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Industry Structure and Emission Abatement

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Abstract

Using the world panel dataset for the pollution emission embedded in international trade of 132 countries for the period between 1988 and 2008, we investigate whether the balance of embodied emission in trade (BEET) is consistent with the implication of pollution haven hypothesis. By using two differently constructed datasets, we are able to distinguish between the composition (i.e., changes in industry structure of international trade) effect and the technique (i.e., improvement in emission abatement) effect. We find that the composition effect is neither related with the income level nor the democracy level of countries whereas the technique effect is. The empirical evidence provides a partial support that income level is negatively related with the BEET.

Keywords: Balance of embodied emission in trade; Environment; Industry structure; International trade; Pollution haven hypothesis.
JEL Classification Codes: F18; O13; Q56.

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1. Introduction

In the past two decades, trade liberalization has been aggressively pursued in both multilateral and bilateral frameworks. By creating the World Trade Organization (WTO) in 1995, introducing a single European currency (the Euro), and creating regional and bilateral free trade agreements, trade barriers from both tariff and non-tariff obstacles were substantially reduced. Consequently, the volume of international trade increased in the world[1]. For countries considering trade policy reforms, it also becomes an important issue that policy makers in appropriately evaluate the effects of international trade on their economies. The effect of international trade on growth is especially important for developing countries[2]. Empirical studies investigating the effects of international trade on the environment also draw much attention from both policy makers and researchers.

The common fear among environmentalists upon trade liberalization was the pollution haven hypothesis wherein the production of dirty industries shifts toward developing countries where environmental regulations are either relatively lax or nonexistent. Recent empirical studies examining the pollution haven hypothesis can be classified into two indirect approaches. The first approach, suggested by a seminal work of Antweiler et al. (2001), regresses the pollution emission of *national* production on variables representing scale, technique, and composition effects. The second approach examines changes in the *value* of international trade with respect to environment variables; see Levinson and Taylor (2008). Neither approach can use the direct measures of pollution emission embodied in international trade simply due to the lack of data on these measures in the world panel database.

Our study contributes to the literature by providing the evidence of the balance of embodied emission in trade (BEET) for the world wide set of countries. We use the two world-wide datasets, constructed by slightly different manners in Honma and Yoshida (2012). The first construction of dataset imposes the restricting assumptions that (1) the pollution intensity by each industry is fixed during the sample period and (2) the pollution emission intensity of industries is the same for all countries. These assumptions are too restrictive for assessing the overall effect of pollution haven hypothesis. However, these assumptions are reasonable and useful in assessing a composition effect of international trade on environment. The second construction of dataset uses the less restrictive assumptions that (1) the pollution intensity of each

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[1] see for example Subramanian and Wei (2007) for WTO role in promoting international trade

[2] See López (2005) and Singh (2011) for recent surveys on trade and growth.

industry is time-varying during the sample period and (2) all countries have different magnitude of pollution emission intensity, but (3) the ranking of industries in terms of pollution emission intensity is fixed across countries and time. This second dataset allows us to investigate both the composition effect and the technique effects on the BEET.

By using two differently constructed datasets, we are able to distinguish between the composition (i.e., changes in industry structure of international trade) effect and the technique (i.e., improvement in emission abatement) effect. We find that the composition effect is neither related with the income level nor the democracy level of countries whereas the technique effect is. The empirical evidence provides a partial support that income level is negatively related with the technique effect on the BEET. Thus, countries with higher income level are more likely to export more of industries with lower intensity of pollution emission and import more of industries with higher intensity of pollution emission. This result is consistent with the pollution haven hypothesis. By contrast, the democracy level of countries is found to be positively associated with the BEET. We further examine this phenomenon and find some supporting evidence for the non-linearity of the relationship between the level of democracy and pollution emission. This non-linearity relationship resembles the finding, the inverted-U shape relationship between pollution emission and the income levels of countries, in Grossman and Krueger (1993).

The structure of the rest of this paper is as follows. Section 2 briefly covers the literature on international trade and environment and reviews the previous studies investigating the BEET. Section 3 describes in detail the construction of the BEET database. Section 4 presents the empirical model for the BEET with explicit incorporation of unbalanced trade. Section 5 provides the empirical evidence and the last section concludes.

2. The balance of embodied emission in trade (BEET)

Before discussing in detail about the BEET, it is important to place the relevance of the BEET in a larger perspective of the literature on international trade and environment. The empirical studies most relevant to this paper can be categorized into three different approaches: (1)studies investigating the effect of international trade on pollution emission from domestic production (Grossman and Krueger, 1993; Antweiler et al., 2001; Cole and Elliot, 2003; Managi et al., 2009), (2)studies investigating the effect of environment regulations on international trade of dirty industries (Ederington et al., 2004; Levinson and Taylor, 2008), and (3)studies measuring the pollution emission embedded in international trade (Muradian et al., 2002; Ederington et al., 2004; Levinson, 2009). These three approaches are closely related and examine the relationship between international trade and environment only from different perspectives. The first approach examines the effect of international trade on domestic production which includes both productions for domestic and foreign demand whereas the second and third approaches focus on the difference in domestic production and domestic demand, which is equal to foreign demand. In all studies, a change in the structure of polluting industries due to international trade is essential.

The effects of international trade on the pollution emission of domestic production are distinguished to three separate mechanisms; scale, composition, and technique effects (Grossman and Krueger, 1993). The scale effect increases pollution emission due to expanded production of economy if international trade stimulates economic growth. The composition effect affects the level of pollution emission through a change, due to (partial) specialization in industry induced by international trade, in the industry structure of economy. Pollution haven hypothesis stresses the international relocation of pollution-intensive industries from country with strict environment regulations to country with lax environment regulations. The technology effect reduces pollution emission by adopting new production process. Antweiler et al. (2001) examines the effect of international trade on pollution emission by regressing pollution emission on scale, technique, and composition factor and their interaction terms with the measure of trade openness, see also Cole and Elliot (2003), Frankel and Rose (2005), and Managi et al. (2009). They find the evidence that free trade with combined effect of all three is beneficial for developing countries although international trade causes composition shift toward dirtier industries for developing countries.

Moreover, instead of indirectly examining the relationship between international trade and environment, efforts are made to calculate the pollution emission incurred in producing products for international trade. The World Bank project develops the Industrial Pollution Projection System (IPPS) database for calculating pollution intensity, η_j, in the US industries (Hettige et al., 1995). This database is used extensively in the following studies. Mani and Wheeler (1999) examines pollution haven hypothesis for the period between 1960 and 1995 and find that displacement of pollution-intensive industries from developed countries to developing countries is self-limiting and only transient.

