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# Trade and the Environment in East Asia: Examining the Linkages with Japan and the USA [*]

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This paper investigates how the environmental pollution in East Asian countries can be affected by trade of ‘dirty’ goods with Japan and the USA. By controlling for trade openness, the share of manufacturing in GDP, and the trade of pollution-intensive products with Japan and the USA, $CO_2$ emissions are estimated for ten East Asian countries between 1988 and 2000. Our results indicate that increasing exports in ‘dirty’ industries to Japan and domestic industrialization in East Asia tend to raise $CO_2$ emissions in East Asian countries, while ‘dirty’ imports from Japan and the USA do not affect $CO_2$ emissions in the area.

JEL Classification: F18, O13, L60, Q56
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## 1. INTRODUCTION

The purpose of this paper is to investigate how the environmental pollution in East Asian countries can be affected by trade of 'dirty' goods with Japan and the USA. The linkage between trade and the environment arose from Grossman and Krueger's (1991) seminal study on the environmental Kuznets curve (EKC). The EKC is an inverted *U*-shaped relationship between pollution and per capita income. This hypothesis has attracted the attention of many researchers and policymakers since the early 1990s, despite considerable criticism of early studies on the EKC on both theoretical and empirical grounds.[1]

In this paper, we estimated $CO_2$ emissions of ten East Asian countries between 1988 and 2000 by using trade intensity, the share of manufacturing in GDP, and 'dirty' trade with Japan and the USA as independent variables. The reasons why we focused on $CO_2$ emissions among many other pollutants are as follows. First, it is widely recognized that reducing $CO_2$ emissions is the key to solve global warming problem. Second, $CO_2$ emissions are highly relevant to the use of energy, which is inevitable for the economic growth.

There has been a long debate on whether the EKC holds in the case of $CO_2$ emissions. As discussed in Brock and Taylor (2004) and Dijgraaf and Vollebergh (2005), recent empirical results showed the failure of the homogeneity assumption that the same shaped EKC applied to any countries of regions, and indicated the need to include cross-country heterogeneity for successful estimation of the EKC. For example, based on the parametric panel data estimation with country and time effects, Holtz-Eakin and Selden (1995) found the EKC for $CO_2$ emissions with a turning point out of sample. Schmalensee *et al*. (1998) also showed that the EKC held for $CO_2$ emissions with a within-sample turning point, by using a flexible method for income effects, along with country and time effects. In addition, Vollebergh *et al.* (2005) provided evidence that non-parametric panel data estimation could

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[1] For surveys on the EKC, see S. Dasgupta *et al*. (2002), Cole (2003), Yandle *et al*. (2004), and D. I. Stern (2004).

not deny the existence of the EKC for $CO_2$ emissions.

Among many variables to control for cross-country heterogeneity, several economists argue that the EKC should take change of trade patterns into account. They claim that developing countries have a comparative advantage in pollution-intensive industries, possibly due to their less strict environmental regulations than advanced countries.2) Thus, 'dirty' industries are likely to shift their production base from developed countries to developing countries. This so-called "pollution-haven hypothesis" may lead to a reduction of pollution in developed countries, but an increase of pollution in developing countries. Therefore, the EKC may reflect a transfer of pollution from developed countries to developing countries, but may not indicate a net reduction in pollution in the entire world.

The effect of trade composition on pollution has been the focus of a number of recent studies (Suri and Chapman, 1988; Antweiler *et al.*, 2001; Cole and Elliot, 2003; Cole, 2004). In particular, Cole (2004) showed the effect of 'dirty' trade on the EKC of OECD countries, by estimating ten air and water pollutants, including as independent variables trade of pollution-intensive industries between OECD and non-OECD countries. Contrary to Cole (2004), this paper examined how the trade of pollution-intensive industries affected the EKCs of developing countries. Analyses on developing countries are particularly important, since they are not compelled to reduce $CO_2$ emissions under the Kyoto Protocol and are likely to be the key countries to solve the global warming problem. For example, according to the Carbon Dioxide Information Analysis Center (CDIAC), total $CO_2$ emissions of China ranked second in 2000, and those of Korea ranked tenth.

The results of our study indicated that increasing 'dirty' industry exports to Japan and domestic industrialization in East Asia tended to raise $CO_2$ emissions in East Asian countries, while 'dirty' imports from Japan and the USA did not affect $CO_2$ emissions in the area. Finally, the estimated peak

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2) Antweiler *et al.* (2001) and Copeland and Taylor (2004) argue that there is another competing theory to determine comparative advantage. So-called factor endowments hypothesis assumes that capital-abundant countries (advanced countries) export the capital-intensive (dirty) goods to developing countries.

turning points in the models that included ‘dirty’ goods trade with Japan were higher than those in models that did not.

The rest of the paper is organized as follows: section 2 reviews the linkages between trade and the environment and examines trends in foreign direct investments and in trade of pollution-intensive products between East Asian countries and Japan. Section 3 explains the estimation method used and the data, and section 4 discusses the results. Concluding remarks are provided in section 5.

## 2. TRADE OF DIRTY INDUSTRIES AND DEVELOPMENT IN EAST ASIA

In the area of trade and the environment, many researchers have investigated the potential linkages between trade liberalization and pollution.[3] A seminal paper of Grossman and Krueger (1991) presents a systematic analysis of the connections between trade and the environment by classifying the effect of trade on the environment into three categories. The first category is the scale effect, which refers to the situation in which growing market access increases economic growth and the resulting pollution. The second category is the technique effect, which refers to the likely improvement of production techniques caused by trade liberalization, and which reduces pollution. The third category is the composition effect, which refers to the change in composition of an economy after trade liberalization, as countries increasingly specialize in the industries in which they enjoy a comparative advantage.

