		(0.019)
Capital abundance (K/L)	-0.037	0.003	-0.046	0.015
	(0.041)	(0.098)	(0.043)	(0.081)
(K/L) Squared		-0.003		-0.005**
		(0.007)		(0.006)
Trade Intensity (TI=X+M/GDP)	-0.004**	-0.004*	-0.004***	-0.004
	(0.002)	(0.002)	(0.002)	(0.001)
Relative Income	0.001	-0.002	0.001	0.002
	(0.004)	(0.004)	(0.003)	(0.003)
Population Density	0.067	0.077	0.031**	0.035***
	(0.055)	(0.061)	(0.013)	(0.012)
TI x Companies/ km^2	0.001	0.002	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.002)
TI x GDP/ km^2	-0.0005	-0.0004	-0.0003	-0.0003
	(0.001)	(0.001)	(0.001)	(0.0006)
TI x Per capita Income	-0.003*	-0.002	-0.002	0.002
	(0.001)	(0.002)	(0.001)	(0.001)
TI x (K/L)	-0.003***	-0.002***	-0.002***	-0.002***
	(0.001)	(0.001)	(0.001)	(0.0008)
Companies x Per capita Income	-0.090**	0.076	0.081**	0.068
	(0.040)	(0.047)	(0.040)	(0.046)
Foreign Direct Investment				
Intercept	-7.538***	-7.821***	-7.115***	-7.366***
	(0.717)	(0.699)	(0.252)	(0.246)
Observations	211	211	211	211
Group	23	23	23	23
R^2 – within	0.8220	0.8249	0.8209	0.8238
R^2 – between	0.6507	0.6495	0.6796	0.6836
R^2 – overall	0.6510	0.6500	0.6804	0.6862
Sargan-Hansen Test/ χ^2 (df)			2369.7***	8704.4***
LR Test/ χ^2 (df)	3.46**			

Table 4: Sensitivity Analysis SOx

Dependent Variable: Log of Sulfur Oxides per sq km

Estimation Method:	Fixed Effects			Random Effects		
Model Specification:	C (No Selection)	D (No Interaction)	E (FDI)	C (No Selection)	D (No Interaction)	E (FDI)
Variable/Column:	(1)	(2)	(3)	(4)	(5)	(6)
Companies/ km^2		0.808***	0.439*		0.688***	0.591**
		(0.102)	(0.145)		(0.230)	(0.264)
GDP/km^2	-0.282	0.177	0.305***	-0.160	-0.130	0.100
	(0.130)	(0.123)	(0.117)	(0.238)	(0.089)	(0.116)
Lagged per capita income	-0.004	-0.426*	-0.464**	0.038	-0.030	-0.033
	(0.226)	(0.188)	(0.177)	(0.259)	(0.211)	(0.207)
Lagged per capita income squared	0.005	0.112	0.069	-0.009	0.008	-0.019
	(0.054)	(0.046)	(0.042)	(0.060)	(0.054)	(0.048)
Capital abundance (K/L)	-0.062	0.462*	0.110	-0.221	-0.101	-0.307*
	(0.206)	(0.158)	(0.157)	(0.218)	(0.004)	(0.173)
(K/L) Squared	-0.026	-0.066**	-0.039***	-0.013	-0.017	-0.007
	(0.017)	(0.013)	(0.013)	(0.014)	(0.020)	(0.012)
Trade Intensity (TI=X+M/GDP)	-0.018***	-0.017***	-0.027***	-0.018***	-0.011***	-0.021***
	(0.003)	(0.002)	(0.003)	(0.007)	(0.040)	(0.007)
Relative Income	0.017	-0.023	0.011	0.019**	0.027***	0.010*
	(0.017)	(0.015)	(0.013)	(0.009)	(0.010)	(0.006)
Population Density	0.206	-0.293**	-0.401***	0.112	0.090***	0.039
	(0.134)	(0.127)	(0.113)	(0.069)	(0.036)	(0.026)
TI x Companies/ km^2			-0.015**			-0.007
			(0.004)			(0.006)
TI x GDP/ km^2	-0.001		0.001	-0.001		-0.002*
	(0.001)		(0.001)	(0.002)		(0.001)
TI x Per capita Income	-0.001		-0.008***	-0.001		-0.006*
	(0.002)		(0.002)	(0.002)		(0.002)
TI x (K/L)	-0.002		0.0001	-0.002		-0.001
	(0.001)		(0.001)	(0.002)		(0.002)
Companies x Per capita Income			-0.239**			-0.203**
			(0.068)			(0.095)
Foreign Direct Investment			-0.009***			-0.007**
			(0.002)			(0.003)

