An Account of Pollution Emission Embodied in Global Trade: PGT1 and PGT2 Database

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Abstract

For the period between 1988 and 2009, we constructed the two sets of the world panel database for the pollution emission embedded in international trade. By applying the time-invariant common pollution intensity at industry level for international trade of over 150 countries, a change in pollution emission from the first database reflects scale and composition effects. This first database allows us to investigate whether the composition of international trade for a country changed toward pollution intensive industries during the last two decades. By utilizing a time-varying and country-varying pollution intensity variable for technique effect, the second database provides a full account of pollution emission embodied in global trade and show to what degree the pollution emission is attributed to scale, composition and technique effects.

Keywords: Database Construction; Environment; International trade; Pollution emission; World Panel Database.
JEL Classification Codes: F18; O13; Q56.

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1. Introduction

The empirical studies investigating the effects of international trade on environment received a lot of attention from both policy makers and researchers. The common fear among environmentalists upon trade liberalization was the pollution haven hypothesis by which production of dirty industries shifts toward developing countries in which environmental regulations are relatively lax or nonexistent. Recent empirical studies examining pollution haven effect can be classified into two different approaches. The first approach, suggested by a seminal work of Antweiler et al. (2001),regresses pollution emission variable 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 is able to use the direct measures of pollution emission directly embodied in international trade due to the lack of direct measures of pollution emission embedded in international trade as the world panel database.

This study contributes to the literature by providing the pollution emission database directly linked to the production of export (and import) for the worldwide set of countries. The construction of this database is made possible by imposing the restricting assumption that the pollution intensity by each industry is fixed during the sample period. This assumption is too restrictive for assessing the overall effect of pollution haven hypothesis. However, this assumption is reasonable and useful in assessing the composition effect of international trade on environment. This paper makes a new dataset available for future studies and compliments earlier studies in the literature.

More specifically, for the period between 1988 and 2009, we constructed the two sets of the world panel database for the pollution emission embedded in international trade. The first database (called as PGT1) is constructed by applying the time-invariant common pollution intensity at industry level for all countries to the values of international trade data at six-digit commodities, which are mapped into four-digit industries with corresponding industry pollution intensity coefficients. This dataset allows us to investigate whether the composition of international trade for a country changed toward pollution intensive industries during the last two decades.

With the incorporation of world panel of pollution emission data at the manufacturing industry, the second database (called as PGT2) is constructed by revising the pollution intensity coefficients to be both time-varying and county-varying. This second database allows us to assess a full account of pollution emission embodied in global trade and show to what degree the pollution emission is attributed to technique, scale and composition effect.

The structure of the paper is constructed as follows. The next section reviews previous studies investigating the relationship between international trade and environment and we argue for necessity to construct the world panel database for pollution emission embodied in global trade. Section 3 describes the PGT1, the first set of the world panel database for pollution in international trade, and discusses the global trend of pollution emission in international trade. Section 4 describes the PGT2, the second set of the world panel database for pollution emission in international trade. Section 5 compares the two databases and show to what degree the pollution emission is attributed to technique, scale, and composition effect. The last section concludes and discusses the possible use of these databases for future research.

2. Pollution emission in international trade

This section reviews the relationship between international trade and environment. Most of empirical studies can be classified to three different approaches: each investigating (1) the effect of international trade on pollution emission associated with production in home country, (2) the effect of environment regulations on international trade of dirty industry, and (3) pollution emission embedded in international trade.

As the seminal work to the first approach, Grossman and Krueger (1993) distinguishes three sources by which a change in trade can induce a change in the level of pollution; scale, composition, and technique effects. 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.

Following Grossman and Krueger (1993), 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) 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. Frankel and Rose (2005) overcome endogeneity problem of trade openness by using instrumental variable estimation.

The second approach is to investigate a change in international trade due to tariff and pollution abatement costs. By regressing the value of net imports on environmental regulation variables, Ederington et al. (2004) find that the stricter regulation in the US industry increases imports in that industry. Levinson and Taylor (2008) also find the US import from Canada and Mexico increases in the industry with higher pollution abatement costs.

As the third approach, 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 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.

Applying this IPPS pollution intensity to other countries, Muradian et al. (2002) calculates pollution embodied in international trade for the US, Japan, and Western Europe. The pollution emissions are calculated by multiplying trade volume by the IPPS pollution intensity although only 11 sectors (out of 79 sectors) are used for calculation. Ederington et al. (2004) calculates pollution embodied in the US export and import by using all 79 IPPS sectors pollution intensity coefficients. This calculation with constant pollution intensity provides interesting insights although this calculation is only chosen by the lack of availability for pollution intensity data. By holding pollution intensity (technique) constant, a one percent increase in trade value should also raise pollution one percent if the composition of industries does not change. Any deviation of pollution emission growth from trade growth only comes from the change in industry composition in trade. For example, pollution emission growth rate is less than trade growth rate if the composition of trade moves more toward cleaner industries. They find that the compositions of both exports and imports of US shifted toward cleaner industries. Levinson (2009) also use the IPPS pollution emission coefficients to calculate the pollution embodied in international trade of the US from 1987 to 2001. He further uses input-output tables to account for intermediate inputs to imports.

This paper follows the line of research in Muradian et al. (2002), Ederington et al. (2004), and Levinson (2009) to construct the world-wide database for pollution emission embodied in international trade for over 150 countries for the period between

1988 and 2009. This dataset provides an opportunity to examine to what extent the composition shifts in international trade are consistent with pollution haven hypothesis, applying the same methodology to both developed and developing countries. The first database is constructed using the IPPS pollution intensity under the assumption the pollution intensity is time-invariant and common for all countries. This database is useful in examining the composition effect as in Ederington et al. (2004).

Furthermore, we also introduce the revised version of the IPPS pollution intensity which is both time-varying and country-varying. We adjust the IPPS pollution intensity by adjustment coefficients calculated from the EDGAR pollution database. With this second database, a full account of pollution emission embodied in international trade can be shown for the world-wide set of countries. We show to what degree the pollution emission in global trade is attributed to scale, composition, and technique effects.

3. Pollution emission embodied in global trade: The PGT1 database

In this section we describe how we construct the first world wide database for pollution emission embodied in global trade, the PGT1 database. Furthermore, we examine how both developed and developing countries in the world shifted their industry structures of exports in terms of pollution-contents.

3-1. Original data sources

Three important data sources are (1) industry-level pollution intensity data, (2) world export and import data at disaggregate industry level, and (3) corresponding tables to match pollution data and trade data.

Industry-level pollution intensity data

The World Bank, under the IPPS 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), version 2. The estimates for 14 categories of pollutants are constructed from approximately 200,000 factories in all regions of the US. The pollutants included in the IPPS data are Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2), Carbon Monoxide (CO), Volatile Organic Compounds (VOC), Particulates less than 10 um in diameter (PM10), Total particulates (TP), Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Toxic pollution to Air, Toxic pollution to Land, Toxic pollution to Water, Bio-Accumulative Metal Pollution to Air, Bio-Accumulative

Metal Pollution to Land, Bio-Accumulative Metal Pollution to Water. For more detailed description of data sources, see Hettige et al. (1995).

Export and import data

The United Nations (UN) Comtrade database provides detailed export and import at Harmonized System (HS) 6-digit level for over 200 countries and regions. For each country with export/import data available, the values of export to and import from each partner country in terms of the US dollars for each HS 6-digit products are obtained for the period between 1988 and 2009. Because the classification definitions have undergone several changes, some codes are terminated and new codes appear after some years in the sample period. The first introduction of HS was in 1988 and revisions were made in 1996, 2002, and 2007. The corresponding governmental organizations in each country adopt the new revision codes with various lag years.

Correspondence tables

The correspondence table between the HS (ver.1996) and the ISIC (ver.3) is taken from the United Nations Statistical Division. Each 6-digit category in the HS (5114 products) is matched with one of 4-digt industry in ISIC (146 industries). Some HS products are not able to be matched with any ISIC industries, namely 74 products.

The corresponding table between ISIC (ver.3) and ISIC (ver.2) is also taken from the same source. Here, the number of industries in ISIC (ver.2) is 159 whereas that in ISIC (ver.3) is 292. The revision from ISIC (ver.2) to ISIC (ver.3) is made by both breaking down a single industry in version 2 to multiple industries in version 3 and combining parts of multiple industries in version 2 to create a new industry in version 3. Therefore, there are 586 listings in this corresponding table.

3-2. Database construction

The values of international trade data at six-digit commodities are mapped into four-digit industries and multiplied by corresponding industry pollution intensity coefficients. The correspondence tables between different classifications are readily available at the United States Statistical Division. For each HS 6-digit export for a given year, we find matching ISIC industry code and pollution emission intensity. Then, we calculated estimated pollution emission in pounds by multiplying the value of exports at particular HS 6-digit by corresponding pollution coefficient intensity from the IPPS. 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 intensity as 279 pounds per US million dollars.

There are some caveats in this calculation process. First, some HS 6-digit products cannot be matched with the corresponding pollution intensity in the IPPS data because of the different industry classification methods used in two data sources. 'No-matching' can occur at converting a code from one classification to a different classification using each corresponding table. Therefore, no-matching occurs at three stages: from the HS (4 different versions) to the HS (ver. 1996); from the HS (ver. 1996) to the ISIC (ver. 3); from the ISIC (ver. 3) to the ISIC (ver. 2). In addition, no-matching still occurs at the final stage because the IPPS only provides pollution intensity for 79 sectors out of 159 sectors in the ISIC (ver. 2). We calculated the ratios of the export values matched with the IPPS pollution coefficients to the total export values for each country-year. These ratios vary among sample countries but the majority of exports is covered by this methodology; for example, the ratio is over 60 percent for Argentina and around 40 percent for Australia.

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

$$\overline{E}_{it} = \sum_{j=1}^{79} \eta_{j,1987} E_{ijt} \,, \tag{1}$$

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:

$$\overline{M}_{it} = \sum_{j=1}^{79} \eta_{j,1987} M_{ijt} \,, \tag{2}$$

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* from country *i* in year *t*.

Figure 1 and 2 show the export values and estimated pollution emission embodied in export to the world, respectively for Australian and Argentine. The ratio of the IPPS manufacturing industry in total exports is also provided. The pollution emissions in Australian export grew less than the value of export. SO2, NO2, and CO grew by 197, 160, and 161 percent whereas the value of export grew by 228 percent from 1988 to 2009. The ratio of the IPPS manufacturing export fell from 54 to 37 percent. The composition of Australian export moved toward much cleaner industries. This type of composition shift found for the US in the previous studies, e.g. Ederington et al. (2004) and Levinson (2009), calls for question the validity of pollution haven hypothesis.

On the contrary, the ratio of IPPS manufacturing is relatively stable between 60 and 70 percent throughout the sample period for Argentina. The solid line indicates that the manufacturing export value for Argentina grew by 314 percent from 1993 to 2009. The dotted lines indicate estimated pollution emission in manufacturing exports and should grow by 314 percent if the composition of exports remains the same. SO2, NO2, and CO grew by 327, 309, and 335 percent, respectively. For Argentina, the composition of export moved toward to dirtier industries in terms of SO2 and CO. The similar estimation for Argentina export to the US indicates much drastic shift to dirtier industries. SO2, NO2, and CO grew by 111, 105, and 173 percent whereas the value of export only grew by 62 percent. This evidence is quite contrary to the shift to cleaner industry in the US import found in Ederington et al. (2004) and Levinson (2009).

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. Second, however, time-invariant coefficients are necessary to address the effect of changes in industry composition for international trade. The sole focus in this paper is to examine the composition effect and not the other scale and technique effects. Third, the actual requirement in underlying assumption need not be the same pollution intensity coefficients for all countries. This empirical exercise stands 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.

3-3. The unadjusted pollution emission embodied in exports

To grasp the overall trend of pollution emission embodied in exports, we plotted pollution in exports against the value of exports. The values of exports are show on the horizontal axis and pollution emissions are shown on the vertical axis. Both values are scaled in logarithm. For each country, data points in general can be read from the left to the right in the ascending order because the value of exports increased over the sample periods except for 8 countries.[1] Those countries with their plots located below relative to those of other countries have cleaner contents in their exports. A country can be said to experience her exports becoming dirtier if the trace of plots represents more than proportionate upward movements. For these plots, we excluded those countries with less than 10 annual observations. In the followings we summarized the results by four regions: (1) Asia and Oceania, (2) Americas, (3) Africa, and (4) Europe.