The last composition effect is the most connected to our analysis of the EKC. In order to enhance economic development, most of the East Asian countries have attempted to promote heavy industries, which usually are pollution-intensive, by accepting foreign direct investment of developed

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[3] For example, Copeland and Taylor (2003) survey both recent theoretical and empirical studies of trade and the environment.

countries, including Japan, which has been the major investor in the region. Figure 1 shows the trend of Japan's foreign direct investment in East Asian countries. After the 1970s, Asian NIEs (Korea, Taiwan, Hong Kong and Singapore) became the first major recipient countries of Japanese investment. However, as production costs, which included wages, land prices, and exchange rates, rose in these countries, ASEAN 4 countries (Malaysia, Indonesia, the Philippines and Thailand) emerged as major recipients in the 1980s. Since the 1990s, China and Vietnam, former socialist countries, have attracted investors.

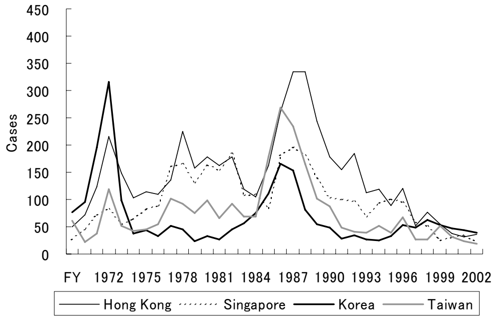
Figure 2 presents the value of foreign direct investments of Japanese pollution-intensive industries in East Asian countries. Pollution-intensive industries here refer to the metal and chemical industries. Investments in Asian NIEs have been relatively small throughout the 1990s, except for those made in Korea in the fiscal years 1999 and 2000. In contrast, ASEAN countries, especially Indonesia and Thailand, received a large amount of investment in the 1990s. China also enjoyed a fair amount of investment after the latter half of the 1990s.

Then we calculate the specialization index of pollution-intensive industries between East Asian countries and Japan (see figure 3). Pollution-intensive industries here include iron and steel, chemicals and chemical products, and non-metallic mineral products, which are the main sources of $CO_2$ emissions. The specialization index of trade of industry $k$ between Japan and country $i$ in year $t$ is expressed in equation 1, where $X$ and $M$ refer to the value of exports and the value of imports, respectively. If the index has a positive value in a certain industry, this means that Japan is a net exporter of that industry, while if it has a negative value, Japan is a net importer.

$$\text{Specialization index} = \frac{X_{kt}^{i} - M_{kt}^{i}}{X_{kt}^{i} + M_{kt}^{i}}. \tag{1}$$

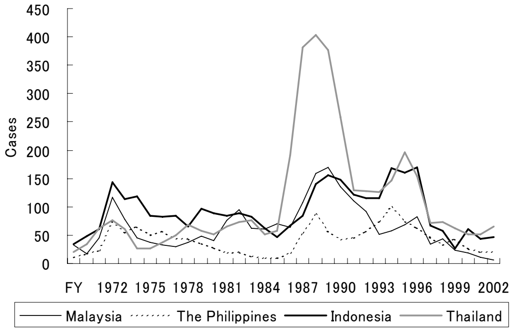
**Figure 1 Japan’s FDI to East Asia**

Japan’s FDI to Asian NIEs



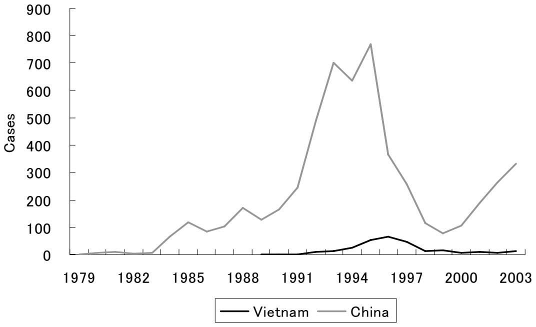
Source: Ministry of Finance.

Japan’s FDI to ASEAN



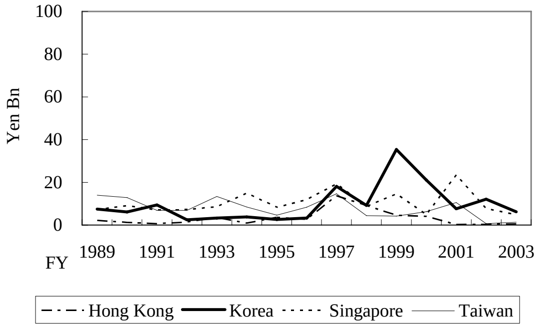
Source: Ministry of Finance.

Japan’s FDI to China & Vietnam

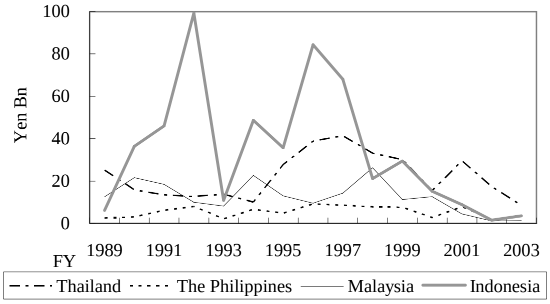


Source: Ministry of Finance.

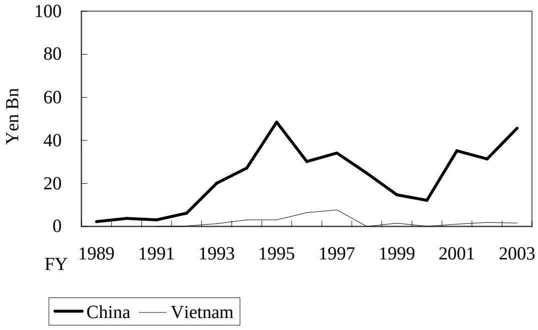
**Figure 2 Japan's FDI to East Asia (Chemical and Metal)**


Japan's FDI to NIEs
(Chemical and Metal)

Source: Ministry of Finance.