By using the pollution intensity coefficients of all 79 IPPS sectors, Ederington et al. (2004) calculates the pollution emission embodied in exports and imports, $\overline{E}$ and

$\overline{M}$, for the US from 1972 to 1994 by the following equation (1) and (2).

$$\overline{E} = \sum_{j \in J} \eta_j E_j \tag{1}$$

$$\overline{M} = \sum_{j \in J} \eta_j M_j \quad , \tag{2}$$

where E_j and M_j are exports and imports of industry j, respectively. At the industry level, pollution emission is calculated by multiplying industry pollution intensity, η_j, and the value of exports (or imports), E_j (or M_j), for the industry. By aggregating over industries, we obtain the pollution emission embodied in total exports and imports.

Industry pollution intensity, η_j, is held constant at 1987 level which is provided by the Industrial Pollution Projection System (IPPS), the World Bank. This calculation with constant pollution intensity provides interesting insights although this calculation is only chosen by the lack of availability for pollution intensity data in different years. By holding pollution intensity (technique) constant, a one percent increase in trade value should also raise pollution by one percent if the composition of industries remains unchanged. A deviation in the growth rate of pollution emission from the growth rate of international trade only arises from the change in the industry composition in trade. For example, the growth rate of pollution emission becomes smaller than the growth rate of international trade only if the composition of trade moves more toward cleaner industries. Interestingly, the calculation in Ederington et al. (2004) shows that both the US exports and imports moved toward cleaner industries although the composition shift is more drastic in the US imports.

The net pollution emission embodied in international trade can be presented as the difference in export pollution emission, $\overline{E}$, and import pollution emission, $\overline{M}$. Formally, we obtain the net trade pollution emission as the following equation.

$$\overline{T} = \overline{E} - \overline{M} = \left(\sum_{j \in J} \eta_j E_j \right) - \left(\sum_{j \in J} \eta_j M_j \right) \tag{3}$$

Muradian et al. (2002) calls the net trade pollution emission in equation (3) as BEET (the balance of embodied emissions in trade) and calculates for the US, Japan, and Western Europe for 6 sparse years in the period between 1976 and 1994. The number of industries in their study is limited to only 11 sectors (out of possible 79 sectors).

Addressing the bias arising from not accounting for imports as inputs in export production, Pan et al. (2008) and Peter and Herwich (2006) among others use input-output tables to account for the imported intermediated products in exports[3]. Levinson (2009) revisits the shift of US production and international trade to cleaner industries for the more recent period between 1987 and 2001 by incorporating input-output table of the US to examine the possible role of intermediate inputs.

In this study we construct the world wide dataset, in which pollution emission embodied in international trade are calculated in a similar manner to Ederington et al. (2004) and Levinson (2009), for the period between 1988 and 2008 over 130 countries. Against the developments in the recent studies in making efforts for implementing different pollution coefficients for each country, we apply the same pollution emission coefficients to all countries in the world. Similarly, Grossman and Krueger (1993) applied the US pollution intensity coefficients to Mexico and Canada to assess the impact of NAFTA on these countries. We are all aware of under-estimating the pollution emission especially for developing countries by applying the U.S. pollution coefficients. However, we cannot conduct a serious research for developing countries otherwise because industry level pollution emission coefficients are yet not available in the most of developing countries. This dataset provides an opportunity to examine to what extent the composition shift in international trade is consistent with pollution haven hypothesis, by applying the same methodology to both developed and developing countries.

Further, we revise the above-mentioned dataset by using the adjusted pollution intensity coefficients which are both time-variant and country-variant. This is done so by incorporating the other environmental data source which annually provides pollution emission of the overall manufacturing industry for the wide set of countries. We call the first dataset as the *unadjusted* BEET and the revised dataset as the *adjusted* BEET. Overcoming the most of issues raised for using the *unadjusted* BEET, the *adjusted* BEET reflects both the composition effect and the technique effect.

3. World International-Trade Pollution Dataset

We use the worldwide panel dataset of pollution emission embodied in international trade. In this section we describe the original data sources and the procedures used for constructing the dataset.

3-1. Pollution emission data

The basic datasets are constructed in Honma and Yoshida (2012). For more

[3] For a recent survey on studies for estimating pollution emission by using input-output structure, see Wiedmann (2009).

detailed description of the original data sources, see the data description appendix in Honma and Yoshida (2012).

Correspondence tables

The correspondence table between the HS (ver.1996) and the ISIC (ver.3) is taken from the United Nations Statistical Division. The corresponding table between ISIC (ver.3) and ISIC (ver.2) is also taken from the same source.

Industry-level pollution intensity data

The World Bank, under the IPPS and in collaboration with the Center for Economic Studies of the US Census Bureau and the US Environmental Protection Agency, developed estimates of pollution intensity for each of 79 sectors for the International Standard Industrial Classification (ISIC). The estimates for 14 categories of pollutants are constructed from approximately 200,000 factories in all regions of the US.

Country-level pollution intensity data

The Emission Database for Global Atmospheric Research (EDGAR) provides pollution emission at sector levels for the world-wide countries.[4] We use the emission of SO2, NO2, and CO for manufacturing sector. Then these emission data are divided by the GDP in 2005 US dollar provided by the Penn World Table 7.0 (May 2011).

Export data

The United Nations (UN) Comtrade database provides detailed exports at Harmonized System (HS) 6-digit level for over 200 countries and regions. For each country with exports data available, the values of exports to the world in terms of US dollars for each HS 6-digit products are obtained for the period between 1988 and 2009. The total size of the dataset exceeded ten gigabytes.

3-2. The first database construction

The values of international trade data at HS six-digit commodities are mapped into ISIC four-digit industries and multiplied by corresponding industry pollution intensity coefficients. The correspondence tables between different classifications are readily available at the United Nations Statistical Division. For each HS 6-digit export

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[4] We chose the EDGAR database over another often used database provided by Stern (2006) because Stern (2006) only provide national level of pollution emission, including other than manufacturing sector.

for a given year, we find matching ISIC industry code and calculated estimated pollution emission in pounds. For example, HS 873323 (automobile with the engine size between 1,500cc and 3,000cc) is matched with ISIC 3843(manufacture of motor vehicles) and IPPS provides estimate of SO2 emission as 279 pounds per US million dollars. The calculation procedure is depicted in Figure 1.

Following the methodology in Ederington et al. (2004), we construct the panel of estimated pollution emission directly related in production of export as follows.

$$\overline{E}_{it} = \sum_{j=1}^{79} \eta_{j,1987} E_{ijt} \text{ ,} \qquad (4)$$

where $\overline{E}_{it}$ is the pollution emission in terms of pound per US million dollars in year *t*, $\eta_{j,1987}$ is the pollution intensity coefficient (being same for all years) in industry *j* from the IPPS, and E_{ijt} is the value of export in industry *j* from country *i* in year *t*. By holding the pollution intensity (technique) constant, a 10% increase in exports value should also raise pollution 10% if the composition of industries does not change, i.e., all exporting industries experience the same growth rate. Similarly for imports, we construct the panel of pollution emission embodied in the production of imports as follows:

$$\overline{M}_{it} = \sum_{j=1}^{79} \eta_{j,1987} M_{ijt} \text{ ,} \qquad (5)$$

where $\overline{M}_{it}$ is the pollution emission embodied in imports in terms of pounds per US million dollars in year *t* and M_{ijt} is the value of imports in industry *j* to country *i* in year *t*.