Asia and Oceania

Figure 3-1-a (for SO2) and Figure 3-1-b (for NO2) depict the plots of pollution emission embodied in exports against the values of exports for the region of Asia and Oceania. On the upper-right corner in both Figures, the plots of China and Japan lay side by side, reflecting the fact that these two countries besides the US are the largest exporters in the region as well as in the world. Interestingly, comparing the plots of two countries at the similar export values, the plots of China is located below those of Japan. This implies that the composition of Chinese exports is cleaner than that of Japanese exports although the plots of China positioned just below the plots of Japan represent different years.

Americas

Figure 3-2-a (for SO2) and Figure 3-2-b (for NO2)

Africa

Figure 3-3-a (for SO2) and Figure 3-3-b (for NO2)

Europe

Figure 3-4-a (for SO2) and Figure 3-4-b (for NO2)

Summary Remarks

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[1] These countries associated with a decrease in the value of exports during the sample periods are Belize, Burundi, Cape Verde, Comoros, Haiti, Sudan, Suriname, and Venezuela.

3-4. The unadjusted pollution emission embodied in imports

3-5. The composition effect

In order to assess the direction of composition shift in international trade, we define *RGPE* index, the relative growth of pollution emission with respect to the growth of export values, for country *i* as the following equation (3).

$$RGPE \equiv \frac{\sum_{j=1}^{79} \eta_{j,1987} E_{ij,LastYear}}{\sum_{j=1}^{79} \eta_{j,1987} E_{ij,FirstYear}} - \frac{\sum_{j=1}^{79} E_{ij,LastYear}}{\sum_{j=1}^{79} E_{ij,FirstYear}} \tag{3}$$

If the value of this index is positive, it indicates that the country experienced the shift of composition toward industries with higher pollution intensity and vice versa if the value of this index is negative. This index is negative for the case of Australia in Figure 1 and positive for the case of Argentina in Figure 2. Table 1 summarizes relative pollution emission growth with respect to the growth of export values for 153 countries[2].Along average, maximum and minimum values, and standard deviation, the numbers of countries are presented for positive value (shift toward dirtier industries) and for negative value (shift toward cleaner industries). The number of countries classified in each group varies by pollutants, but for the most of the cases, the sample countries are split in about half. The important question arises regarding to 'pollution haven hypothesis' whether these directions are associated with the income level of countries.

We also followed the same methodology to calculate the RGPE indices for all countries for import. Statistical summary for the RGPE for imports are presented in Table 2. By combining exports and imports, we classify countries by the change in pollution emission in international trade. The distributions of countries grouped by whether the RGPE is positive or negative are represented in Table 3. In Figure 4, we show the combined plots of the RGPE indices for both exports and imports. Figures are shown in groups of countries by income-level. We return to full examination of this database in section 5 after we introduce the second database in the following.

4. Pollution emission embodied in global trade: The PGT2 database

In this section we construct the second world panel database for pollution emission embodied in global trade, the PGT2 database. Pollution intensity coefficients in the PGT1 database are time-invariant and common among all countries. We introduce

[2] The number of selected countries is reduced by eliminating those countries with fewer than two observations for GDP per capita.

adjustment coefficients to allow pollution intensity to be both time-variant and country-variant. By comparing data from the PGT2 with that of the PGT1, inference can be made to what extent technique effect affects pollution emission in global trade.

4-1. Original data sources

With the PGT2 database, we introduce the country-level pollution intensity data in addition to the previous three data sources: Industry-level pollution intensity data, world export and import data at disaggregate industry level, corresponding tables to match pollution data and trade data. For industry-level pollution intensity data, export and import data, and corresponding tables, see section 3-1.

Country-level pollution intensity data

The Emission Database for Global Atmospheric Research (EDGAR) provides pollution emission at sector levels for the world-wide countries.[3] 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).

4-2. 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*:

$$\hat{\eta}_{ijt} = \left(\frac{\mu_{it}}{\mu_{US,1988}} \right) \eta_{j,1987}. \qquad (4)$$

[3] 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.

A change in the term in the parenthesis should indicate a change of emission intensity due to adopting new pollution abatement technology.[4] 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 (2), 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:

$$\overline{M}_{it} = \sum_{k \neq i} \sum_{j=1}^{79} \hat{\eta}_{kjt} M_{ikjt} \tag{5}$$

4-3. The pollution emission embodied in exports

To grasp the overall trend of pollution emission embodied in exports, we plotted pollution in exports against the value of exports. The values of exports are show on the horizontal axis and pollution emissions are shown on the vertical axis. Both values are scaled in logarithm. For each country, data points in general can be read from the left to the right in the ascending order because the value of exports increased over the sample periods for except 8 countries.[5] Those countries with their plots located below relative to those of other countries have cleaner contents in their exports. A country can be said to experience her exports becoming dirtier if the trace of plots represents more than proportionate upward movements. For these plots, we excluded those countries with less than 10 annual observations. In the followings we summarized the results by four regions: (1) Asia and Oceania, (2) Americas, (3) Africa, and (4) Europe.

Asia and Oceania

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[4] Note that this term also captures the industry structure change in overall production of country.

[5] These countries associated with a decrease in the value of exports during the sample periods are Belize, Burundi, Cape Verde, Comoros, Haiti, Sudan, Suriname, and Venezuela.

The plots for countries in the region of Asia and Oceania are shown in Figure 5-1-a (for SO2), 5-1-b (for NO2), and 5-1-c (for CO). There are three noteworthy points. First, the plots of China are located in the furthest end of the upper-right corner in all pollutants. This means that China bears the most pollution produced domestically for other countries, reflecting China being the largest exporter in the region.[6] Second, the environment content in the Japan's exports is much cleaner than China because the plots of Japan are located far below China. Third, countries like Azerbaijan, China Macao SAR, Cyprus, Israel, New Zealand, and Singapore experienced decrease in pollution emission in all three pollutants although their exports increased during the sample period.

Americas

The plots for countries in the region of Americas are shown in Figure 5-2-a (for SO2), 5-2-b (for NO2), and 5-2-c (for CO). We note the following three points for the Americas region. First, from comparing the plots among Brazil, Canada, and Mexico, the exports of Mexico demonstrate much cleaner contents than those of Brazil and Canada. The plots of Mexico lie below those of Brazil and Canada. Second, the pollution emission embodied in exports for some countries in the Central America actually decline for all three pollutants, namely Dominica, Jamaica, Panama, and Saint Kitts and Nevis. Third and more importantly, SO2 and CO pollutant emission embodied in the export for the world largest country, i.e., the US, declined. This has substantial impact on the global scale.

Africa

The plots for countries in the region of Africa are shown in Figure 5-3-a (for SO2), 5-3-b (for NO2), and 5-3-c (for CO). We find two interesting features in the Africa region. First, as also found in the other regions, Burkina Faso, Cameroon, and Seychelles experienced declines in pollution emission embodied in their exports for all three pollutants. Second, we observe the wide spread in terms of pollution emission for CO in the African region. The plots of countries with similar export values are located at large difference in the vertical scale.

[6] It is important to note that the actual pollution incurred on the land of China can be much less because the import content of China's exports in the manufacturing industries is very high.

Europe

The plots for countries in the region of Europe are shown in Figure 5-4-a (for SO2), 5-4-b (for NO2), and 5-4-c (for CO). We observe two noteworthy points in the European region. First, Finland stands out at showing greater pollution emission embodied in her exports relative to other countries. Finland; however, demonstrate declines in pollution emission in her exports over the sample period. Second, the United Kingdom also show declines in all three pollutants in her exports.

Summary Remarks

Unlike the underlying background for pollution haven hypothesis which states trade liberalization shifts dirty industries from developed countries to developing countries, we found many developing countries experience the decline in pollution emission embodied in their exports although their values of exports actually increased.

5. Decomposing pollution emission embodied in exports

For the first dataset, PGT1, we imposed two restricting assumptions on pollution emission coefficients for constructing the global dataset. One is that all countries have same technique and the other is no improvement in reducing pollution emission over sample years. It should be reminded that this database has one advantage; The composition effect, i.e., the effect caused by a change in export industry structure on pollution embodied in international trade, can be assessed after controlling for scale effect.

By reflecting the argument by Levinson (2009) that the largest effect is technique effect, we improve the dataset by rescaling the pollution coefficients by applying technique adjustment coefficients which is both time-variant and country-variant. By comparing these two databases, changes in pollution emission embodied in international trade can be broken down to three components; scale, composition, and technique effects.

5-1. The pollution emission from the world perspective

To make comparison possible between the PGT1 and the PGT2, we selected year 2000 to plot pollution emissions for both databases. Pollution emissions from the PGT1 (calculated by using the unadjusted IPPS pollution intensity) are shown on the horizontal axis and pollution emissions from the PGT2 (calculated by using the adjusted IPPS pollution intensity) on the vertical axis. In each figure, the reference line (45 degree diagonal line) is also shown. Countries (in year 2000) above this reference line have only access to pollution abatement technology below that of the US in the 1988 level. Figure 6-1, 6-2, and 6-3, respectively show SO2, NO2, and CO pollution emission embodied in exports.

The pollution abatement technology adopted in the world widely differs in the types of pollutions. For SO2 in Figure 6-1, 125 countries in 2000 use the better pollution abatement technology than the 1988 US technology and only 17 countries still lag behind. For NO2 in Figure 6-2, fewer countries are able to use better technology than that of the US in 1988. 101 countries use the better technology whereas 41 countries use the worse technology. For CO in Figure 6-3, the number evenly splits between those countries adopting better technology and those countries with worse technology; 71 versus 71. This wide difference among pollutants in adaptation of newer technology in the world partly reflects the facts SO2 pollution emission is easier to be captured by a simple filter gadgets.

More interesting and informative figures are shown for imports. The above results for exports largely reflect the trend of overall manufacturing industry obtained from the EDGAR data source. The complicated data construction process conducted in this paper was unnecessary to show the results in Figure 6-1 through 6-3, (note that that is not to say other results could have been obtained without examination in this paper). However, corresponding calculations for imports are much complicated because calculations are necessary at each bilateral base as shown in equation (5).

Figure 7-1, 7-2, and 7-3, respectively show SO2, NO2, and CO pollution emission embodied in imports. Similar to the export figures, countries (in year 2000) above this reference line import on average from countries which have only access to pollution abatement technology below that of the US in the 1988 level. For SO2 in Figure 7-1 and NO2 in Figure 7-2, the most of countries are located below the reference line. Those countries which import products produced with dirtier technology than the 1988 US level are Botswana, China Macao SAR, Lesotho, Namibia, Seychelles, and Swaziland for SO2 and Botswana, Burundi, Central African Republic, Lesotho, Malawi, Namibia, and Swaziland for NO2. For SO2 and NO2 emission embodied in imports, the most of countries in the world experiences less pollution contents in imports due to adaptation of improved technology in pollution abatements.

The interesting finding in NO2 is that only 7 importing countries are above the reference line whereas 41 exporting countries are above the reference line. These seemingly contradicting two facts can be reconciled only if importing countries imports more from countries which adopt the better pollution abatement technology. This is similar to the composition effect, but we refined the notion to include a shift in the composition of partner countries in addition to a shift in the composition of industry structures.

Reflecting the fact that a half of countries are above the reference line in CO emission embodied in exports, CO emission embodied in imports shown in Figure 7-3 indicate 79 countries are also above the reference line.

5-2. Selected countries: The BRICs, Japan, Mexico and the US

So far, we observed the pollution emission in international trade at the world perspective in the preceding subsection, but it is also important to examine individual countries in more detail. We select four emerging economies (Brazil, Russia, India, and China), Japan, Mexico and the United States in this subsections. To help understand the evolution of pollution contents of these countries' international trade, time-series data of trade values and pollution emission are potted with the initial values being normalized to 100. The figures in this subsection are constructed in a similar manner as Figure 1 and 2. The tendency of international trade moving toward cleaner industries can be found if pollution emission plots appear below the plot of trade values. Note that pollution emissions are plotted using both the PGT1 and the PGT2 databases. The data plots with the PGT1 database are indicated with (scale + composition) and those with the PGT2 database are indicated with (scale + composition + technique). Note that scale effect disappears when compared with the trade values, so the difference between pollution emission of the PGT1 and trade value, for example, is pure composition effect. Likewise, the difference between pollution plots of the PGT2 database and pollution plots of the PGT1 database indicate pure technique effect. Below, we describe and discuss the evolution of pollution emission embodied in international trade of these selected seven countries.