Japan's FDI to ASEAN4
(Chemical and Metal)

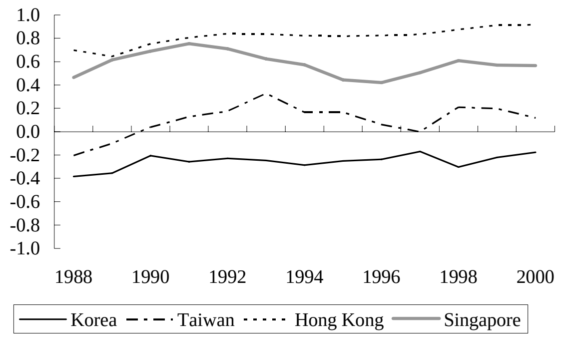
Source: Ministry of Finance.


Japan's FDI to China and Vietnam
(Chemical and Metal)

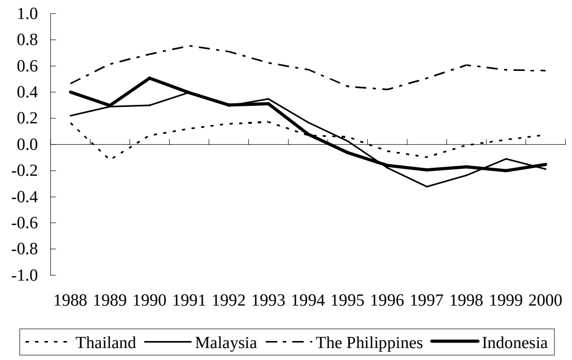
Source: Ministry of Finance.

**Figure 3 Specialization Patterns for Pollution-Intensive Industries in East Asia**

Specialization Index (Asian NIEs)



Specialization Index (ASEAN4)



Specialization Index (China and Vietnam)

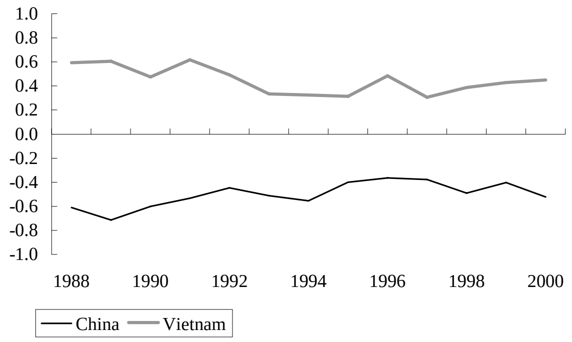
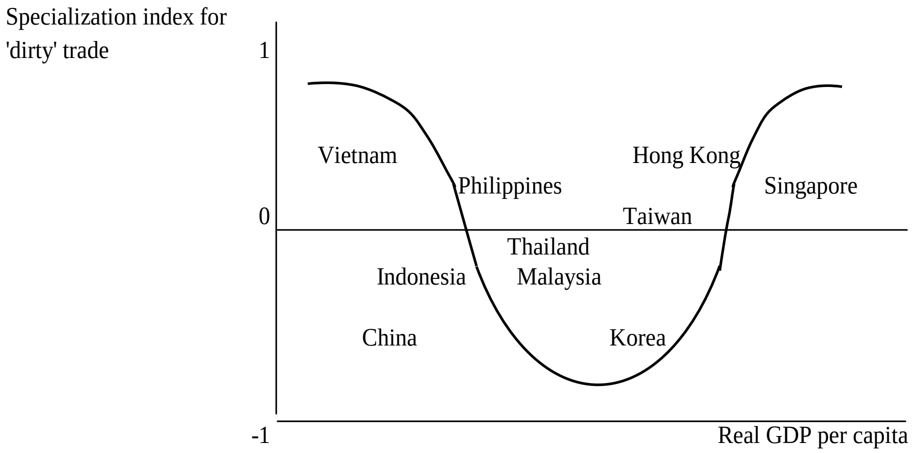


**Figure 4 Specialization Patterns and Development in East Asia**



From figure 3 we can interpret the specialization index of pollution-intensive industries between 1988 and 2000 as in figure 4. For Vietnam, which has the lowest per capita GDP in the region, and the Philippines, Japan has been a net exporter of dirty goods. In cases of ASEAN countries including Indonesia, Malaysia, and Thailand, Japan was a net exporter of dirty goods until the mid-1990s, while it turned out to be a net importer after that. This is because these countries proceeded in industrialization and then became exporters of dirty goods to Japan. In the next developmental stage, Japan has been a net importer of Korean dirty goods over the sample period. In the final stage, for other Asian NIEs, including Singapore and Hong Kong, Japan has again been a net exporter of dirty goods, since these countries focused more on service- and information-intensive industries than heavy industries. In the case of China, Japan has been a net importer of dirty goods, as has Korea, over the sample period. This seems to be an exceptional case, considering the fact that China’s per capita GDP was close to Indonesia’s. However, since in cities like Beijing and Shanghai, per capita GDP has been three or four times of the national average, China’s level of industrialization seemed to catch up with Korea’s.

As discussed in this section, Japanese data on foreign direct investments and trade indicate that the economic development in East Asia has been associated with trade patterns between Japan and East Asian countries. In the following section, we will analyze the effect of the change in trade structure on pollution by including dirty trade between East Asian countries and Japan in the estimation of the EKC.