The balance of pollution emission embodied in trade is then calculated as follows:

$$\overline{T}_{it} = \overline{E}_{it} - \overline{M}_{it} = \left(\sum_{j=1}^{79} \eta_{j,1987} E_{ijt} \right) - \left(\sum_{j=1}^{79} \eta_{j,1987} M_{ijt} \right) . \qquad (6)$$

Several caveats in this empirical methodology should be noted. First, we impose that all countries have the same pollution intensity coefficients as in the US because such data are not available for many countries. The estimation results, therefore, need to be interpreted with great care. Due to the lack of pollution emission data at the industry level, especially for developing countries, an empirical investigation using this dataset should be interpreted as the first attempt, with the best effort to approximate, to examine the worldwide changes in the composition of industries from the perspective of pollution emission. Second, however, time-invariant coefficients are necessary to address the effect of changes in industry composition for international trade. The sole focus in this exercise is to examine the composition effect and not the other scale and technique effects. Third, the actual requirement in the underlying assumption need not be the same pollution intensity coefficients for all countries. This empirical exercise will be valid as long as there are only moderate differences in pollution intensity coefficients, such that the ordering of industries in pollution intensity are similar in all countries. Grossman and Krueger (1993) similarly apply the US pollution intensity coefficients to Mexico and Canada to assess the impact of NAFTA on these countries. Fourth, we do not account for the imported intermediated products in exports as other studies using input-output tables, see Pan et al. (2008) and Peter and Herwich (2006).

3-3. The second database construction

For the second database, we relax the preceding assumptions so that pollution emission intensity is both time-variant and country-variant. We do so by introducing the overall-manufacturing industry pollution intensity coefficients which are constructed by pollution emission data from the EDGAR, adjusted by constant US dollar GDP from the Penn World Table. Thus, the overall-manufacturing industry pollution intensity coefficient for country *i* at year *t* is denoted as μ_{it}. To adjust the (common for all countries and years) industry pollution coefficient, $\eta_{j,1987}$, for a specific pair of country and time, we construct the following *adjusted* pollution emission intensity of industry *j*:

$$\hat{\eta}_{ijt} = \left(\frac{\mu_{it}}{\mu_{US,1988}} \right) \eta_{j,1987} . \quad (7)$$

A change in the term in the parenthesis should indicate a change of emission intensity due to adopting new pollution abatement technology.[5] Note that the term in the parenthesis is one for the US in 1988.

By allowing the pollution intensity coefficients to become country-variant, another important issue arises in calculating pollution emission in imports. In equation (5), the aggregated import from the world is used because all exporting countries are assumed to have the same pollution intensity coefficients. Now we need to apply pollution intensity coefficients distinct for each exporting country. Thus, the import needs to be disaggregated at the bilateral level. By denoting imports of industry *j* from country *k* to country *i* at year *t* as M_{ikjt}, the pollution emission embodied in the production of imports is defined as follows:

$$\overline{M}_{it} = \sum_{k \neq i} \sum_{j=1}^{79} \hat{\eta}_{kjt} M_{ikjt}$$

Correspondingly, the balance of pollution emission embodied in trade in equation (6) is rewritten for this second dataset as the following equation (8).

$$\overline{T}_{it} = \overline{E}_{it} - \overline{M}_{it} = \left(\sum_{j=1}^{79} \hat{\eta}_{ijt} E_{ijt} \right) - \left(\sum_{k \neq i} \sum_{j=1}^{79} \hat{\eta}_{kjt} M_{ikjt} \right)$$
$$= \left(\sum_{j=1}^{79} \left(\frac{\mu_{it}}{\mu_{US,1988}} \right) \eta_{j,1987} E_{ijt} \right) - \left(\sum_{k \neq i} \sum_{j=1}^{79} \left(\frac{\mu_{it}}{\mu_{US,1988}} \right) \eta_{j,1987} M_{ikjt} \right) \quad (8)$$

A change in the BEET now arises from both a change in the industry structure of international trade and a change in pollution emission intensity caused by pollution abatement efforts in each country. By comparing the BEET from the unadjusted dataset (the first dataset) with this adjusted dataset, we can infer the technique effect on the BEET across countries and time.

4. Determinants of the balance of embodied pollution emission in trade

Antweiler et al. (2001) investigates the effect of international trade on

[5] Note that this term also captures the industry structure change in overall production of country. So the BEET variables constructed this way may have an excessive response to a change in industry structure. However, as we later show in the empirical section, we only find a weak evidence of the composition effect.

environment in a traditional Heckscher-Ohlin model with introduction of pollution tax and pollution abatement cost. The only one of two industries is assumed to emit pollution. The total pollution emission from production, $\bar{Y}$, can be decomposed into three factors; pollution intensity of dirty industry, η, the share of dirty industry in economy, θ, and the scale of economy, *Y*.

$$\bar{Y} = \eta\theta Y \tag{9}$$

A generalization of the above equation to a multi-industry setting can be represented as

$$\bar{Y} = \left(\sum_{j \in J} \eta_j \theta_j\right) Y, \tag{10}$$

where *J* is the number of industries. Now, θ_j represents the share of industry j in economy and therefore the sum of θ_j is equal to one, i.e., $\sum_{j \in J} \theta_j = 1$

Now from the consumption side, pollution emission embodied in aggregate demand, $\bar{C}$, can be shown as the sum of pollution emission embodied in demand in each industry. C_j is consumption in industry *j* and λ_j is the *j* industry's share of consumption and $\sum_{j \in J} \lambda_j = 1$. For the CES utility function, the share of consumption is constant regardless of income level.

$$\bar{C} = \left(\sum_{j \in J} \eta_j C_j\right) = \left(\sum_{j \in J} \eta_j \lambda_j\right) Y \tag{11}$$

International trade allows production and consumption to be different for each industry. The balance of the pollution emission embodied in international trade or the BEET can be expressed as $\bar{T}$ in the following equation.

$$\bar{T} = \bar{Y} - \bar{C} = \left(\sum_{j \in J} \eta_j \left(\theta_j - \lambda_j\right)\right) Y \tag{12}$$

The net pollution emission embodied in international trade is decomposed into the pollution intensity of industry, the difference in production and consumption share of industry and the scale of economy. In a classical Heckschere-Ohlin framework, an industry simply exports if the difference in production and consumption share is positive. In a monopolistic competition model which allows intra-industry trade, net export is positive for this case.