Exports

Time-series data for the Brazil's exports are shown in Figure 8-1. All three pollution emissions embodied in the Brazil's exports are reduced (relatively to export values) marginally by the composition effect, i.e., all pollution plots with (scale + composition) appear just below the export. In contrast, the technique effect significantly reduced the SO2 and CO pollution emission relatively to Brazil's exports.

Similarly, time-series data for exports of China, India, Russia, Japan, Mexico, and the US are respectively shown in Figure 8-2 through 8-7. We can group these countries into three types: (1) Dirty (counties moving toward dirtier exports), (2) Clean by Technology (countries becoming dirtier with only composition effect but cleaner when combined with technique effect), (3) Clean (countries moving toward cleaner exports). Only one country falls in the first 'Dirty' category: India. Only SO2 with (scale + composition + technique) appear below the export value. The recent jump in CO pollution with (scale + composition) is striking. For the second category of 'Clean by Technology', we observe China, Russia, Japan, and the US fit into this group. For the third category of 'Clean', Brazil and Mexico demonstrate that their pollution emission embodied in their exports have become cleaner with or without technology effect.

Imports

Time-series data for imports of Brazil, China, India, Russia, Japan, Mexico, and the US are respectively shown in Figure 9-1 through 9-7. For Russia, Japan, and Mexico, all pollution emissions are reduced by both composition effect and technique effect. Especially, SO2 pollution emission embodied in imports, accounting for both composition effect and technique effect, only increased about 30 percent (Japan), 50 percent (Russia), and 200 percent (Mexico) during the sample period whereas the value of imports increased 200 percent (Japan), 500 percent (Russia), and 900 percent (Mexico). For India in Figure 9-3, the composition effects are at work to reduce pollution emission, but additional technique effect is limited. Strikingly, CO pollution emission becomes dirtier by technique effect.

For the US in Figure 9-7, the composition effect seems almost negligible especially at the end of sample period. The value of imports, SO2, NO2, and CO all clusters together in 2008. When technique effect is considered, on the other hand, SO2 and NO2 pollution grow substantially lower than the import values whereas CO pollution growth is much higher than that of the import values. Brazil in Figure 9-1 demonstrates very similar changes as the US.

The most interesting case is for China in Figure 9-2. We have evidence that the composition effects shifted China's import industry structure toward dirtier industries for all three pollutants. Considering China as developing country, this evidence is inconsistent with the pollution haven hypothesis. Then again, it is important to keep in mind that the large portion of China's trade takes a form of processing trade. Finally, even when the technique effect is considered, NO2 and CO pollution grow faster than the growth of import values.

6. Discussions and conclusions

For the period between 1988 and 2009, we constructed the two world panel databases for the pollution emission embedded in international trade. The first database allows us to investigate whether the composition of international trade for a country changed toward pollution intensive industries during the last two decades. The second database further implements time-varying and country-varying pollution emission intensity coefficients. By doing so, we are able to provide a full account of pollution emission embodied in global trade.

As consistent with previous studies (limited to the small number of countries due to the lack of available datasets), we also find that the composition effect in many cases is limited, marginal at the best, whereas the technique effect sometimes reduces substantial amount of pollution emission embodied in international trade. Of course, this observation is only a general view on the global basis. What our databases can provide is an opportunity to investigate individual countries or/and countries in the region with three separate components (scale, composition, and technique) affecting the pollution emission embodied in international trade. Combining other micro, industry, and macro economic variables with these database, further examinations on the relationship between international trade and environment can be pursued. We make these databases publicly available to other researchers for further uses and improvements (upon the publication of this paper).

As concluding, we should 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 industry ranking of pollution emission to other countries, especially to developing countries, may produce bias in evaluating the pollution emission embodied in international trade. 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.

Appendix:

Data

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.

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.

Appendix table A1. The relative growth of pollutants in exports, equation (3)

Country Name	SO2	NO2	CO	VOC	Fine Part	TS Part	BOD (LB)
Afghanistan	0.11	0.09	0.20	0.05	0.79	0.60	0.02
Albania	5.51	4.97	0.11	−1.13	18.50	5.33	4.78
Algeria	0.52	0.49	0.09	0.51	1.07	0.57	−0.15
Antigua and Barbuda	14.66	12.24	2.37	13.52	−4.75	1.20	−0.63
Argentina	0.14	−0.05	0.21	−0.64	1.21	1.07	−0.43
Armenia	1.64	0.57	5.09	0.07	1.47	3.51	0.25
Australia	−0.31	−0.68	−0.67	0.18	−0.03	−0.10	−0.06
Austria	−0.49	−0.69	−0.44	−0.35	0.58	−0.44	−1.53
Azerbaijan	−0.82	−0.67	−0.84	−0.91	10.62	2.46	1.26
Bahrain	0.33	0.58	0.30	1.06	−0.24	−0.14	1.02
Bangladesh	−5.46	−5.94	−2.86	−7.25	4.45	−1.83	−7.41
Belarus	−0.02	0.11	−0.07	−0.22	0.87	0.29	1.46
Belgium	0.05	0.01	−0.12	0.10	0.01	−0.04	−0.31
Belize	−0.06	−0.07	−0.06	−0.42	−0.01	−0.06	−0.28
Benin	11.84	7.23	6.85	0.03	48.24	11.11	−0.39
Bhutan	−1.03	−1.54	15.71	−3.04	−1.95	−1.73	−5.40
Bolivia	4.42	1.70	−1.42	3.10	6.62	2.97	2.50
Bosnia Herzegovina	2.64	2.27	0.21	0.54	1.70	0.22	4.35
Botswana	−0.12	−0.25	−0.79	−0.88	0.51	0.23	−0.76
Brazil	−0.52	0.06	−0.66	0.06	−1.10	−0.47	0.32
Brunei Darussalam	72.62	56.73	180.64	30.38	292.69	44.04	5.58
Bulgaria	−1.31	−1.29	−1.13	−1.26	−1.25	−0.48	−1.39
Burkina Faso	8.34	4.97	−1.49	−9.26	33.28	17.00	−10.02
Burundi	−0.24	0.00	−0.01	0.18	−0.33	−0.32	1.12
Cambodia	−1.47	−2.48	−2.32	−1.15	1.89	−1.39	−2.40
Cameroon	−0.73	−0.41	2.08	2.45	−0.85	−0.13	−0.34
Canada	−0.66	−0.48	−0.85	−0.15	0.01	−0.41	−1.18
Cape Verde	−0.40	−0.41	−0.42	−0.36	−0.38	−0.38	2.48
Central African Rep	−1.85	−1.59	−1.99	−0.75	−2.12	−1.15	−0.60
Chile	0.19	0.26	0.16	0.06	−0.02	−0.02	0.26
China	−1.97	−0.17	3.15	1.98	−6.37	−2.54	−3.08
Colombia	0.77	0.59	1.74	1.77	−0.46	2.10	1.64
Comoros	−0.04	−0.01	−0.04	−0.07	−0.01	0.01	−0.17
Congo	−0.28	−0.15	−0.17	−0.34	0.23	0.23	0.37
Costa Rica	0.40	−1.02	−0.33	0.23	5.05	0.66	−1.06
Cote d Ivoire	0.07	−0.33	0.07	0.36	−0.66	−0.80	−0.49
Croatia	0.11	−0.13	−0.25	−0.48	0.87	0.21	−0.41
Czech Rep	−4.85	−4.52	−3.65	−2.66	−6.46	−5.47	−4.70
Denmark	−0.17	−0.44	−0.37	−0.24	−0.31	−0.44	−0.72
Dominica	−0.91	−0.68	−1.06	−0.31	−0.38	−0.67	−1.06
Dominican Rep	−2.94	−2.92	−5.12	−0.86	0.59	−2.61	−3.10
Ecuador	10.46	3.58	4.44	13.34	50.73	14.06	0.28
Egypt	6.71	5.81	6.73	7.82	13.52	6.44	16.52
El Salvador	−0.34	−1.58	−0.78	0.47	4.68	−0.26	−1.61
Estonia	−1.24	−1.10	0.60	−0.20	−2.01	−1.32	−0.56
Ethiopia	0.41	−0.19	−0.14	−1.20	13.87	11.65	−0.19
Fiji	0.39	0.27	0.31	0.10	0.67	0.20	0.48
Finland	−1.27	−1.16	−1.30	−0.64	−0.72	−1.09	−1.58
France	−0.31	−0.32	−0.25	−0.13	−0.40	−0.44	−0.66
Gabon	−4.53	−3.66	−1.00	−3.57	0.03	3.95	−4.69
Georgia	10.22	6.88	2.19	−1.70	62.64	31.01	−0.20

Country Name	SO2	NO2	CO	VOC	Fine Part	TS Part	BOD (LB)
Germany	−0.46	−0.53	−0.43	−0.34	0.11	−0.31	−0.91
Ghana	0.01	−0.03	−0.41	−0.41	0.46	0.23	0.64
Greece	−0.85	−0.55	0.38	0.13	−1.35	−0.92	2.28
Grenada	3.90	0.42	7.24	0.26	5.27	3.12	−0.18
Guatemala	0.81	−0.43	0.63	2.09	2.59	0.66	1.39
Guinea	−2.51	−3.03	−3.12	−3.35	10.65	6.44	−3.78
Guinea Bissau	−0.01	−0.01	−0.01	0.00	−0.01	−0.01	0.02
Honduras	4.90	0.83	0.90	4.01	8.39	5.75	−0.44
Hungary	−1.19	−1.72	−0.78	−1.23	−1.04	−2.09	−1.38
Iceland	1.67	1.91	0.58	1.39	2.55	3.72	−1.23
India	5.06	4.43	11.70	2.32	10.88	5.87	4.65
Indonesia	−0.05	−0.48	2.32	3.17	−3.26	−0.58	7.29
Iran	2.53	2.41	2.51	2.54	2.62	3.49	2.05
Ireland	−0.34	−1.11	−1.73	−0.42	−0.66	−0.64	−1.98
Israel	0.18	0.05	1.39	0.04	1.05	0.39	−0.37
Italy	0.03	−0.20	0.24	−0.21	0.52	−0.09	−0.33
Jamaica	0.44	0.35	0.07	3.53	0.34	−0.13	3.16
Japan	0.90	0.85	1.06	0.35	1.39	1.03	0.38
Jordan	−2.73	−2.14	1.81	−0.09	−4.54	−3.60	1.98
Kazakhstan	0.76	1.15	0.30	2.64	−0.39	−0.44	7.77
Kenya	3.80	3.35	3.12	4.07	3.87	3.92	4.72
Kiribati	134.43	53.44	38.01	65.26	4815.65	726.36	−2.13
Kyrgyzstan	−1.18	−1.71	−2.30	−2.44	0.29	2.61	−2.08
Latvia	0.64	0.24	0.27	0.84	0.55	0.68	3.83
Lebanon	3.02	1.20	0.96	−1.31	11.04	6.25	−2.74
Lesotho	20.14	1.76	23.27	0.20	1.44	0.75	13.99
Lithuania	−3.08	−1.69	−1.82	−1.53	−3.82	−2.27	−1.86
Luxembourg	−0.07	−0.07	−0.04	−0.05	0.09	−0.03	−0.33
Madagascar	−2.55	−3.38	−1.19	−1.53	−2.57	−2.85	−2.15
Malawi	0.51	−0.67	0.56	2.02	10.78	1.36	−0.06
Malaysia	−1.17	0.15	0.04	0.69	−2.28	−2.37	0.67
Maldives	0.42	0.43	−0.47	−1.82	0.31	−0.25	0.77
Mali	−0.03	−0.75	−2.18	−6.45	3.50	3.36	−2.11
Mauritania	30.91	31.42	233.73	320.83	1741.20	289.00	−1.65
Mauritius	−0.23	−0.35	−0.10	0.06	2.06	−0.36	−0.21
Mexico	−5.85	−5.03	−5.27	−3.41	−7.27	−5.29	−6.58
Mongolia	1.32	−0.89	−1.14	−1.21	17.17	14.37	−1.50
Morocco	−0.69	−0.53	−0.66	−0.91	0.65	−0.27	−1.05
Mozambique	−0.08	0.69	3.47	1.44	−1.14	−0.72	0.78
Namibia	−0.54	−0.74	−1.81	−1.03	5.05	3.55	−2.90
Nepal	19.76	15.72	80.03	6.14	15.90	9.55	5.35
Netherlands	−0.05	−0.18	−0.06	0.08	−0.15	−0.28	−0.64
Nicaragua	−0.72	−0.45	−0.73	7.19	−1.53	−1.77	14.22
Niger	0.33	0.19	0.53	1.23	18.37	9.93	0.18
Nigeria	2.71	2.33	11.19	3.00	−5.33	−5.06	11.53
Norway	−0.23	−0.14	−0.84	0.41	−0.31	−0.29	−1.41
Pakistan	4.50	1.74	0.87	0.08	17.67	6.29	0.45
Panama	−0.05	−0.22	−0.01	−0.16	0.30	−0.06	0.12
Papua New Guinea	−0.24	−0.35	0.55	−0.45	−0.33	0.14	−0.24
Paraguay	3.37	0.38	−2.38	0.02	8.61	6.70	−3.20
Peru	1.30	0.25	2.21	2.01	1.94	1.74	−0.78