## 3. ESTIMATION METHOD

The EKCs of $CO_2$ emissions were estimated for ten East Asian countries (China, Hong Kong, Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan, Thailand and Vietnam) between 1988 and 2000. Specifically, we estimated the following time-demeaned equation, using unbalanced panel data. Since heteroscedasticity was present, the model used White's heteroscedasticity-adjusted standard errors.[4]

$$\begin{aligned}\tilde{E}_{it} = K_t + \beta_1\tilde{Y}_{it} + \beta_2\tilde{Y}^2_{it} + \beta_3\tilde{Y}^3_{it} + \delta\tilde{I}_{it} + \gamma\tilde{M}_{it} + \eta_1\tilde{J}\tilde{D}\tilde{X}_{it} \\ + \eta_2\tilde{J}\tilde{D}\tilde{M}_{it} + \lambda_1\tilde{U}\tilde{S}\tilde{D}\tilde{X}_{it} + \lambda_2\tilde{U}\tilde{S}\tilde{D}\tilde{M}_{it} + \varepsilon_{it}.\end{aligned}$$

where, $\tilde{E}_{it} = \ln E_{it} - \sum_{t=1}^{T}\ln E_{it}/T$, $\tilde{Y}_{it} = \ln Y_{it} - \sum_{t=1}^{T}\ln Y_{it}/T$,

$\tilde{Y}^2_{it} = \left(\ln Y_{it}\right)^2 - \sum_{t=1}^{T}\left(\ln Y_{it}\right)^2/T$, $\tilde{Y}^3_{it} = \left(\ln Y_{it}\right)^3 - \sum_{t=1}^{T}\left(\ln Y_{it}\right)^3/T$,

$\tilde{I}_{it} = \ln I_{it} - \sum_{t=1}^{T}\ln I_{it}/T$, $\tilde{M}_{it} = \ln M_{it} - \sum_{t=1}^{T}\ln M_{it}/T$,

$\tilde{J}\tilde{D}\tilde{X}_{it} = \ln JDX_{it} - \sum_{t=1}^{T}\ln JDX_{it}/T$,

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[4] We test the non-stationarity of our data by employing the procedure of Levin, Lin, and Chu (2002). As shown in table A1, for all variables a null hypothesis of integration of order 0 can be rejected. Next, we conduct autocorrelation test by examining the data of the ninth period in model 3, in which real GDP per capita is based on market exchange rates. The coefficient of the residual term is 0.457 with 0.342 as a standard error. Thus, we do not find autocorrelation. Finally, the strict exogeneity for all the independent variables is supported, as presented in table A2.

$$\tilde{J}\tilde{D}\tilde{M}_{it} = \ln JDM_{it} - \textstyle\sum_{t=1}^{T} \ln JDM_{it} \big/ T ,$$

$$\tilde{U}\tilde{S}\tilde{D}\tilde{X}_{it} = \ln USDX_{it} - \textstyle\sum_{t=1}^{T} \ln USDX_{it} \big/ T , \text{ and}$$

$$\tilde{U}\tilde{S}\tilde{D}\tilde{M}_{it} = \ln USDM_{it} - \textstyle\sum_{t=1}^{T} \ln USDM_{it} \big/ T .$$

$E$ is per capita $CO_2$ emission, $K$ refers to year-specific effects, $Y$ is per capita real GDP based on either a market exchange rate or a purchasing power parity (PPP) exchange rate. By including a cubic income term, our estimation allowed for the possibility of pollution beginning to rise again, as in an *N*-shaped curve, at the high-income level. I represents trade intensity, and $M$ is the share of manufacturing in GDP. $JDX$ refers to ‘dirty’ exports share of the total exports from Japan to the East Asian country in question, while $JDM$ is ‘dirty’ imports share of the total imports of Japan from an East Asian country. Likewise, $USDX$ refers to ‘dirty’ exports share of the total exports from the USA to the East Asian country in question, while $USDM$ is ‘dirty’ imports share of the total imports of the USA from an East Asian country. Subscripts $i$ and $t$ represent country and year, respectively.

The trade intensity $I$ is the ratio of the sum of exports and imports (excluding re-exports for Hong Kong and Singapore) to GDP. $K$ is included to represent effects like technological progress, which change over time but are common to all countries. $JDX$ and $JDM$ are included to analyze the effects of dirty trade between Japan and East Asian countries. For comparison, $USDX$ and $USDM$ are also included to examine the effects of dirty trade between the USA and East Asian countries. Dirty goods here include iron and steel, chemicals and chemical products, non-metallic mineral products, and paper-pulp, which are the top four industries in terms of $CO_2$ emission.

Sources of data and their descriptive statistics are presented in table 1 and table 2, respectively. Figure 5 and figure 6 show the relationship between $E$ and $Y$ . Figure 5 is drawn by using per capita real GDP based on market exchange rates, while figure 6 is based on PPP exchange rates. In both

**Table 1 Data Information**

| Variables | Source |
|---|---|
| $CO_2$ emission | Marland, G., T. A. Boden, and R. J. Andres (2003) |
| Real GDP per capita | IMF (2004) |
| Trade as % of GDP | IMF (2004), and trade statistics of each country |
| Manufacturing as % for GDP | World Bank (2003), National Statistics of Taiwan (2004), and Asian Development Bank (2004) |
| Share of Japanese 'dirty' imports and exports in total imports and exports | Calculated using trade statistics from Ministry of Finance Japan (2004). Chemicals / chemical products, iron and steel, and non-metallic mineral products are classed as 'dirty' sectors. |
| Share of US 'dirty' imports and exports in total imports and exports | Calculated using ITCS International Trade Data, OECD. Chemicals and related products (5), iron and steel (67), non-metallic mineral manufactures (66), and paper, paperboard, articles of paper, paper-pulp/board (64) are classed as 'dirty' sectors. |