In deriving equation (11) we implicitly assumed that the sum of consumption is equal to the national income or alternatively international trade is balanced; however, the most of countries in our sample exhibit large trade surplus or deficit. We explicitly incorporate unbalanced trade, with which a country with trade deficit consume more than the national income, by slightly modifying equation (11) and (12). TB is defined as exports minus imports.

$$\bar{C} = \left(\sum_{j \in J} \eta_j C_j \right) = \left(\sum_{j \in J} \eta_j \lambda_j \right) \{Y - TB\} . \quad (11')$$

$$\bar{T} = \left(\sum_{j \in J} \eta_j (\theta_j - \lambda_j) \right) Y + \left(\sum_{j \in J} \eta_j \lambda_j \right) TB \quad (12')$$

Dividing the both side of equation by national income yields the equation for the ratio of the BEET to national income.

$$\frac{\bar{T}}{Y} = \left(\sum_{j \in J} \eta_j \theta_j \right) - \left(\sum_{j \in J} \eta_j \lambda_j \right) \left(1 - \frac{TB}{Y} \right) \quad (13)$$

The first term on the right-hand side is the (production share) weighted sum of pollution emission coefficient. Due to the restriction of constant pollution emission coefficients, this term can change only when the production shares, θ_j, change. A change in the production structure can be induced for the number of reasons. For example, the economic growth driven by adopting a higher technology shifts a developing county more toward high-tech industries.

To see a formal presentation of the effects of possible determinants on GDP-adjusted BEET, we totally differentiate equation (13). Denoting the variables as X_k which affects the sum of pollution emission coefficients weighted by production shares, a total differentiation of equation (13) is as follows.

$$d\left(\frac{\overline{T}}{Y}\right)=\sum_{k=1}^{K}\frac{\partial\left[\sum_{j\in J}\eta_j\theta_j\right]}{\partial X_k}dX_k-\left(\sum_{j\in J}\eta_j\lambda_j\right)d\left(1-\frac{TB}{Y}\right) \tag{14}$$

In the literature of environment and international trade, we focus on the effect of trade liberalization on a change in the composition of industries. The pollution haven hypothesis (PHH) assumes that trade liberalization leads to a reduction in the production of dirty industry in developed countries and an increase in the dirty industry production in developing countries. According to the PHH, the BEET should be negatively related with the income level of countries.

The graphical interpretation of the effect of income level on the BEET is shown in Figure 2. On the horizontal axis, industries are ordered in terms of pollution emission coefficients; the cleanest industry on the leftmost and the dirtiest industry on the rightmost. Production shares of industries are measured along on the vertical axis. Note that production share curve is shown as continuous only for the ease of exposition. Three curves are plotted to represent typical economies: (a)relatively clean production, (b)even production, and (c)relatively dirty production. The value of the first term in equation (13) is greater in order of (c), (b), and (a). The pollution haven hypothesis claims that the order of three curves, {(a), (b), and (c)}, is negatively correlated with the income of countries. We test this hypothesis by using income per capita as an explanatory variable in equation (14).

As an additional explanatory variable in equation (14), we also use the Polity index constructed by the Polity IV project. The Polity index takes value from -10 (hereditary monarchy) to +10 (consolidated democracy) to measure the degree of concomitant qualities of democratic and autocratic authority in governing institutions[6]. This variable represents the stringency of environmental regulations. Therefore, a county with a higher value of this Polity index produces less of dirtier industries at home and import more of those industries products. The null hypothesis for the Polity index is also negative. We checked the correlation between income per capita and the Polity index and it is moderately low, i.e., 0.249.

The second term on the right-hand side of equation (14) can be divided into two parts. The term in the first parenthesis is the (consumption share) weighted sum of pollution intensity. If we assume homothetic preference with common parameters

6 See the homepage of the Polity IV Project for full description of constructing this index.

among countries, the part in the first parenthesis is constant. The second parenthesis term is trade-balance adjusted income. Note that the BEET is positive, i.e., a country emits more pollution on the home ground in net term, if the country only exports with no imports. Associated with a greater demand for foreign products, a higher (trade-balance adjusted) income (or more consumption) decreases the BEET. Therefore, the second term, including two parentheses, in equation (14) is negatively associated with the BEET.

The empirical model of equation (14), with discussion above, can be represented as the following equation,

$$\left(\frac{BEET}{GDP}\right)_{i,t} = \alpha_1 GDPPC_{i,t} + \alpha_2 Polity_{i,t} + \alpha_3 TBADJ_{i,t} + \varepsilon_{i,t} \qquad (15)$$

where BEET is the balance of embodied emissions in trade in equation (6) or (8) and $TBADJ = (1 - TB/Y)$. The expected sign is negative for all α_1, α_2, and α_3.

5. Income, Polity, and Pollution in International Trade

We constructed the BEET variable by following the steps described in section 3 and obtained gross domestic product, gross domestic product per capita from the *World Development Indicator*, the World Bank and polity index from the Polity IV project. In the following subsection, we use the unadjusted BEET dataset, in which the pollution emission intensity of industry is common in all countries and all years. The objective of using this unadjusted BEET dataset is to evaluate the effect of a change in industry structures of international trade on the balance of pollution emission embodied in trade in the world panel. In section 5-2, we use the second adjusted BEET dataset, in which the pollution emission intensity of industry is both time-varying and country-varying. With this second adjusted BEET dataset, we can infer from an empirical result how both the composition effect and the technique effects combined affect the balance of pollution emission embodied in trade.

5-1. The unadjusted BEET

We estimated equation (15) by panel data analysis, using the unadjusted BEET variables for three pollutants, namely SO2, NO2, and CO, constructed in the way shown in equation (6). The results are shown in the left three columns in Table 1. First, the control variable denoted as *TBADJ*, which represents trade balance effect normalized by size of economy, has correct sign for all pollutants regardless of estimation methods. Second, the coefficients of *GDPPC* are not statistically significant for SO2 and NO2 pollutants. The coefficient of *GDPPC* for NO2 even indicates incorrect sign with statistical significance. For CO pollutant; however, the coefficients has correct negative sign and statistically significant at five (one) percent level for fixed- (random-) effects specification. Third, for Polity index, we find for no case in which the estimated coefficient has correct sign and is statistically significant, except for NO2 pollutant in fixed-effects model. It is noteworthy that the Hausman specification test, with the null hypothesis of a random effect estimator is consistent, indicates that random-effects model should be selected for all pollutants. The goodness of fit for random-effects in terms of adjusted R-squared is, in general, smaller in comparison with regressions with fixed-effects model. At this point, we observe that the composition effect on the BEET is related, as we expected, with the income level of countries only for CO pollutant.