Country Name	SO2	NO2	CO	VOC	Fine Part	TS Part	BOD (LB)
Philippines	0.00	0.35	0.42	−0.30	−0.62	−0.46	0.42
Poland	−4.33	−3.10	−3.40	−0.55	−6.05	−4.52	−2.59
Portugal	−0.69	−0.37	−1.19	−0.02	3.60	0.59	−1.74
Qatar	1.26	0.41	−0.18	1.80	−6.01	−2.26	−4.51
Rep of Korea	3.15	6.42	5.99	4.25	0.12	2.85	3.60
Rep of Moldova	0.52	−0.04	−0.98	−0.96	7.43	1.42	−1.43
Romania	−2.00	−1.70	−1.40	−1.73	−2.00	−1.54	−2.07
Russian Federation	0.46	0.32	0.66	0.13	0.83	0.22	−0.44
Rwanda	139.18	7.13	83.55	18.19	1129.11	170.42	−0.65
St Kitts and Nevis	−0.68	−1.12	−1.31	−0.21	−1.37	−1.39	−1.26
Saint Lucia	2.67	2.59	2.04	5.30	−1.70	−0.63	−0.05
St Vincent and the Grenadines	1.32	1.10	1.72	1.04	0.48	0.23	1.69
Samoa	0.09	0.12	0.11	0.10	0.00	0.12	−0.22
Saudi Arabia	−1.02	−0.36	−0.42	−0.36	−2.34	−1.14	1.22
Senegal	5.67	2.36	−0.98	−3.77	50.48	17.51	−4.02
Serbia	−0.34	−0.41	−0.44	−0.41	−0.20	−0.26	−0.10
Seychelles	−2.88	−2.92	−3.03	−2.93	2.95	−1.74	1.45
Sierra Leone	−0.27	0.33	−0.04	0.85	−0.94	−0.83	1.10
Singapore	0.19	0.74	0.00	0.88	−2.03	−1.16	−0.17
Slovakia	−3.61	−3.61	−2.98	−2.42	−3.88	−3.63	−4.87
Slovenia	−0.56	−0.38	−0.75	−0.09	−0.05	−0.38	−1.55
South Africa	−0.44	−0.47	−0.48	−0.57	0.33	0.61	−0.79
Spain	−1.46	−1.04	−1.22	−1.08	−0.89	−0.66	−1.88
Sri Lanka	−0.01	−0.06	−1.26	1.11	−1.20	−0.93	−1.76
Sudan	−2.27	−2.59	−0.11	−4.24	−1.64	0.28	−4.50
Suriname	1.34	1.86	4.78	7.92	−0.48	−0.45	10.45
Swaziland	−0.08	−0.01	−0.26	0.02	−0.49	0.07	−0.21
Sweden	−0.53	−0.42	−0.66	−0.08	−0.09	−0.37	−0.91
Switzerland	−0.81	−1.13	−1.16	−0.81	−0.61	−0.73	−1.67
Syria	0.54	0.27	64.33	−0.79	−2.18	−6.16	1.01
TFYR of Macedonia	0.03	−0.03	0.21	−0.54	0.02	−0.61	0.36
Thailand	6.99	6.98	4.81	7.37	16.32	3.62	0.47
Timor Leste	−0.25	−0.12	−0.31	−0.15	−0.24	−0.25	−0.03
Togo	40.53	32.77	26.34	−0.93	46.30	37.25	−3.59
Tonga	7.45	3.41	1.81	0.18	29.13	25.88	4.01
Trinidad and Tobago	−0.58	−0.49	−0.31	−0.03	−1.47	−1.14	−0.12
Tunisia	−0.94	−0.68	−0.63	−0.64	−1.26	−1.16	−0.97
Turkey	1.34	−0.06	−0.91	−1.86	8.97	4.48	−5.52
Turkmenistan	0.31	0.22	0.41	0.39	−0.93	0.00	−0.01
Uganda	116.49	6.66	18.37	43.74	509.98	133.67	6.54
Ukraine	0.56	0.15	1.13	−0.54	1.49	0.71	−1.42
U Arab Emirates	−67.36	−35.98	34.69	143.64	−87.78	−75.18	30.57
United Kingdom	−0.22	−0.20	−0.54	−0.09	−0.18	−0.20	−0.58
U R of Tanzania	0.34	−1.11	6.28	9.12	−1.21	6.12	1.41
Uruguay	−0.18	−0.19	0.14	−0.91	1.49	0.60	0.58
USA	0.20	0.28	−0.14	0.27	0.53	0.21	−0.30
Vanuatu	6.88	0.28	−0.75	0.63	77.13	4.77	−0.71
Venezuela	−0.01	−0.05	0.32	−0.15	0.26	0.13	0.05
Viet Nam	3.43	3.62	10.94	2.61	6.86	3.97	−1.45
Yemen	−0.48	−0.47	−0.49	−0.75	3.71	0.40	0.46
Zambia	0.57	0.57	0.61	0.37	0.72	0.10	4.02

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Table 1.Growth of pollution emission relative to export growth

Pollutant	positive	positive (>std)	negative	negative (<std)	ave	max	min	sd
SO2	76	6	77	1	3.9	139.2	−67.4	20.3
NO2	68	6	85	1	1.3	56.7	−36.0	8.2
CO	73	8	80	0	5.5	233.7	−5.3	26.3
VOC	76	5	77	0	4.4	320.8	−9.3	29.1
Fine Particulates	86	4	67	0	59	4816	−88	423
TS Particulates	77	4	76	1	10.0	726.4	−75.2	65.5
BOD (LB)	59	15	94	10	0.3	30.6	−10.0	4.3
BOD (IQ)	54	2	98	0	8.1	800.4	−15.6	71.7
TSS (LB)	98	8	55	0	29.1	1354.4	−5.4	144.7
TSS (IQ)	51	4	102	2	0.0	61.6	−40.7	7.2
Air (LB)	68	11	85	2	1.1	61.9	−7.1	6.8
Air (IQ)	85	1	68	0	157	23752	−26	1914
Land (LB)	80	9	73	0	1.7	89.0	−8.7	9.3
Land (IQ)	73	1	80	0	25.1	3715.8	−38.1	299.4
Water (LB)	67	2	86	0	7.1	524.1	−9.4	56.8
Water (IQ)	53	2	96	0	91.5	11321.9	−19.1	929.8
Air (LB)	104	1	49	0	1877.8	286218.5	−7.5	23063.1
Air (IQ)	69	3	82	0	6.6	508.4	−6.2	49.2
Land (LB)	93	2	60	0	35.7	4002.0	−7.9	326.0
Land (IQ)	93	3	58	0	9.0	652.2	−4.7	57.7
Water (LB)	86	3	67	0	22.2	2218.1	−7.1	186.2
Water (IQ)	44	4	104	0	12.8	817.2	−14.3	89.5

Note: The number of countries is 153 (but smaller for some pollutants due to missing data). The first column “positive” indicates the number of countries in which pollution emission grew by more than the growth rate of export value. Positive (>std) denotes the relative growth of pollution emission is greater than one standard deviation.

Table 2. Growth of pollution emission relative to import growth

	positive	positive (>std)	negative	negative (<std)	ave	max	min	sd
SO2	67	5	86	1	0.2	38.6	−4.2	3.6
NO2	62	6	91	9	0.0	12.8	−4.2	1.7
CO	65	2	88	0	0.4	69.9	−5.1	5.8
VOC	50	4	103	24	−0.4	2.1	−7.8	1.1
Fine Particulates	103	6	50	0	2.5	112.2	−2.4	10.4
TS Particulates	85	5	68	1	0.6	39.8	−4.0	3.8
BOD (LB)	23	2	130	31	−1.2	3.3	−17.5	1.9
BOD (IQ)	19	2	134	39	−1.5	5.3	−16.8	2.0
TSS (LB)	111	4	42	0	2.0	103.9	−3.2	8.9
TSS (IQ)	16	2	137	40	−1.0	11.8	−5.3	1.6
Air (LB)	47	6	106	24	−0.3	1.8	−5.6	0.8
Air (IQ)	61	17	92	12	0.0	5.4	−2.7	0.8
Land (LB)	64	11	89	22	−0.2	6.6	−4.0	1.3
Land (IQ)	75	9	78	7	0.2	12.2	−2.0	1.5
Water (LB)	49	7	104	28	−0.5	4.7	−5.1	1.4
Water (IQ)	23	7	130	40	−1.4	15.7	−9.8	2.5
Air (LB)	113	5	40	0	1.6	78.5	−2.9	6.7
Air (IQ)	77	6	76	2	0.4	23.1	−3.2	2.7
Land (LB)	104	5	49	0	1.3	61.9	−3.2	5.6
Land (IQ)	93	12	60	0	0.7	22.4	−2.3	2.4
Water (LB)	84	7	69	2	0.5	40.9	−3.7	3.6
Water (IQ)	19	2	134	9	−1.1	43.5	−8.3	3.9

Note: The number of countries is 153. The first column "positive" indicates the number of countries in which pollution emission grew by more than the growth rate of export value. For these countries, the composition of export moved toward dirtier industries. Positive (>std) denotes the relative growth of pollution emission is greater than one standard deviation.

Table 3.Distribution of countries by composition changes and income group

width=0.0	ex(+) im(+)	ex(+) im(−)	ex(−) im(−)	ex(−) im(+)
high	0.15	0.18	0.50	0.18
upper middle	0.24	0.24	0.37	0.16
lower middle	0.25	0.38	0.21	0.17
low	0.45	0.10	0.10	0.35
width=0.1	ex(+) im(+)	ex(+) im(−)	ex(−) im(−)	ex(−) im(+)
high	0.15	0.19	0.46	0.19
upper middle	0.25	0.28	0.40	0.08
lower middle	0.27	0.39	0.20	0.15
low	0.47	0.13	0.13	0.27
width=0.5	ex(+) im(+)	ex(+) im(−)	ex(−) im(−)	ex(−) im(+)
high	0.22	0.11	0.44	0.22
upper middle	0.21	0.21	0.53	0.05
lower middle	0.26	0.39	0.22	0.13
low	0.67	0.00	0.17	0.17

Note: Pollutant is SO2. Width indicates the threshold value of changes in absolute term. The number of countries is 153. For width=0.1, the number of countries with changes greater than 0.1 in both exports and imports is 122. For width=0.5, the number of countries with changes greater than 0.5 in both exports and imports is 57.