**Table 2 Descriptive Statistics**

| | Real GDP per capita Constant price | | $CO_2$ emission (kg/person) | I (%) | M (%) | JDX (%) | JDM (%) | USDX (%) | USDM (%) |
|---|---|---|---|---|---|---|---|---|---|
| | (US$) | PPP (2000$) | | | | | | | |
| Mean | 6,906.6 | 8,493.1 | 1,268.8 | 94.4 | 24.8 | 3.8 | 3.6 | 14.5 | 3.4 |
| Median | 2,060.4 | 4,118.0 | 870.0 | 72.7 | 26.1 | 2.6 | 2.2 | 14.1 | 3.4 |
| Max. | 25,260.4 | 25,492.7 | 5,120.0 | 268.9 | 37.1 | 18.2 | 17.8 | 53.9 | 9.3 |
| Min. | 183.9 | 937.7 | 70.0 | 16.3 | 5.8 | 0.4 | 0.1 | 0.0 | 0.5 |
| Std.dev. | 8,046.1 | 7,680.2 | 1,163.8 | 61.5 | 7.1 | 3.2 | 3.6 | 6.8 | 1.7 |
| Skewness | 0.9 | 0.6 | 1.3 | 1.2 | –0.8 | 1.6 | 1.6 | 1.6 | 0.5 |
| Kurtosis | –0.5 | –1.2 | 1.0 | 0.4 | 0.3 | 2.6 | 2.4 | 8.3 | 0.1 |
| Obs. | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 124 |

graphs, per capita $CO_2$ emissions stop rising in high-income countries. These graphs indicate the possibility of the existence of the EKC in East Asian countries.

**Figure 5 Relationship between Real GDP per Capita and $CO_2$ Emission Based on Market Exchange Rates**

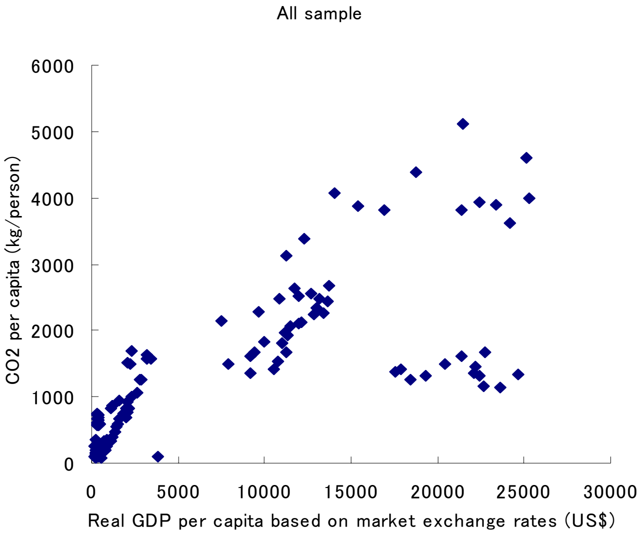
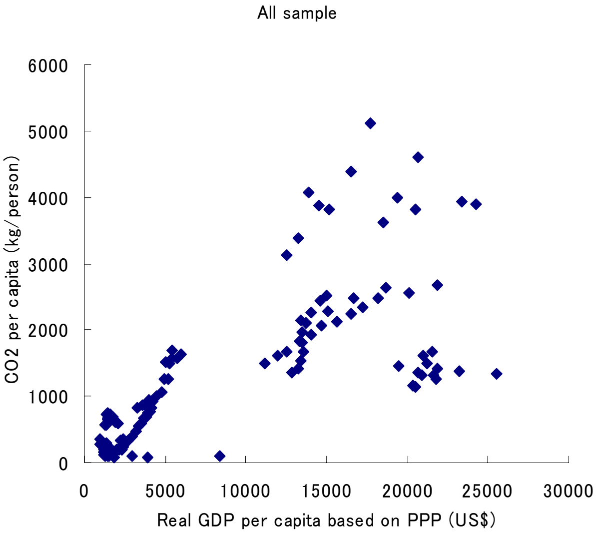


**Figure 6 Relationship between Real GDP per Capita and $CO_2$ Emission Based on PPP**



We next considered the relationship of pollution to ‘dirty’ trade. An increase in ‘dirty’ imports from East Asian countries indicates growing production of ‘dirty’ goods in East Asian countries. In contrast, an increase in ‘dirty’ exports to East Asian countries suggests that exports of ‘dirty’ goods are substituted for production of these goods in the East Asian countries. Thus, we would expect to estimate a positive relationship between $JDM/USDM$ and $E$, but a negative relationship between $JDX/USDX$ and $E$.

## 4. RESULTS

Table 3 and table 4 present estimation results. Real GDP per capita is based on market exchange rates in table 3, while it is based on PPP exchange rates in table 4. Model 1 picks up the relationship among pollution ($E$), income ($Y$), trade intensity ($I$), and the share of manufacturing in GDP ($M$), whereas model 2 adds ‘dirty’ trade ($JDX$, $JDM$, $USDX$, and $USDM$) as independent variables. Considering the possibility of multicollinearity between ‘dirty’ trade with Japan ($JDX$ and $JDM$) and that with the USA ($USDX$ and $USDM$), we separately estimate the effect of ‘dirty’ trade with these countries in model 3 and model 4.

For all regressions, the income-cubed term is statistically significant, providing two turning points in the relationship between income and pollution. In other words, $CO_2$ emissions are estimated to fall at very low-income levels before exhibiting an inverted *U*-shaped curve for most of the income range within the sample, drawing an inverted *N*-shaped curve on the whole, as shown in figure 7.