Next, we introduce time dummies in estimating equation (15). Time dummies may capture unobservable common changes in the world such as overall improvements in pollution abatement technology in the world, which we ignored intentionally for the construction of the BEET variables in this subsection. We remind that a change in the unadjusted BEET can only occur from a change in the composition of industries. However, the income level and the democracy level of countries affect the actual (unobservable) changes in the BEET. We control this unobservable effect by using time dummies. The right three columns in Table 1 show estimation results for estimation of equation (15) with time dummies. In comparison with results without time dummies, the coefficient of CO pollutant in fixed-effects model becomes no longer statistically significant. In random-effects model, two pollutants have incorrect signs with statistical significance. Polity index is not statistically significant for any pollutants. As an overall assessment, the inclusion of time dummies wipes out the weak link between the composition effect on the BEET and the income level and the democracy level of countries. As a conclusion, the composition effect on the BEET is neither related with the income level nor the democracy level of countries. Thus, we do not observe the prediction of pollution haven hypothesis that a country with more democratic institution and higher income level is more likely to export more of industries with a lower intensity of pollution emission and import more of industries with a higher intensity of pollution emission.

5-2. The adjusted BEET

In Table 2, we present the estimation results of equation (15) by using the *adjusted* BEET constructed by equation (8). As in Table 1, results without time dummies are presented in the left three columns and results with time dummies are shown in the right three columns. First, the coefficient of control variable, *TBADJ*, is negative and statistically significant for all pollutants and both specifications of the model. Second, in contrast to the results in the previous subsection with the *unadjusted* BEET, the coefficients of GDPPC are negative and statistically significant for the most of the case. More surprisingly, the coefficients of Polity index is positive and often with statistically significant, especially for random-effects model. However, it is noteworthy that the Hausman tests for regressions with time dummies indicate in favor of fixed-effects model for SO2 and CO pollutants where neither GDPPC nor Polity index is statistically significant.

As a conclusion, we find some evidence that a reduction in the BEET, i.e., less of domestic production and more of imports for dirtier industries, is negatively correlated with the income level of countries when an improvement in adoption of abatement technology is considered. Thus, in contrast to the result in the preceding subsection, a lower income country tends to export more of industries with a higher intensity of pollution emission and import more of industries with a lower intensity of pollution emission. What remains perplexing to our intuition is that the result with Polity index that a more democratic country experiences exporting more of dirtier products. We further examine this issue in the following subsections. First, we drop more recent years which underwent the changes in the classification of international trade. Second, we examine a possible non-linearity relationship between pollution emission and the democracy of countries.

5-3. Robustness check with sub-samples

We have some concerns that the BEET variables in recent years may have some biases that drive the preceding results. First, the original sample covers 21 years and the underlying relationships of the BEET with the explanatory variables may undergo some structural changes in recent years. Second, the classification of international trade is sometimes altered to update the definitions of new products and the large changes in industry structures.[7] Due to non-matching of newer version of HS classifications to old HS classifications, more industries may drop from the calculation

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[7] This problem can be less severe when we implement the corresponding table between the old coding and the new coding. But this process has not yet implemented in this version of the paper.

of the BEET in recent years. Third, the unprecedented hike of petroleum price in 2007 and 2008 may cause unrelated shifts in international trade which is beyond the scope of this paper. As a robustness check, we address this issue of problem by running the same regressions with two sub-samples of periods, namely between 1988 and 2004 and between 1988 and 2004. The results are shown in Table 3. The most important change in the estimation results by using these subsamples is that more estimates of *GDPPC* are negative and are statistically significant. Noting that the Hausman tests indicate the null of random-effects is rejected for only NO2 with the subsample between 1988 and 2004, four out of six estimates are negative and statistically significant. On *Polity* index, likewise, four out of six estimates are positive and are statistical significant. By analyzing the results with subsamples, they only strengthen the previous results that the income level is negatively correlated with the adjusted BEET whereas the democracy level is positively correlated.

In addition to subsamples in terms of annual observations, the relationship between the BEET and the explanatory variables may not be stable in the sample of countries with income levels so largely different. We investigated with the subsample excluding the high income countries defined by the World Bank. These countries are listed in the Appendix. The results are shown Table 4. We estimated the adjusted BEET regressions for non-high-income countries with two different samples, full sample between 1988 and 2008 and subsample between 1988 and 2004. Comparing with the right three columns in Table 2, the estimates of both *GDPPC* and *Polity* index for NO2 for full sample become no longer statistically significant. With the subsample between 1988 and 2004, the estimates of *GDPPC* for all three pollutants are no longer statistically significant. These results indicate that the explanatory power of *GDPPC* for the adjusted BEET cannot be attributed to the difference in the income level among developing countries. What we find robust is the positive sign of Polity index and we turn to this issue in the next subsection.

5-4. Discussions on the inverted-U pollution emission

As we have shown that the positive sign of estimates of Polity index is quite robust for different sample periods and different set of countries. This result leads to the interpretation which contradicts with the notion that countries with more stringent environment regulations tend to export less of dirtier industries and import more of cleaner industries. In search of possible explanations to this result, we refer to the empirical evidence of Grossman and Krueger (1993) which find the income level of countries is non-linearly related to pollution emission of national production. To address this issue, we introduce 20 Polity dummies instead of Polity index variable. The estimates of these dummies are shown in Figure 3a through 3c. An estimate with statistical significance at ten percent level is shown with an asterisk. Surprisingly, the democracy levels of 0 and 1 have additional positive impact on the BEET whereas the countries with low democracy level (negative values for Polity index) often have negative impacts on the BEET. Likewise, the most democratic countries also add positive impact on the BEET. From the medium level of democracy to the highest level of democracy, the BEET may decline due to the greater stringency of environment regulations. Our results, however, may have picked up the upward slope of the relationship between the democracy level and the BEET.

6. Discussions and conclusions

For the period between 1988 and 2008, we constructed the two world panel dataset for the pollution emission embedded in international trade. The first dataset (unadjusted BEET) allows us to investigate whether the composition of international trade for a country changed toward pollution intensive industries during the last two decades. We investigated whether the BEET is related with the income and democracy level of countries. We find little supporting evidence that these two explanatory variables affect the unadjusted BEET.

Then, with the second dataset (adjusted BEET), the effect of adopting improved technology of pollution abatement is also investigated along the composition effect. We find supporting evidence that a country with a higher income level is more likely to reduce pollution emission in export due to technique effect and to experience less of reduction in pollution emission in import. Thus, the induced change in the BEET by both industry composition changes and improvements in abatement technology is consistent with pollution haven hypothesis in which developing countries export more of dirty industries and import more of clean industries after trade liberalization.

The effect of the democracy level of countries on the BEET, contradicting to our prior expectation, show positive impact. We examined the estimated coefficients of dummies for each level of democracy and we find that the relationship between the democracy level and the BEET may be non-linear. The shape resembles the inverted-U shape found in Grossman and Krueger (1993).

Finally, we note that the analysis in this research needs to be interpreted with some cautions. First, the overall effect of international trade on production needs to consider both direct effect for domestic production for exports and indirect effect for production, induced by specialization due to trade opening, for domestic consumption.