Figure 1. The export value and estimated pollution emission in Australian export to the world

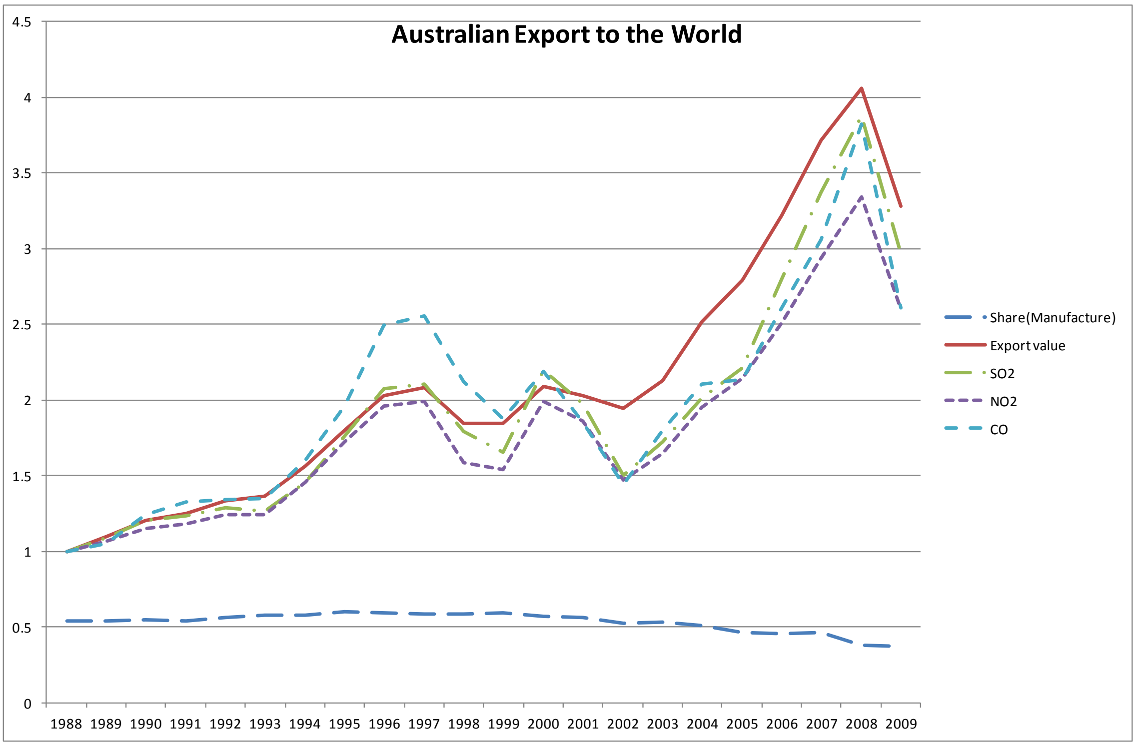


Figure 2. The export value and estimated pollution emission in Argentine export to the world

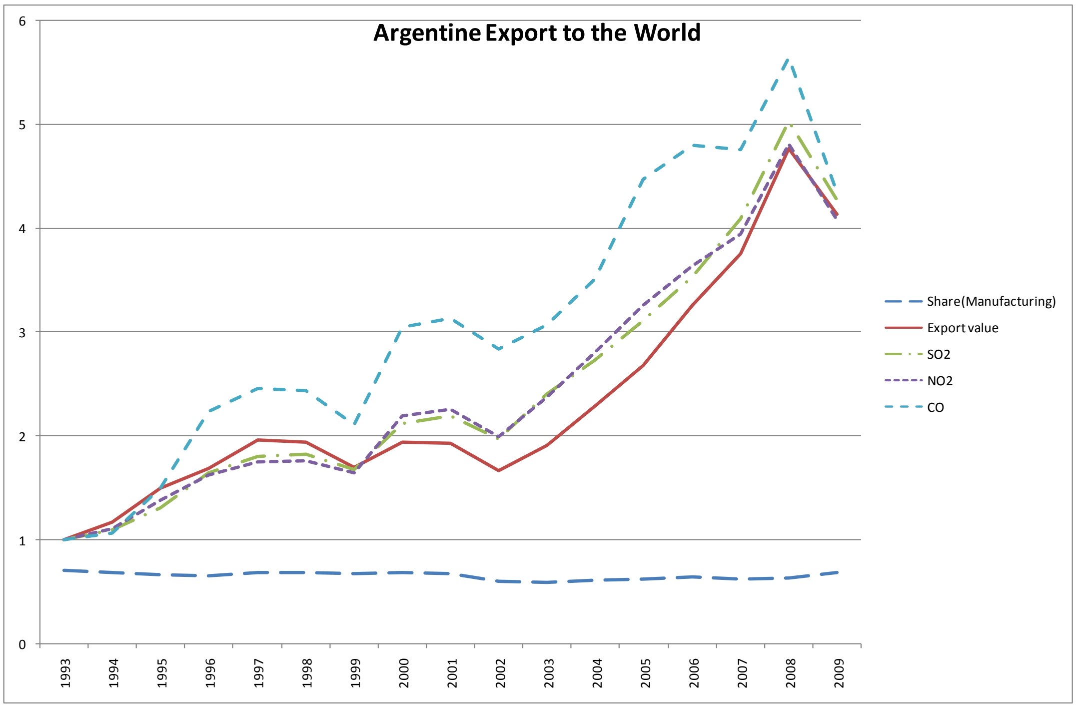


Figure 3-1-a. SO2 emission embodied in exports (Eastern Europe)

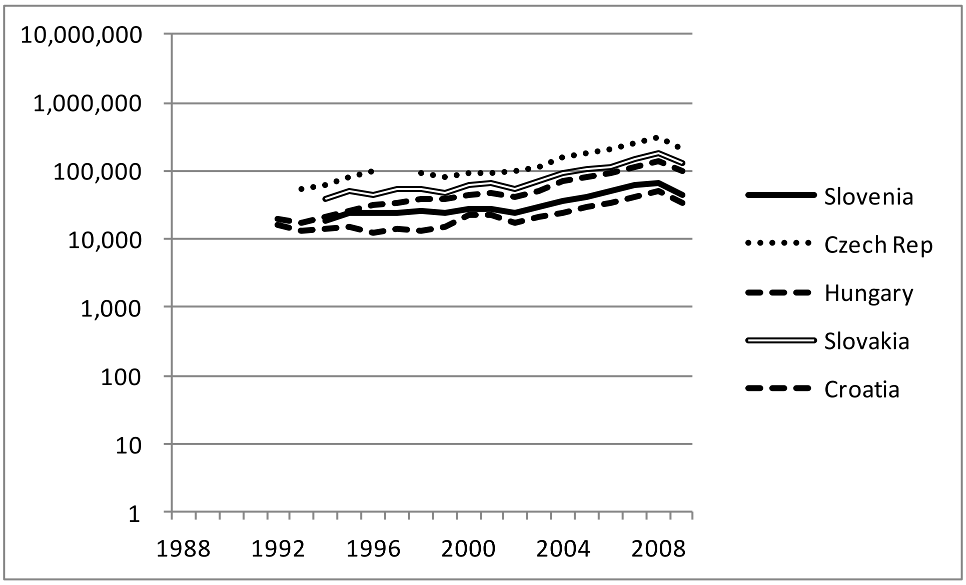


Figure 3-1-b. SO2 emission embodied in exports (Eastern Europe)

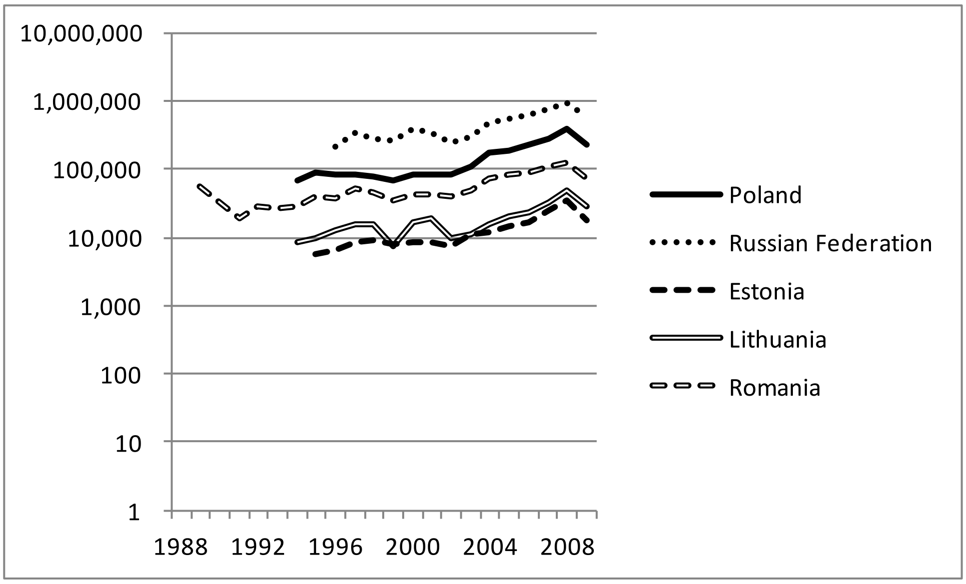


Figure 3-1-c. SO2 emission embodied in exports (Eastern Europe)

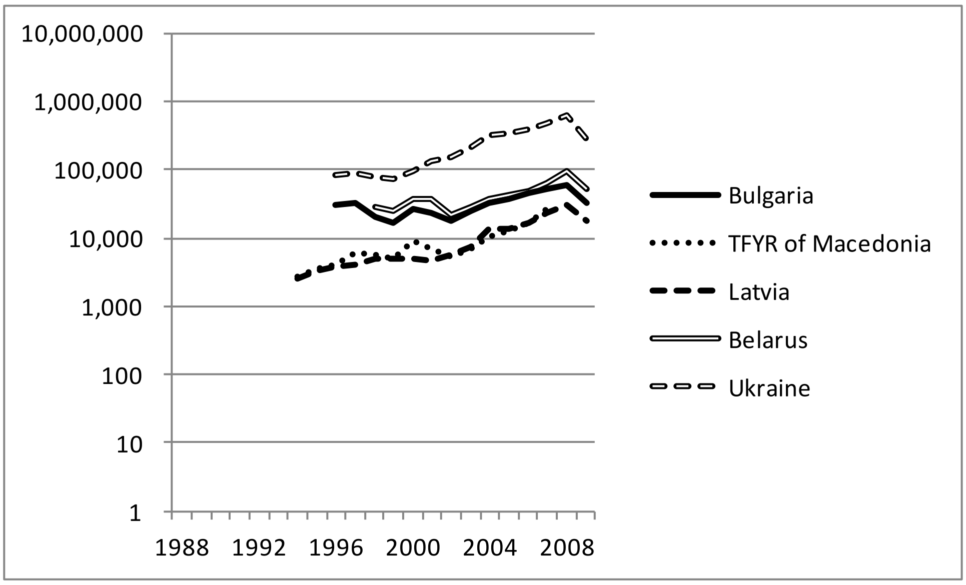


Figure 3-1-d. SO2 emission embodied in exports (Eastern Europe)

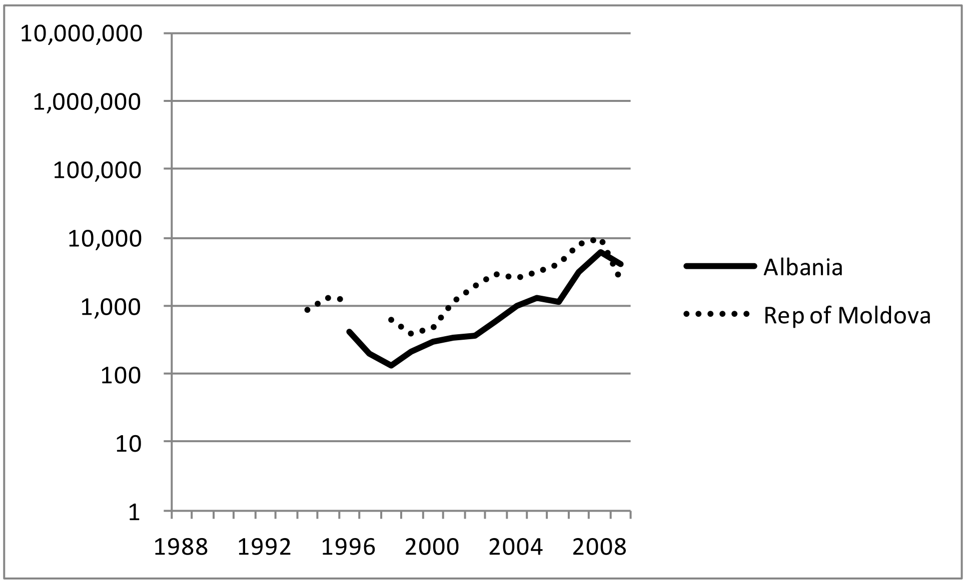


Figure 3-2-a. SO2 emission embodied in exports (Western Europe)