The estimated income level at which the emission peaks (peak turning point) and the estimated income level at which the emission bottoms out (bottom turning point) are within the income range of the sample for all types of estimation used. In our sample, only Singapore and Hong Kong have already peaked out and are estimated to be in the downward portion of the

## Table 3 Estimation Results for $CO_2$ Emissions Based on Market Exchange Rates

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| $\tilde{Y}$ | –4.406<br>(1.60)$^{***}$ | –7.934<br>(2.25)$^{***}$ | –3.752<br>(1.61)$^{**}$ | –8.248<br>(2.20)$^{***}$ |
| $\tilde{Y}^2$ | 0.634<br>(0.21)$^{***}$ | 1.118<br>(0.30)$^{***}$ | 0.548<br>(0.22)$^{**}$ | 1.159<br>(0.30)$^{***}$ |
| $\tilde{Y}^3$ | –0.028<br>(0.01)$^{***}$ | –0.049<br>(0.30)$^{***}$ | –0.024<br>(0.01)$^{**}$ | –0.051<br>(0.01)$^{***}$ |
| $\tilde{I}$ | 0.345<br>(0.11)$^{***}$ | 0.226<br>(0.14) | 0.368<br>(0.11)$^{***}$ | 0.237<br>(0.14)$^{*}$ |
| $\tilde{M}$ | 0.282<br>(0.07)$^{***}$ | 0.244<br>(0.08)$^{***}$ | 0.208<br>(0.08)$^{***}$ | 0.260<br>(0.07)$^{***}$ |
| $\tilde{J}\tilde{D}\tilde{X}$ | | –0.041<br>(0.05) | –0.017<br>(0.04) | |
| $\tilde{J}\tilde{D}\tilde{M}$ | | 0.025<br>(0.04) | 0.070<br>(0.03)$^{**}$ | |
| $\tilde{U}\tilde{S}\tilde{D}\tilde{X}$ | | 0.121<br>(0.08) | | 0.124<br>(0.08) |
| $\tilde{U}\tilde{S}\tilde{D}\tilde{M}$ | | –0.056<br>(0.06) | | –0.053<br>(0.05) |
| Peak turning point | 15,308.2 | 13,675.3 | 19,329.6 | 14,311.2 |
| Bottom turning point | 228.2 | 285.9 | 188.2 | 287.4 |
| Adjusted $R^2$ | 0.989 | 0.989 | 0.989 | 0.989 |
| S.E. | 0.114 | 0.107 | 0.113 | 0.107 |
| Hausman test for $H_0$: RE vs. FE | Chisq(5)= 24.6$^{***}$ | Chisq(9)= 29.4$^{***}$ | Chisq(7)= 32.1$^{***}$ | Chisq(7)= 27.8$^{***}$ |
| $N$ | 130 | 124 | 130 | 124 |

Notes: 1) Standard errors are in parenthesis.

2) ***, ** and * denote statistical significance at 99%, 95% and 90% confidence levels, respectively.

3) The number of observation of model 2 and 4 is smaller than that of model 1 and 3, due to the lack of data on trade between Vietnam and the USA.

### Table 4 Estimation Results for $CO_2$ Emissions Based on PPP

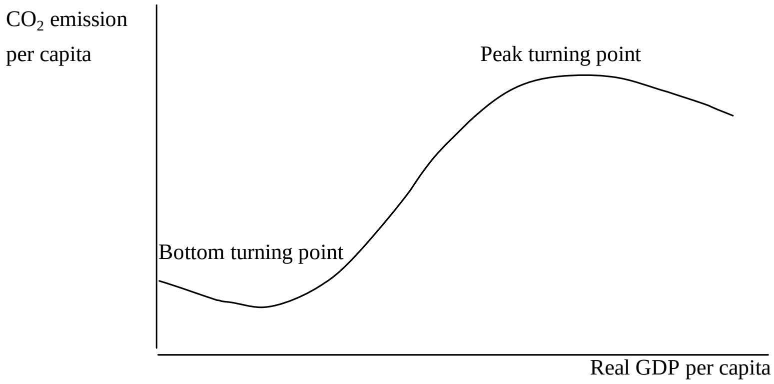
| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| $\tilde{Y}_{PPP}$ | –20.386<br>(6.18)$^{***}$ | –55.356<br>(10.27)$^{***}$ | –17.698<br>(6.35)$^{***}$ | –57.956<br>(9.93)$^{***}$ |
| $\tilde{Y}^2_{PPP}$ | 2.435<br>(0.73)$^{***}$ | 6.625<br>(1.22)$^{***}$ | 2.117<br>(0.75)$^{***}$ | 6.926<br>(1.18)$^{***}$ |
| $\tilde{Y}^3_{PPP}$ | –0.095<br>(0.03)$^{***}$ | –0.259<br>(0.05)$^{***}$ | –0.082<br>(0.03)$^{***}$ | –0.270<br>(0.05)$^{***}$ |
| $\tilde{I}$ | 0.171<br>(0.10)$^{*}$ | 0.057<br>(0.12) | 0.212<br>(0.10)$^{**}$ | 0.040<br>(0.12) |
| $\tilde{M}$ | 0.310<br>(0.07)$^{***}$ | 0.254<br>(0.09)$^{***}$ | 0.221<br>(0.10)$^{**}$ | 0.262<br>(0.07)$^{***}$ |
| $\tilde{J}\tilde{D}\tilde{X}$ | | –0.042<br>(0.04) | –0.034<br>(0.05) | |
| $\tilde{J}\tilde{D}\tilde{M}$ | | 0.021<br>(0.04) | 0.075<br>(0.04)$^{*}$ | |
| $\tilde{U}\tilde{S}\tilde{D}\tilde{X}$ | | 0.022<br>(0.08) | | 0.023<br>(0.08) |
| $\tilde{U}\tilde{S}\tilde{D}\tilde{M}$ | | –0.079<br>(0.05) | | –0.085<br>(0.05)$^{*}$ |
| Peak turning point<br>Bottom turning point | 16,553.6<br>1,566.3 | 16,974.6<br>1,505.4 | 19,586.1<br>1,396.3 | 17,107.4<br>1,526.9 |
| Adjusted $R^2$ | 0.988 | 0.989 | 0.988 | 0.990 |
| S.E. | 0.122 | 0.103 | 0.121 | 0.103 |
| Hausman test for $H_0$: RE vs. FE | Chisq(5)= 29.0$^{***}$ | Chisq(9)= 24.1$^{***}$ | Chisq(7)= 28.7$^{***}$ | Chisq(7)= 24.6$^{***}$ |
| $N$ | 130 | 124 | 130 | 124 |

Notes: 1) Standard errors are in parenthesis.