We only investigated the direct effect. Second, applying the US pollution emission coefficient to other countries, especially to developing countries, produces bias in evaluating the composition shifts. However, bias needs not be large if the rankings of industries in terms of pollution emission are similar in countries across the world. We presume dirty industries are dirty in both developed and developing countries. In addition, for the adjusted BEET dataset, these assumptions are relaxed. Third, the study with the unadjusted BEET investigates the composition effect and (implicitly) scale effect by Grossman and Krueger (1993). For a more complete assessment, the remaining effect, i.e., technique effect, needs to be considered along the other two effects. This is done with the adjusted BEET dataset. Antwiler et al. (2001) conclude that the net effect of international trade improves environment and Levinson (2009) argues that the largest effect is technique effect. Our results indicate a similar implication in which the income level and democracy level affects only the adjusted BEET which incorporates both the composition effect and technique effect.

Appendix:

Income data and grouping by WDI

Country grouping by income level is provided in the World Development Indicators (WDI), the World Bank. The World Bank classifies countries into low, lower middle, upper middle, and high-income countries. We obtained these data for 1988, 1995, and 2009 from the issues in 1990, 1997, and 2010, respectively. The matching between the UN Comtrade and WDI requires careful procedures. The most updated UN Comtrade database keeps former country names, whereas the WDI delete those country names in the updated database. We chose the 1995 data for the WDI country classification because these data represent a fairly middle of the sample period. The 1988 WDI data misses 103 countries appearing in the later issues of the WDI, and the 2009 data may bias the initial income level of countries with relatively rapid growth. Out of 224 countries (including former countries), 206 countries appeared at least two times in the three sample years. The change in income classification occurred for 77 countries, of which more than one rank change are observed for only 5 countries. In the followings, countries are classified into four income groups.

High income (27)

Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Japan, Kuwait, Netherlands, New Zealand, Norway, Portugal, Qatar, Rep of Korea, Singapore, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States.

Upper-middle income (17)

Argentina, Bahrain, Brazil, Chile, Croatia, Czech Rep, Gabon, Greece, Hungary, Malaysia, Mauritius, Mexico, Oman, Saudi Arabia, Slovenia, South Africa, Uruguay.

Lower-middle income (46)

Algeria, Belarus, Bolivia, Botswana, Bulgaria, Colombia, Costa Rica, Djibouti, Dominican Rep, Ecuador, Egypt, El Salvador, Estonia, Fiji, Guatemala, Indonesia, Iran, Jamaica, Jordan, Kazakhstan, Latvia, Lebanon, Lesotho, Lithuania, Morocco, Namibia, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Rep of Moldova, Romania, Russian Federation, Serbia, Slovakia, Swaziland, Syria, TFYR of Macedonia, Thailand, Tunisia, Turkey, Turkmenistan, Ukraine, Venezuela.

Low income (47)

Albania, Armenia, Azerbaijan, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Rep, China, Comoros, Congo, Eritrea, Ethiopia, Georgia, Ghana, Guinea, Guinea Bissau, Guyana, Honduras, India, Kenya, Kyrgyzstan, Madagascar, Malawi, Mali, Mauritania, Mongolia, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone, Sri Lanka, Sudan, Togo, Uganda, United Rep of Tanzania, Viet Nam, Yemen, Zambia.

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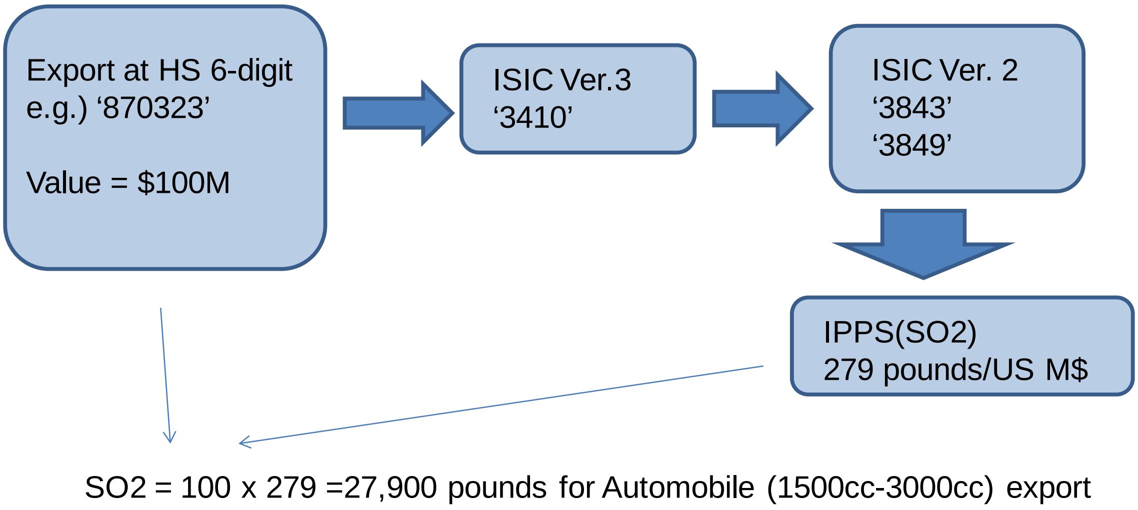
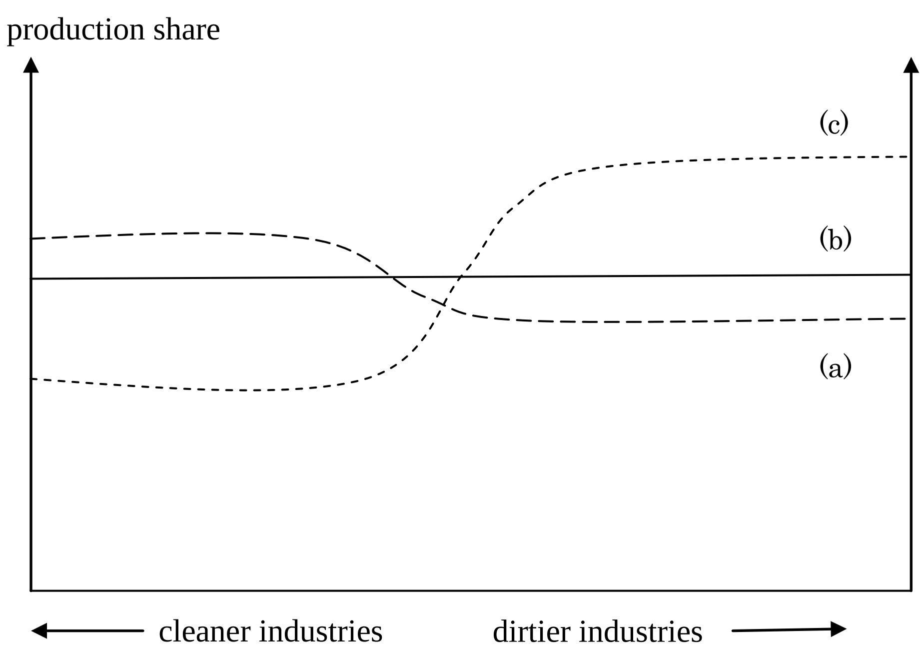
Figure 1. An example of calculating SO2 emission embodied in automobile export