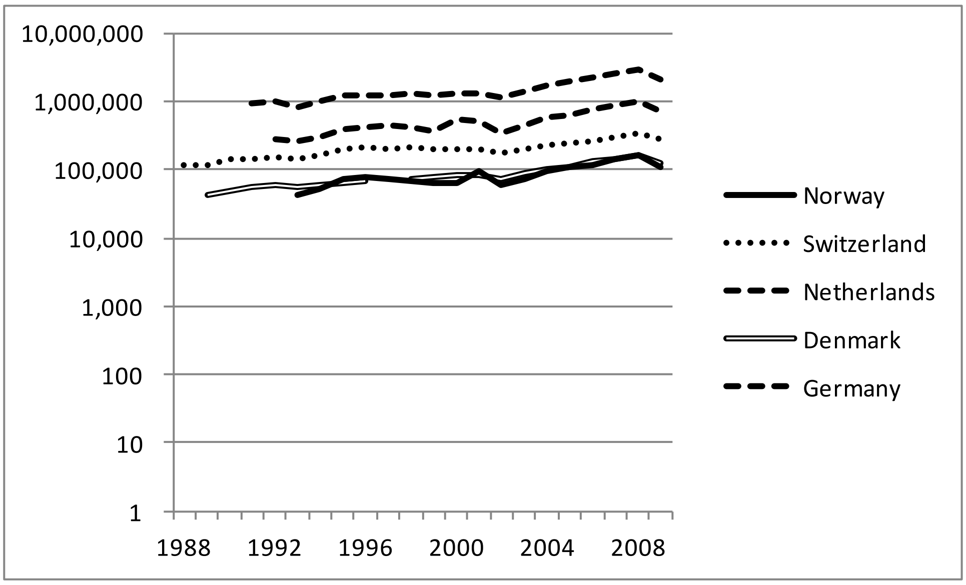


Figure 3-2-b. SO2 emission embodied in exports (Western Europe)

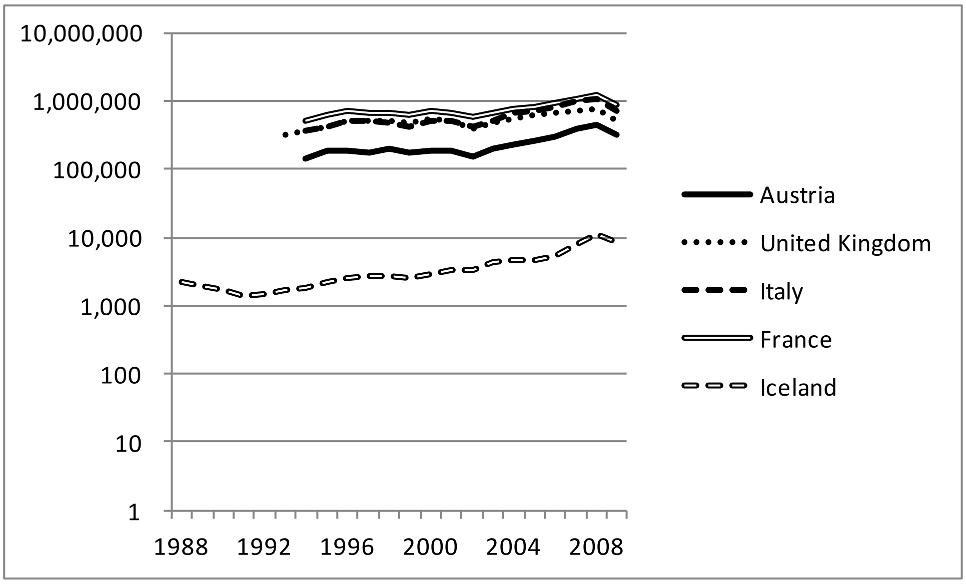


Figure 3-2-c. SO2 emission embodied in exports (Western Europe)

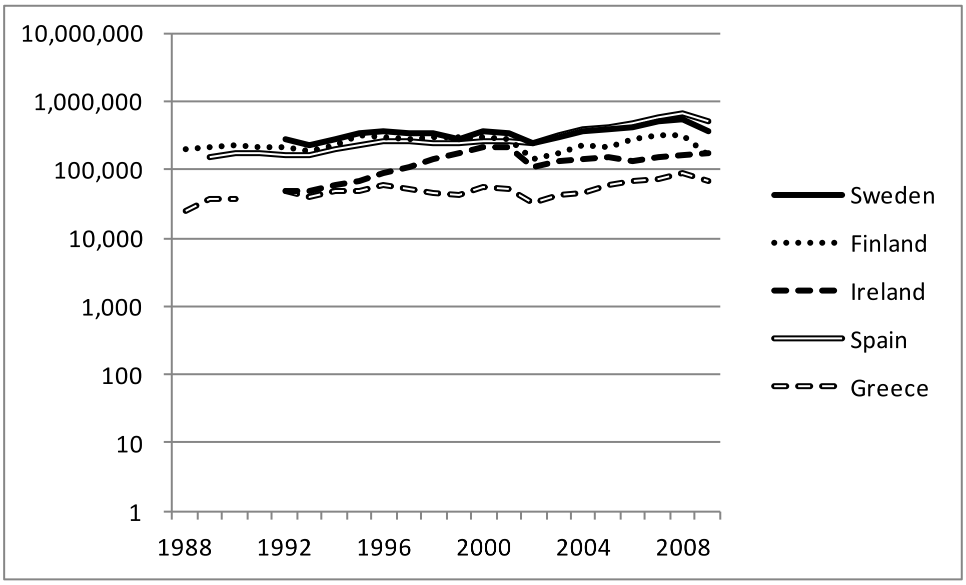


Figure 3-2-d. SO2 emission embodied in exports (Western Europe)

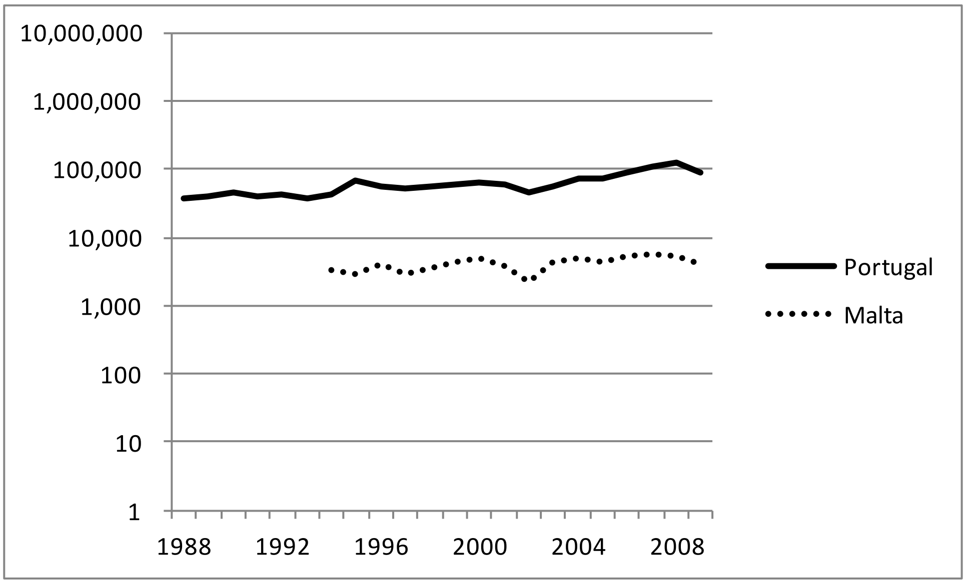


Figure 3-3-a. SO2 emission embodied in exports (Africa)

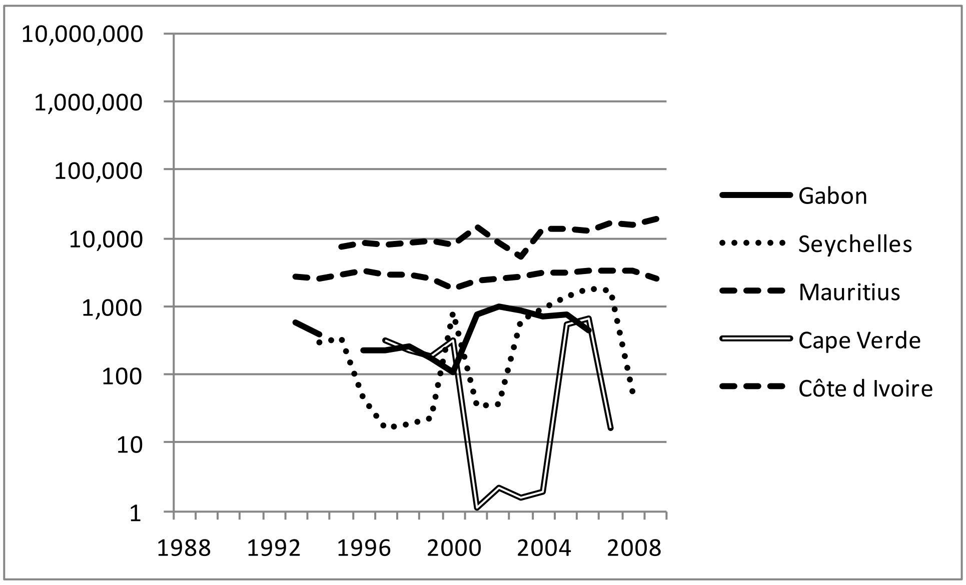


Figure 3-3-b. SO2 emission embodied in exports (Africa)

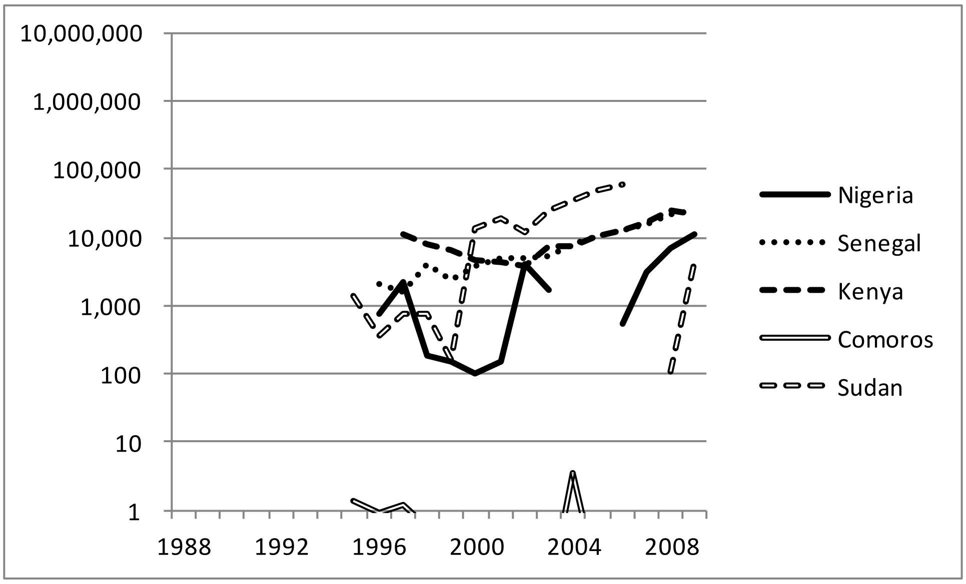


Figure 3-3-c. SO2 emission embodied in exports (Africa)

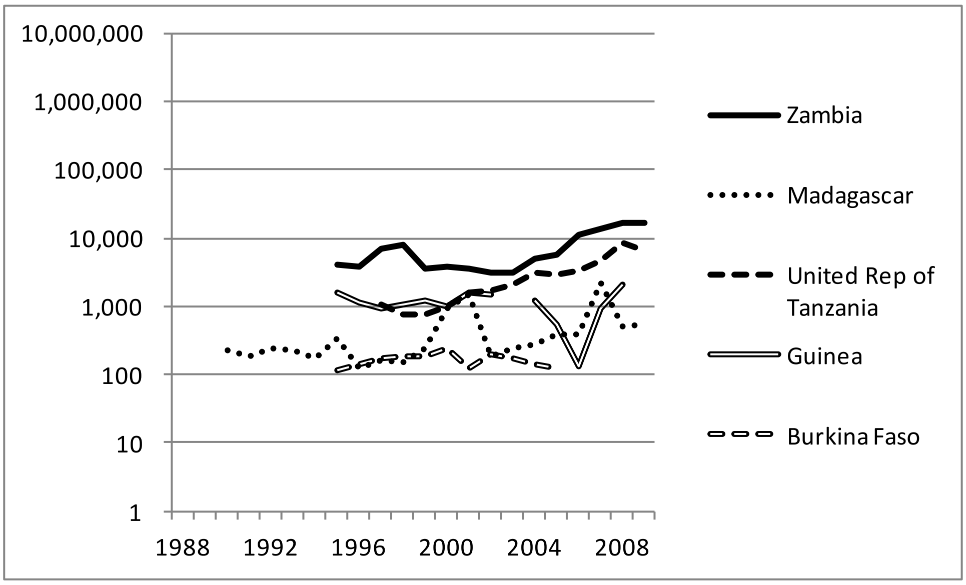


Figure 3-3-d. SO2 emission embodied in exports (Africa)