2) ***, ** and * denote statistical significance at 99%, 95% and 90% confidence levels, respectively.

3) The number of observation of model 2 and 4 is smaller than that of model 1 and 3, due to the lack of data on trade between Vietnam and the USA.

**Figure 7 Environmental Kuznets Curve**



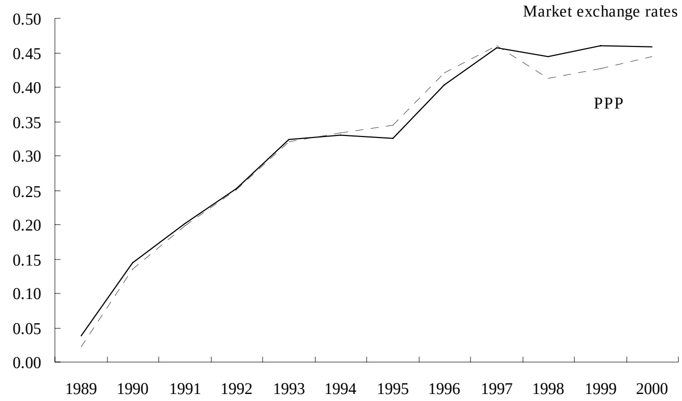
EKC for $CO_2$ emissions. We also find that higher turning points are obtained for regressions using PPP exchange rates relative to regressions using market exchange rates.

The share of manufacturing in GDP (*M*) has a significantly positive relationship with $CO_2$ emissions (*E*) for all regressions. That is, domestic industrialization is an important factor in the rise of $CO_2$ emissions. By contrast, the coefficients of *USDX* and *USDM* are not statistically significant for three of the four regressions. This indicates that 'dirty' trade with the USA (*USDX* and *USDM*) does not seem to affect $CO_2$ emissions.

With regard to 'dirty' trade between Japan and East Asian countries, model 3 shows that 'dirty' imports share of total imports (*JDM*) has a significantly positive relationship with $CO_2$ emissions (*E*). That is, an increase in exports of 'dirty' goods to Japan raises the production of dirty goods and $CO_2$ emissions in East Asian countries. In contrast, the coefficients of 'dirty' exports share of total exports (*JDX*) are not statistically significant. This result indicates that imports of dirty goods from Japan do not affect $CO_2$ emissions in East Asian countries.

If 'dirty' trade with Japan contributes to the inverted *U* relationship, estimated turning points from simpler models, which do not include *JDX* and *JDM* (models 1 and 4), are expected to differ from those that include

**Figure 8 Coefficients of Year Dummies**



them (model 3). The estimated peak turning point in model 3 is higher than those in model 1 and model 4. This is consistent with Cole (2004) and suggests that the EKC models that exclude ‘dirty’ trade variables may underestimate the turning point compared to models that include it.

Our results also provide controversial evidence of a positive relationship between trade intensity and $CO_2$ emissions. That is, trade liberalization tends to increase $CO_2$ emission in East Asian countries. This indicates that trade liberalization facilitates international reallocation of industries according to comparative advantages, which are determined by environmental regulation as well as factor endowments. In an extreme case, trade openness can be said to result in a so-called “race to the bottom,” as East Asian countries, which face intense international competition, may ease their environmental regulation to attract foreign funds.

Figure 8 shows that estimated coefficients of year dummies in model 3 increase over time. This finding contradicts the results of Cole and Elliott (2003) and Taguchi (2004), in which the coefficients of time trends are negatively related to pollutants, possibly because of the improvement of technology. Our result suggests that the EKC tends to become higher over time in East Asian countries during the sample period, since most of the countries still proceed in industrialization.

**Table 5 Estimation Results for $CO_2$ Emissions**

| | Model 3 |
|---|---|
| $\ln Y$ | –3.752 (1.61) $^{**}$ |
| $(\ln Y)^2$ | 0.548 (0.22) $^{**}$ |
| $(lnY)^3$ | –0.024 (0.01) $^{**}$ |
| $\ln T$ | 0.368 (0.11) $^{***}$ |
| $\ln M$ | 0.208 (0.08) $^{***}$ |
| $\ln JDX$ | –0.017 (0.04) |
| $\ln JDM$ | 0.070 (0.03) $^{**}$ |
| Peak turning point<br>Bottom turning point | 19,329.6<br>188.2 |
| Adjusted $R^2$ | 0.989 |
| S.E. | 0.113 |
| Hausman test for $H_0$: RE vs. FE | Chisq(7)=32.1$^{***}$ |
| $N$ | 130 |

Notes: 1) Standard errors are in parenthesis.

2) *** and ** denote statistical significance at 99% and 95% confidence levels, respectively.

3) Coefficients of country-specific effects are as follows. China: 0.498, Hong Kong: –0.086, Indonesia: –0.390, Korea: 0.424, Malaysia: 0.128, The Philippines: –0.518, Singapore: 0.796, Taiwan: 0.382, Thailand: –0.050, Vietnam: –1.183.