Intercept	-6.561**	-3.668*	-0.541	-5.339***	-6.625***	-5.022***
	(1.609)	(1.372)	(1.333)	(1.217)	(0.639)	(1.025)
Observations	211	211	210	211	211	210
Group	23	23	23	23	23	23
R^2 – within	0.6312	0.7021	0.8002	0.6276	0.6643	0.7702
R^2 – between	0.6203	0.2446	0.2779	0.6729	0.7120	0.7586
R^2 – overall	0.6255	0.2200	0.2610	0.6811	0.7366	0.7894
Sargan-Hansen Test/ χ^2 (df)				525.13***	714.12***	7625.98***
LR Test/ χ^2 (df)	111.45***	66.44***				

Table 5: Sensitivity Analysis NOx

Dependent Variable: Log of Nitrogen Oxides per sq km

Estimation Method:	Fixed Effects			Random Effects		
Model Specification:	C (No Selection)	D (No Interaction)	E (FDI)	C (No Selection)	D (No Interaction)	E (FDI)
Variable/Column:	(1)	(2)	(3)	(4)	(5)	(6)
Companies/ km^2		0.360***	0.246**		0.365***	0.321***
		(0.039)	(0.066)		(0.051)	(0.090)
GDP/km^2	-0.185	0.074*	0.086	-0.113	0.049***	0.074
	(0.054)	(0.047)	(0.053)	(0.126)	(0.018)	(0.050)
Lagged per capita income	0.122	-0.009	-0.016	0.066	0.015	0.025
	(0.095)	(0.072)	(0.080)	(0.117)	(0.078)	(0.090)
Lagged per capita income squared	-0.039	-0.008	-0.010	-0.027	-0.014	-0.017
	(0.023)	(0.018)	(0.019)	(0.030)	(0.022)	(0.019)
Capital abundance (K/L)	0.098	0.200*	0.130	0.115	0.146	0.089
	(0.086)	(0.061)	(0.071)	(0.113)	(0.096)	(0.065)
(K/L) Squared	-0.008	-0.017	-0.011*	-0.010	-0.014	-0.009
	(0.007)	(0.005)	(0.006)	(0.009)	(0.009)	(0.006)
Trade Intensity (TI=X+M/GDP)	-0.0003	-0.001	-0.004	-0.001	-0.001	-0.003
	(0.001)	(0.001)	(0.001)	(0.004)	(0.001)	(0.003)
Relative Income	-0.002	-0.003	-0.005*	0.002	0.001	-0.001
	(0.007)	(0.006)	(0.006)	(0.004)	(0.003)	(0.003)
Population Density	0.226**	0.024	0.008	0.107***	0.060***	0.054***
	(0.056)	(0.049)	(0.052)	(0.042)	(0.013)	(0.011)
TI x Companies/ km^2			-0.004			-0.002
			(0.002)			(0.003)
TI x GDP/km^2	0.0004		0.0004	0.001		-0.00004
	(0.0006)		(0.001)	(0.001)		(0.0007)
TI x Per capita Income	0.0001		-0.0004	-0.00005		-0.0002
	(0.0008)		(0.001)	(0.002)		(0.002)
TI x (K/L)	-0.0006		-0.0004	-0.001		-0.0004
	(0.0005)		(0.0004)	(0.001)		(0.001)
Companies x Per capita Income			0.011			0.009