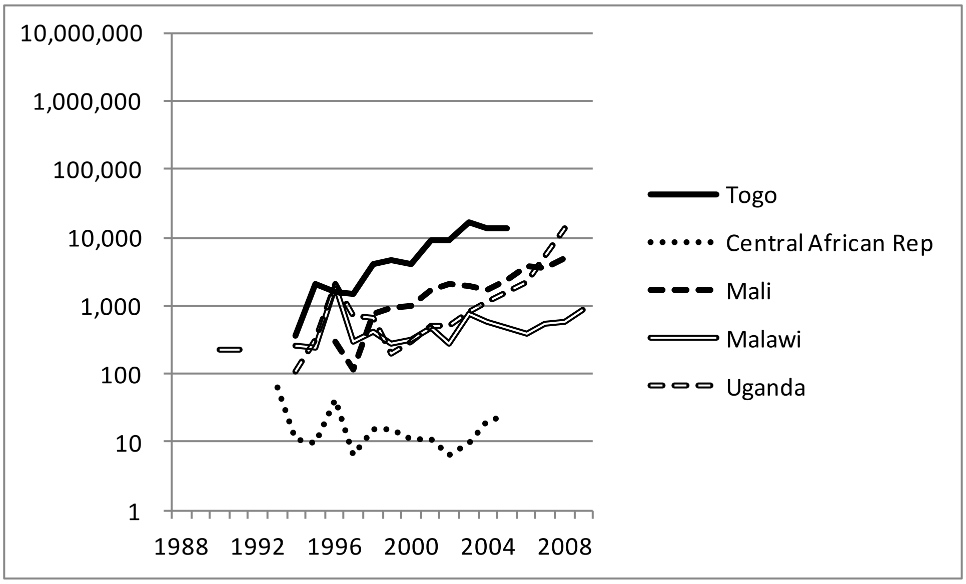


Figure 3-3-e. SO2 emission embodied in exports (Africa)

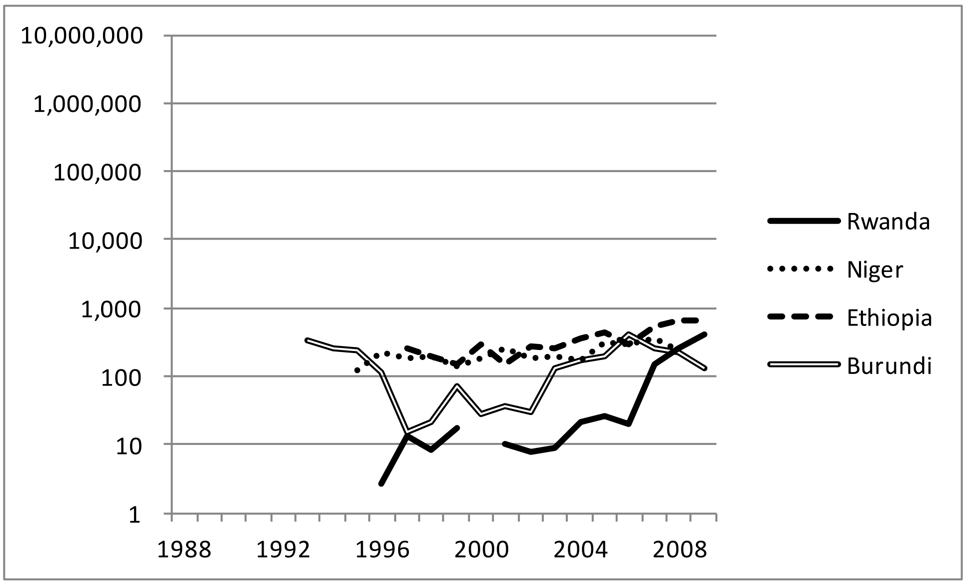


Figure 3-4. SO2 emission embodied in exports (North America)

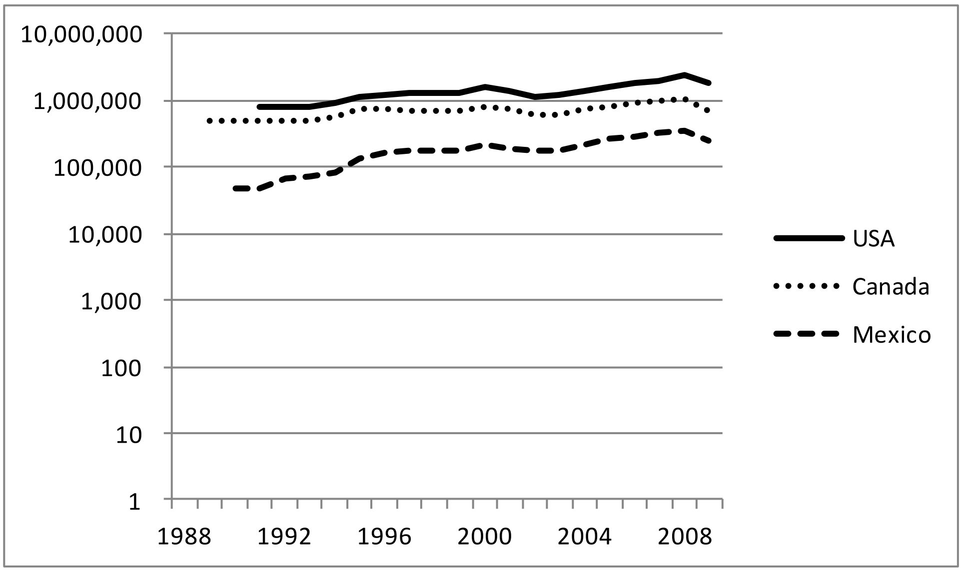


Figure 3-5-a. SO2 emission embodied in exports (Latin America)

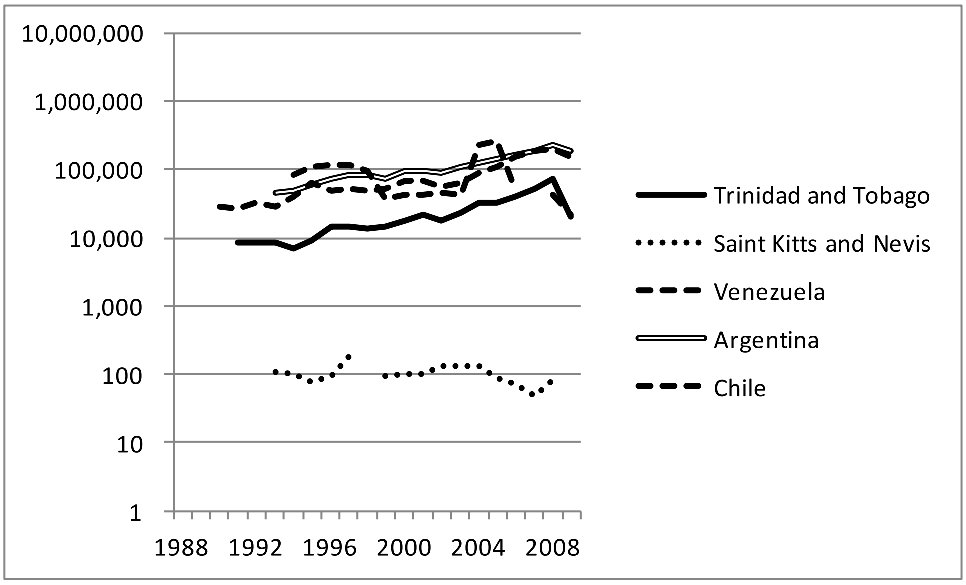


Figure 3-5-b. SO2 emission embodied in exports (Latin America)

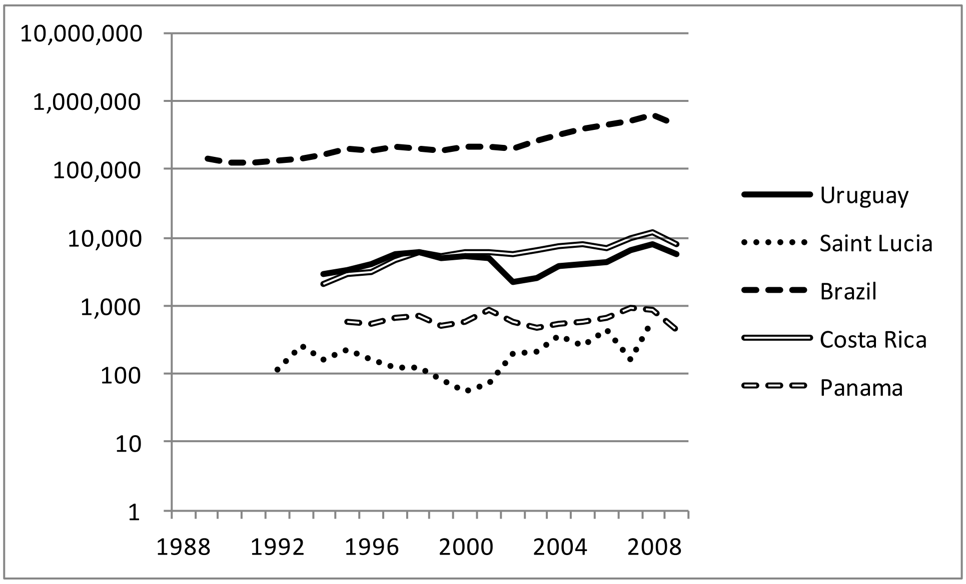


Figure 3-5-c. SO2 emission embodied in exports (Latin America)

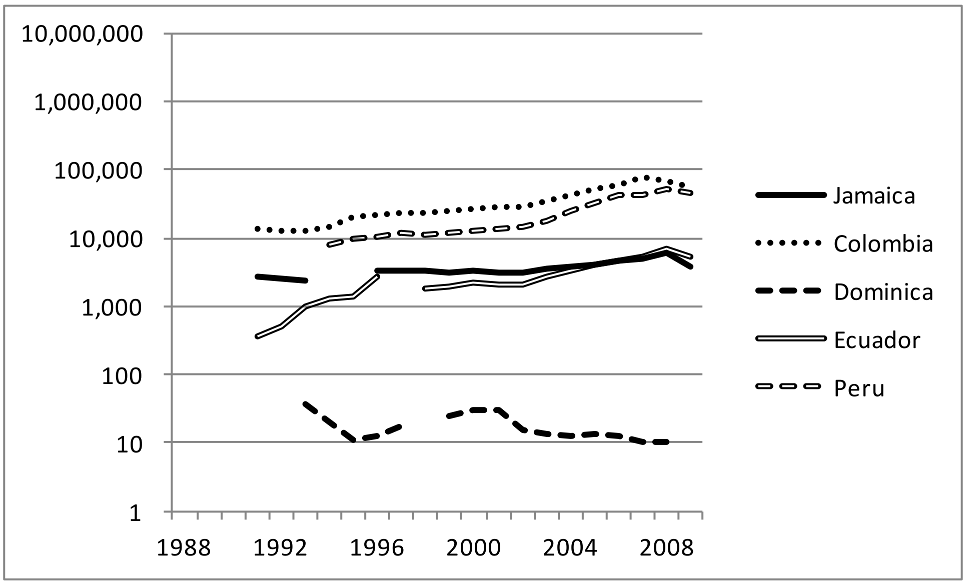


Figure 3-5-d. SO2 emission embodied in exports (Latin America)