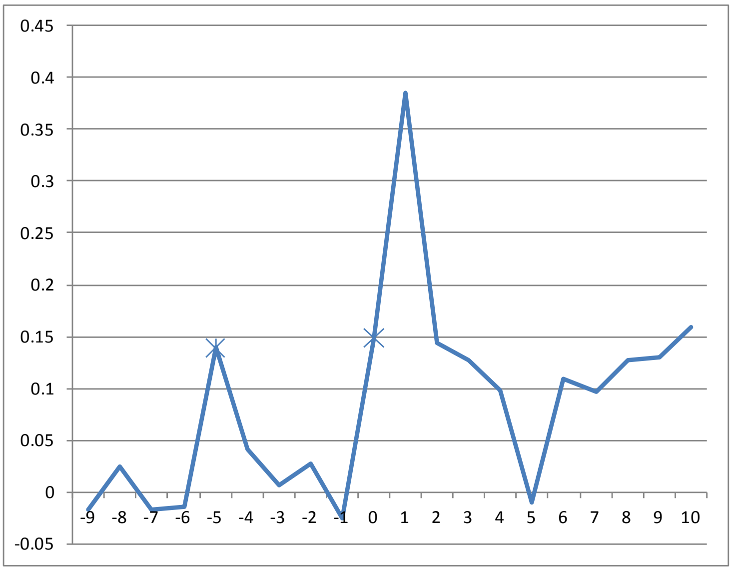
Notes: From HS 6-digit code to ISIC(ver.3) 4-digit code and from ISIC(ver.3) to ISIC(ver.2) , the older version which is used in calculating the IPPS pollution intensity, we use the correspondence tables provided by the UN Statistical Division. Finally, we use the corresponding pollution emission intensity coefficient from the IPPS dataset to calculate the estimated pounds of a specific pollutant in export of a particular product at HS 6-digit level.

Figure 2. Changes in production shares



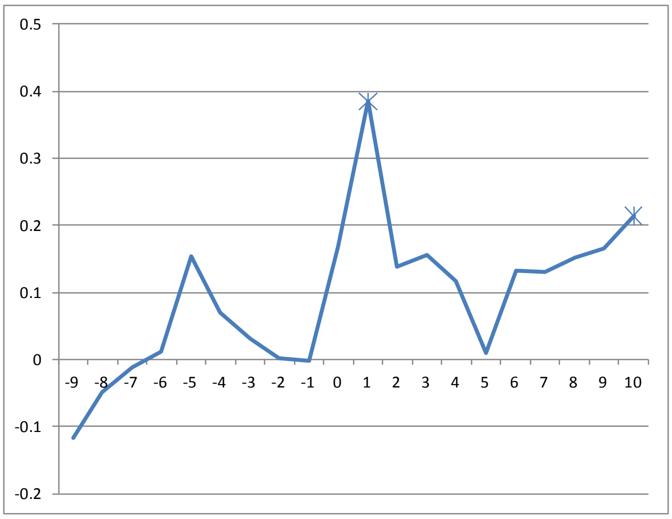
Notes: industries are ordered in terms of pollution emission coefficients; the cleanest industry on the leftmost and the dirtiest industry on the rightmost.

Figure 3a. Estimated coefficients of Polity dummies for the SO2 BEET



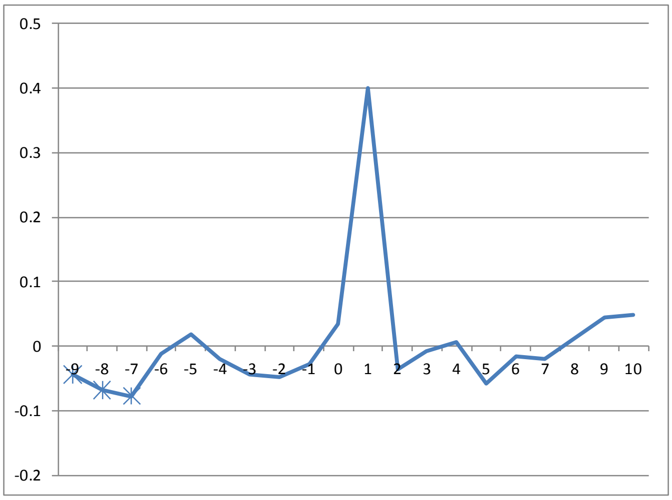
Notes: The Polity index ranges from -9 to 10 on the horizontal axis, the value of -10 is omitted in the estimation. An asterisk indicates that the estimated coefficient is statistically significant at ten percent level.

Figure 3b. Estimated coefficients of Polity dummies for the NO2 BEET



Note: See the notes in Figure 3a.

Figure 3c. Estimated coefficients of Polity dummies for the CO BEET



Notes: See the notes in Figure 3a.

Table 1. Unadjusted emission coefficient BEET with GDP per capita and Polity index (1988-2008, all countries)

Fixed effects	SO2	NO2	CO	SO2	NO2	CO
GDPPC	-0.000008	-0.000003	-0.000014**	0.000000	0.000004	-0.000007
	(0.000007)	(0.000005)	(0.000006)	(0.000010)	(0.000007)	(0.000007)
Polity	-0.003927	-0.003865*	-0.002504	-0.002980	-0.002557	-0.001515
	(0.003901)	(0.002154)	(0.002107)	(0.004569)	(0.002462)	(0.002291)
TBADJ	-1.05***	-0.85***	-0.69***	-0.81**	-0.67***	-0.50**
	(0.37)	(0.26)	(0.26)	(0.35)	(0.23)	(0.24)
Time dummies	no	no	no	yes	yes	yes
Adj. R^2	0.69	0.70	0.82	0.70	0.71	0.82
Random effects	SO2	NO2	CO	SO2	NO2	CO
GDPPC	0.000001	0.000002**	-0.000007***	0.000006***	0.000005***	-0.000001
	(0.000002)	(0.000001)	(0.000001)	(0.000002)	(0.000001)	(0.000001)
Polity	0.000482	-0.000845	0.000132	0.001784	-0.000032	0.001704
	(0.002284)	(0.001248)	(0.001656)	(0.002314)	(0.001255)	(0.001686)
TBADJ	-1.14***	-0.90***	-0.75***	-0.87***	-0.72***	-0.52***
	(0.12)	(0.07)	(0.08)	(0.13)	(0.07)	(0.09)
Time dummies	no	no	no	yes	yes	yes
Adj. R^2	0.15	0.24	0.00	0.19	0.28	0.10
Hausman	4.47	5.12	7.72*	1.63	1.57	4.66

Note: The sample includes all 132 countries with at leaset one observation; however, data points are omitted if any one of GDPPC, Polity, and TBADJ is missing. The number of observation is 1757. Observation data with polity index equal to -66, -77, or -88 are also excluded.