			(0.031)			(0.029)
Foreign Direct Investment			-0.001*			-0.001
			(0.001)			(0.001)
Intercept	-8.755***	-7.415***	-6.818***	-7.462***	-7.668***	-7.355***
	(0.675)	(0.528)	(0.606)	(0.509)	(0.321)	(0.377)
Observations	211	211	210	211	211	210
Group	23	23	23	23	23	23
R^2 – within	0.4037	0.5948	0.6191	0.3869	0.5896	0.6103
R^2 – between	0.6489	0.7424	0.6783	0.6483	0.7715	0.7619
R^2 – overall	0.6508	0.7895	0.7535	0.6529	0.7931	0.7841
Sargan-Hansen Test/ χ^2 (df)				2065.9***	2126.5***	1.8e+06***
LR Test/ χ^2 (df)	93.44***	11.93**				

Table 6: Sensitivity Analysis VOC

Dependent Variable: Log of Volatile Organic Compounds per sq km

Estimation Method:	Fixed Effects			Random Effects		
Model Specification:	C (No Selection)	D (No Interaction)	E (FDI)	C (No Selection)	D (No Interaction)	E (FDI)
Variable/Column:	(1)	(2)	(3)	(4)	(5)	(6)
Companies/ km^2		0.470***	0.524***		0.478**	0.539***
		(0.055)	(0.063)		(0.046)	(0.065)
GDP/km^2	-0.266	0.066	0.112***	-0.158	0.066**	0.132***
	(0.242)	(0.052)	(0.033)	(0.219)	(0.033)	(0.045)
Lagged per capita income	0.175	-0.106	0.089	0.067	-0.093	0.062
	(0.166)	(0.098)	(0.116)	(0.143)	(0.096)	(0.097)
Lagged per capita income squared	-0.047	0.017	-0.020	-0.025	0.013	-0.014
	(0.040)	(0.025)	(0.022)	(0.035)	(0.025)	(0.019)
Capital abundance (K/L)	-0.017	0.259	0.001	0.045	0.217	0.124
	(0.165)	(0.164)	(0.099)	(0.153)	(0.143)	(0.084)
(K/L) Squared	-0.001	-0.023**	-0.003	-0.006	-0.019**	-0.005
	(0.013)	(0.010)	(0.008)	(0.011)	(0.009)	(0.006)
Trade Intensity (TI=X+M/GDP)	-0.001	0.001	-0.003*	-0.002	0.001	-0.004**
	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
Relative Income	0.006	0.007*	-0.002	0.007	0.008**	0.002
	(0.007)	(0.004)	(0.004)	(0.005)	(0.004)	(0.003)
Population Density	0.324**	0.050	0.079	0.120*	0.054***	0.037**
	(0.149)	(0.059)	(0.061)	(0.066)	(0.021)	(0.012)
TI x Companies/ km^2			0.002			0.002
			(0.002)			(0.002)
TI x GDP/km^2	0.001		-0.0005	0.001		-0.0003
	(0.001)		(0.0008)	(0.001)		(0.0006)
TI x Per capita Income	0.001		-0.002	0.001		0.002
	(0.002)		(0.0002)	(0.002)		(0.002)
TI x (K/L)	-0.002		-	-0.002		-0.002***

	(0.001)		0.002***	(0.001)		(0.001)
			(0.001)			
Companies x Per capita Income			-0.077			0.070
			(0.047)			(0.047)
Foreign Direct Investment			-0.0005			0.0005
			(0.0008)			(0.0008)
Intercept	-9.535***	-8.062***	-7.855***	-7.353***	-8.018***	-7.392***
	(1.447)	(0.556)	(0.702)	(0.546)	(0.461)	(0.238)
Observations	211	211	210	211	211	210
Group	23	23	23	23	23	23
R^2 - within	0.6295	0.7577	0.8252	0.6048	0.7569	0.8242
R^2 - between	0.5351	0.6728	0.6496	0.5105	0.6840	0.6809
R^2 - overall	0.5276	0.6876	0.6514	0.5049	0.6940	0.6849
Sargan-Hansen Test/ χ^2 (df)				1520.4***	2732.9***	1.5e+06***
LR Test/ χ^2 (df)	158.06***	68.46***				

***Significance at the 99-percent confidence level.
**Significance at the 95-percent confidence level.
*Significance at the 90-percent confidence level.
Note: Standard errors in parentheses are cluster-robust.