Finally, in order to show country-specific effects explicitly, we estimate model 3, in which real GDP per capita is based on market exchange rates, by the following OLS model including both country- ($F$) and year-specific effects.

$$\ln E_{it} = K_t + F_i + \beta_1 \ln Y_{it} + \beta_2 (\ln Y_{it})^2 + \beta_3 (\ln Y_{it})^3 + \delta \ln I_{it} + \gamma \ln M_{it}$$
$$+ \eta_1 \ln JDX_{it} + \eta_2 \ln JDM_{it} + \lambda_1 \ln USDX_{it} + \lambda_2 \ln USDM_{it} + \varepsilon_{it}.$$

The result of the estimation is presented in table 5. We can confirm that coefficients of other variables, adjusted R-squared and standard errors are exactly the same as those of model 3 in table 3.

## 5. CONCLUDING REMARKS

This paper investigated how the EKC inverted-U relationship in East Asian countries can be affected by trade of ‘dirty’ goods with Japan and the USA. By controlling for trade openness and the trade of pollution-intensive products with Japan and the USA, $CO_2$ emissions were estimated for ten East Asian countries between 1988 and 2000. Our results indicated that increasing exports in ‘dirty’ industries to Japan and domestic industrialization in East Asia tended to raise $CO_2$ emissions in East Asian countries, while ‘dirty’ imports from Japan and the USA did not affect $CO_2$ emissions in the area. Although we do not find persuasive evidence to explain why effects of exports to Japan on $CO_2$ emissions in East Asia are different from effects of exports to the US, we hope that our work will facilitate the future research in this area. Finally, we also found that the estimated peak turning points in the models that include ‘dirty’ goods trade with Japan are higher than those in models that do not.

## APPENDIX

**Table A1 Results of Non-Stationality Tests Based on Levin, Lin and Chu (2002)**

| | | | |
|---|---|---|---|
| $\ln E$ | constant | Statistic | –3.585 |
| | | Prob. $^{***}$ | 0.000 |
| | constant & time trend | Statistic | –1.709 |
| | | Prob. $^{**}$ | 0.044 |
| $\ln Y$ | constant | Statistic | –1.386 |
| | | Prob. $^{*}$ | 0.083 |
| | constant & time trend | Statistic | –11.013 |
| | | Prob. $^{***}$ | 0.000 |
| $(\ln Y)^2$ | constant | Statistic | –1.126 |
| | | Prob. | 0.130 |
| | constant & time trend | Statistic | –14.236 |
| | | Prob. $^{***}$ | 0.000 |

| | | | |
|---|---|---|---|
| $(\ln Y)^3$ | constant | Statistic | –0.462 |
| | | Prob. | 0.322 |
| | constant & time trend | Statistic | –19.195 |
| | | Prob. $^{***}$ | 0.000 |
| $\ln I$ | constant | Statistic | 3.550 |
| | | Prob. | 1.000 |
| | constant & time trend | Statistic | –2.363 |
| | | Prob. $^{***}$ | 0.009 |
| $\ln M$ | constant | Statistic | –2.629 |
| | | Prob. $^{***}$ | 0.004 |
| | constant & time trend | Statistic | –3.352 |
| | | Prob. $^{***}$ | 0.000 |
| $\ln JDM$ | constant | Statistic | –0.254 |
| | | Prob. | 0.400 |
| | constant & time trend | Statistic | –2.748 |
| | | Prob. $^{***}$ | 0.003 |
| $\ln JDX$ | constant | Statistic | –0.100 |
| | | Prob. | 0.460 |
| | constant & time trend | Statistic | –3.767 |
| | | Prob. $^{***}$ | 0.000 |
| $\ln USDM$ | constant | Statistic | –1.105 |
| | | Prob. | 0.135 |
| | constant & time trend | Statistic | –3.871 |
| | | Prob. $^{***}$ | 0.000 |
| $\ln USDX$ | constant | Statistic | –1.489 |
| | | Prob. $^{*}$ | 0.068 |
| | constant & time trend | Statistic | –4.647 |
| | | Prob. $^{***}$ | 0.000 |
| $\ln Y_{ppp}$ | constant | Statistic | –0.541 |
| | | Prob. | 0.294 |
| | constant & time trend | Statistic | –2.662 |
| | | Prob. $^{***}$ | 0.004 |
| $(\ln Y_{ppp})^2$ | constant | Statistic | 0.124 |
| | | Prob. | 0.549 |
| | constant & time trend | Statistic | –2.503 |
| | | Prob. $^{***}$ | 0.006 |
| $(\ln Y_{ppp})^3$ | constant | Statistic | 0.862 |
| | | Prob. | 0.806 |
| | constant & time trend | Statistic | –2.574 |
| | | Prob. $^{***}$ | 0.005 |

Note: ***, ** and * indicate that null hypothesis of non-stationality is rejected at the 1%, 5%, and 10% significance levels, respectively.

**Table A2 Results of Tests for the Strict Exogeneity**

| | $\chi^2$-statistic | |
|---|---|---|
| $\ln Y=(\ln Y)^2=(\ln Y)^3=0$ | Value | 4.289 |
| | df | 3 |
| | Probability | 0.232 |
| $\ln I=\ln M=0$ | Value | 1.871 |
| | df | 2 |
| | Probability | 0.392 |
| $\ln JDX=\ln JDM=0$ | Value | 0.307 |
| | df | 2 |
| | Probability | 0.858 |
| $\ln USDX=\ln USDM=0$ | Value | 0.307 |
| | df | 2 |
| | Probability | 0.858 |
| $\ln Y_{ppp}=(\ln Y_{ppp})^2=(\ln Y_{ppp})^3=0$ | Value | 5.735 |
| | df | 3 |
| | Probability | 0.125 |

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