Table 2. Adjusted emission coefficient BEET with GDP per capita and Polity index (1988-2008, all countries)

Fixed effect	SO2	NO2	CO	SO2	NO2	CO
GDPPC	-0.000012*	-0.000007	-0.000056***	-0.000009	-0.000006	-0.000028
	(0.000006)	(0.000005)	(0.000019)	(0.000008)	(0.000007)	(0.000021)
Polity	0.004742	0.000419	0.005718	0.005480	0.000821	0.012964
	(0.004295)	(0.002833)	(0.009611)	(0.003898)	(0.002657)	(0.008985)
TBADJ	-0.59**	-0.45***	-1.74***	-0.52**	-0.41**	-1.06**
	(0.26)	(0.15)	(0.53)	(0.24)	(0.16)	(0.48)
Time dummies	no	no	no	yes	yes	yes
Adj. R^2	0.77	0.84	0.73	0.77	0.84	0.74
Random effects	**SO2**	**NO2**	**CO**	**SO2**	**NO2**	**CO**
GDPPC	-0.000007***	-0.000005***	-0.000035***	-0.000003**	-0.000002*	-0.000014***
	(0.000001)	(0.000001)	(0.000004)	(0.000002)	(0.000001)	(0.000004)
Polity	0.006369***	0.001548	0.010939**	0.007794***	0.002451*	0.017490***
	(0.001778)	(0.001415)	(0.005461)	(0.001830)	(0.001465)	(0.005537)
TBADJ	-0.64***	-0.48***	-1.92***	-0.53***	-0.41***	-1.16***
	(0.09)	(0.07)	(0.28)	(0.10)	(0.07)	(0.29)
Time dummies	no	no	no	yes	yes	yes
Adj. R^2	0.01	0.00	0.01	0.06	0.02	0.05
Hausman	0.89	0.93	2.61	11.46**	1.32	38.16***

Note: The sample includes all 132 countries with at leaset one observation; however, data points are omitted if any one of GDPPC, Polity, and TBADJ is missing. The number of observation is 1757. Observation data with polity index equal to -66, -77, or -88 are also excluded.

Table 3. Adjusted emission coefficient BEET with GDP per capita and Polity index (sub-sample years, all countries)

	sub-sample (1988-2004)			sub-sample (1988-2000)		
Fixed effect	SO2	NO2	CO	SO2	NO2	CO
GDPPC	-0.000017**	-0.000012	-0.000036	-0.000014*	-0.000011*	-0.000029
	(0.000007)	(0.000008)	(0.000025)	(0.000009)	(0.000007)	(0.000019)
Polity	0.002701	0.000711	0.012144	0.003620	-0.000374	0.020644**
	(0.003741)	(0.002388)	(0.008446)	(0.005516)	(0.003186)	(0.009863)
TBADJ	-1.69***	-1.29***	-2.98***	-1.60***	-1.62**	-2.80***
	(0.42)	(0.30)	(0.77)	(0.44)	(0.63)	(0.90)
Time dummies	yes	yes	yes	yes	yes	yes
Adj. R^2	0.81	0.89	0.79	0.86	0.94	0.88
Random effects	SO2	NO2	CO	SO2	NO2	CO
GDPPC	-0.000005**	-0.000005***	-0.000014***	-0.000003	-0.000004**	-0.000013**
	(0.000002)	(0.000002)	(0.000005)	(0.000002)	(0.000002)	(0.000006)
Polity	0.006847***	0.003077*	0.015744***	0.007618***	0.002117	0.021197***
	(0.002109)	(0.001695)	(0.005998)	(0.002591)	(0.001951)	(0.006779)
TBADJ	-1.62***	-1.25***	-3.11***	-1.53***	-1.57***	-3.05***
	(0.17)	(0.13)	(0.48)	(0.24)	(0.17)	(0.61)
Time dummies	yes	yes	yes	yes	yes	yes
Adj. R^2	0.07	0.03	0.05	0.09	0.04	0.05
Hausman	6.13	70.19***	2.07	3.13	5.82	1.05
NOB	1295	1295	1295	823	823	823
Num. of countries	130	130	130	121	121	121

Note: The full-sample (1988-2008) includes 132 countries and the number of observation is 1757. Data points are omitted if any one of GDPPC, Polity, and TBADJ is missing. The number of observation is 1757. Observation data with polity index equal to -66, -77, or -88 are also excluded.

Table 4. Adjusted emission coefficient BEET with GDP per capita and Polity index (developing countries)

	full-sample (1988-2008)			sub-sample (1988-2004)		
Fixed effect	SO2	NO2	CO	SO2	NO2	CO
GDPPC	-0.000014**	0.000003	-0.000020	-0.000013	0.000003	-0.000014
	(0.000006)	(0.000004)	(0.000017)	(0.000011)	(0.000005)	(0.000020)
Polity	0.005193	0.000660	0.012745	0.002392	0.001093	0.010757
	(0.003839)	(0.002773)	(0.009046)	(0.003542)	(0.002303)	(0.008207)
TBADJ	-0.28	-0.27**	-0.96*	-1.76***	-1.24***	-3.81***
	(0.20)	(0.13)	(0.57)	(0.37)	(0.31)	(1.15)
Time dummies	yes	yes	yes	yes	yes	yes
Adj. R^2	0.74	0.71	0.72	0.77	0.77	0.77
Random effects	SO2	NO2	CO	SO2	NO2	CO
GDPPC	-0.000004*	0.000001	-0.000012**	-0.000001	0.000000	-0.000008
	(0.000002)	(0.000001)	(0.000006)	(0.000003)	(0.000002)	(0.000007)
Polity	0.006213***	0.001524	0.013298**	0.004964**	0.002241	0.010857*
	(0.001864)	(0.001225)	(0.005732)	(0.002131)	(0.001383)	(0.006041)
TBADJ	-0.32***	-0.31***	-1.16***	-1.76***	-1.20***	-4.04***
	(0.11)	(0.07)	(0.33)	(0.20)	(0.13)	(0.58)
Time dummies	yes	yes	yes	yes	yes	yes
Adj. R^2	0.01	0.02	0.05	0.02	0.04	0.04
Hausman	5.58	0.50	0.47	2.14	0.80	0.24
NOB	1339	1339	1339	971	971	971
Num. of countries	108	108	108	106	106	106

Note: The full-sample (1988-2008) includes 132 countries and the number of observation is 1757. Data points are omitted if any one of GDPPC, Polity, and TBADJ is missing. The number of observation is 1757. Observation data with polity index equal to -66, -77, or -88 are also excluded.