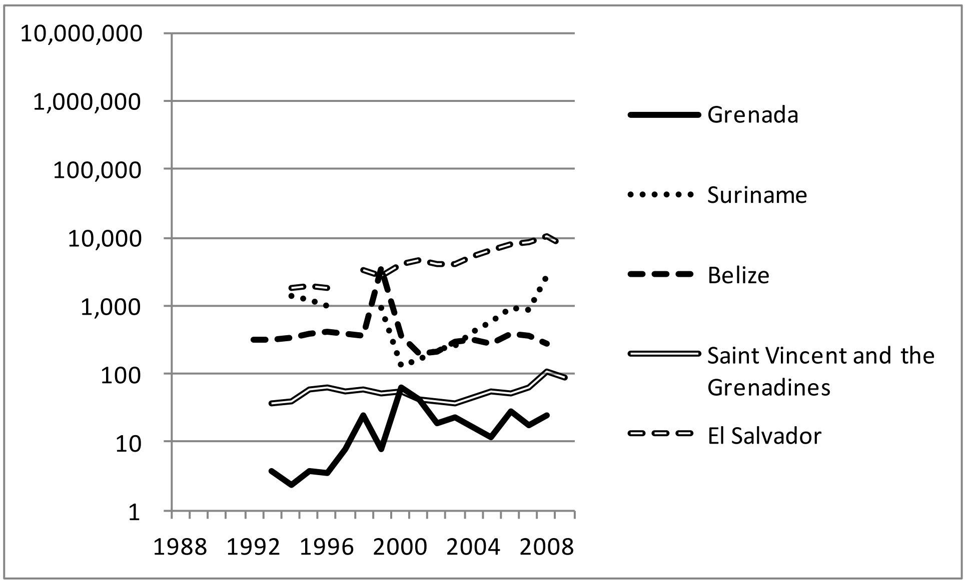


Figure 3-5-e. SO2 emission embodied in exports (Latin America)

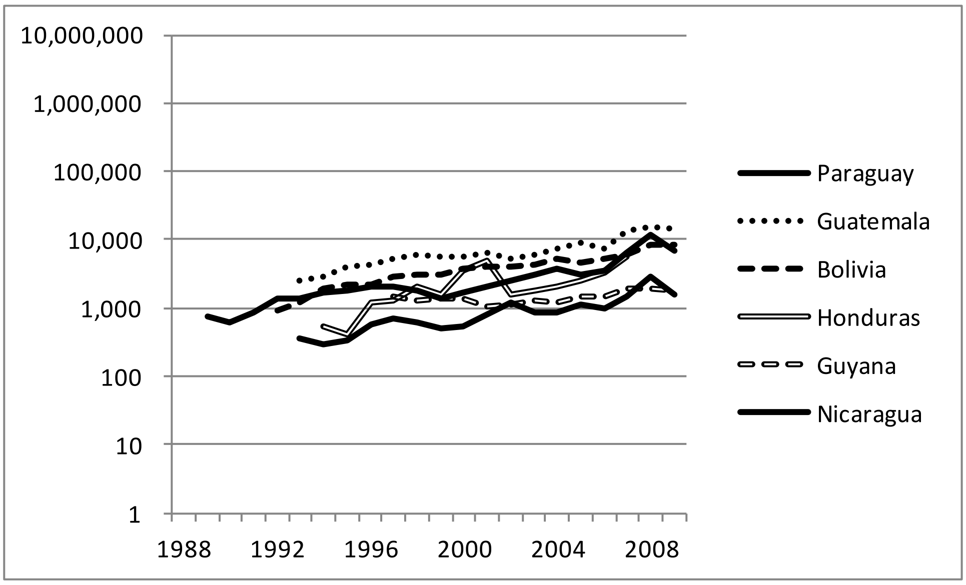


Figure 3-6-a. SO2 emission embodied in exports (Asia)

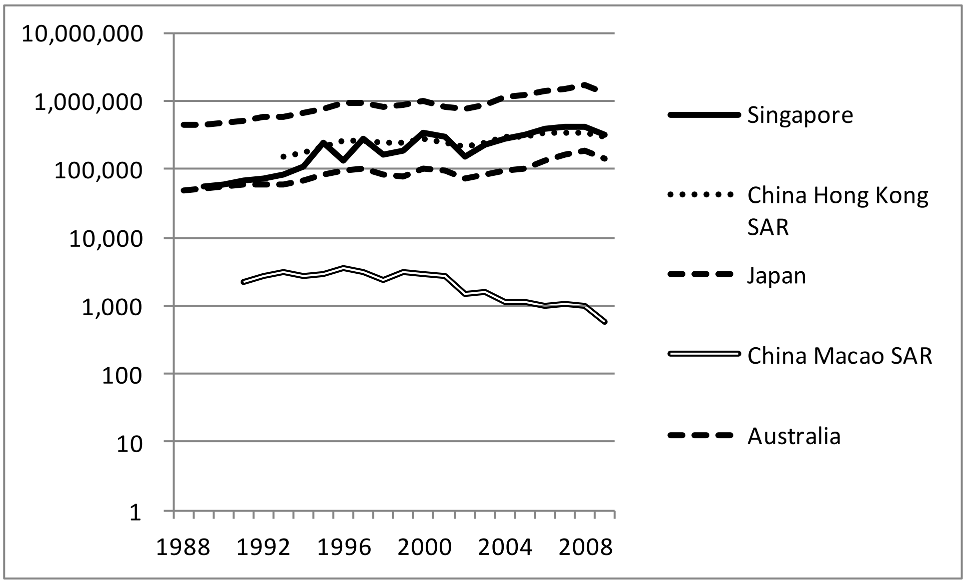


Figure 3-6-b. SO2 emission embodied in exports (Asia)

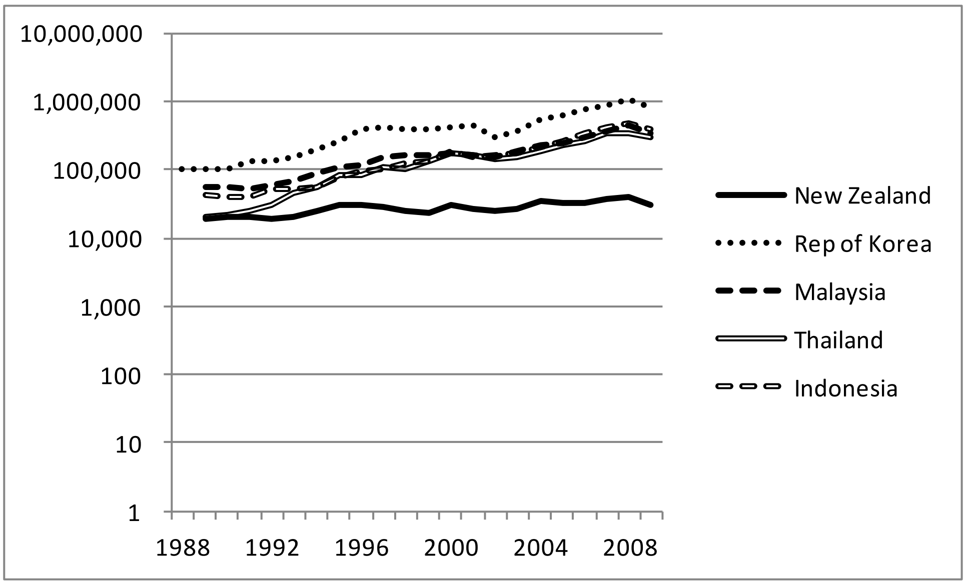


Figure 3-6-c. SO2 emission embodied in exports (Asia)

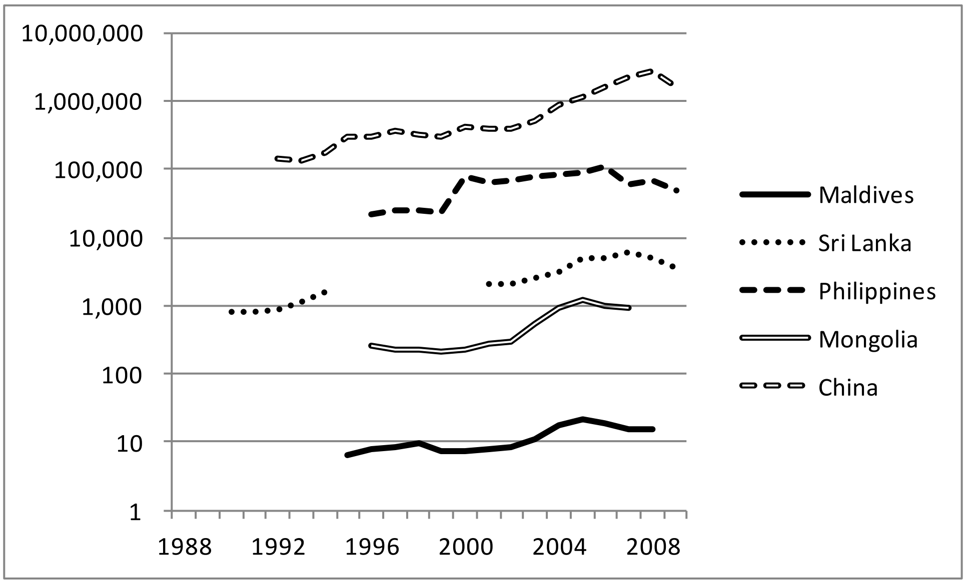


Figure 3-6-d. SO2 emission embodied in exports (Asia)

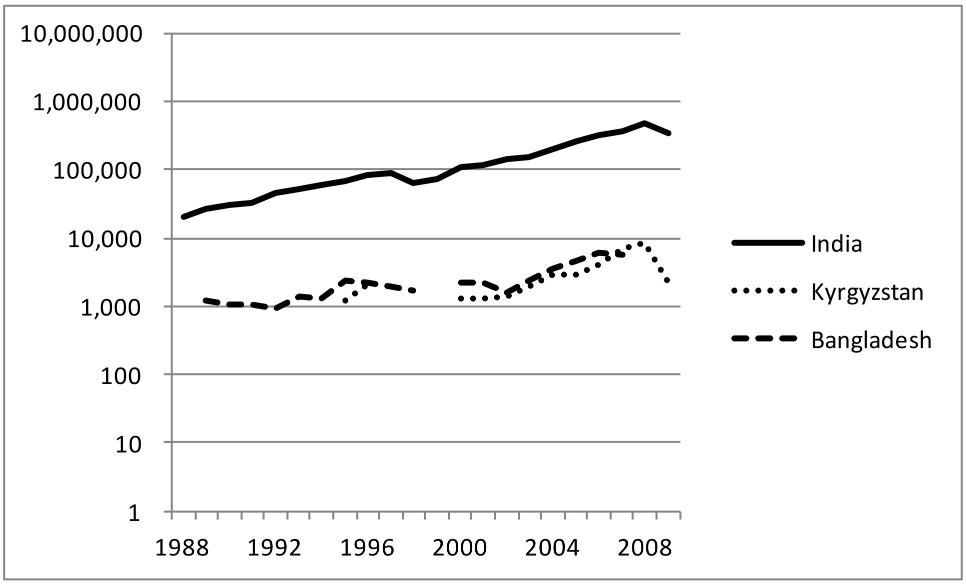


Figure 3-7-a. SO2 emission embodied in exports (Middle East)

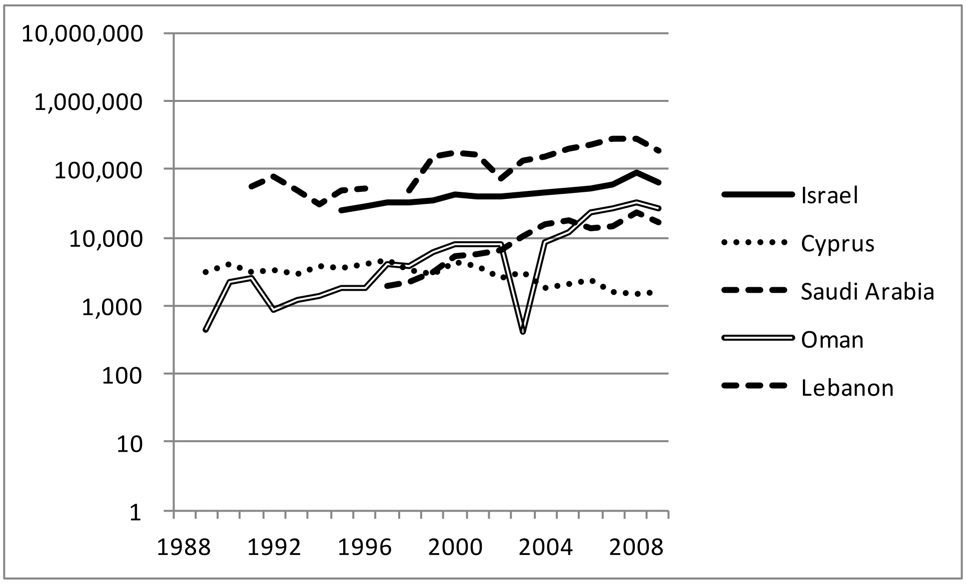


Figure 3-7-b. SO2 emission embodied in exports (Middle East)

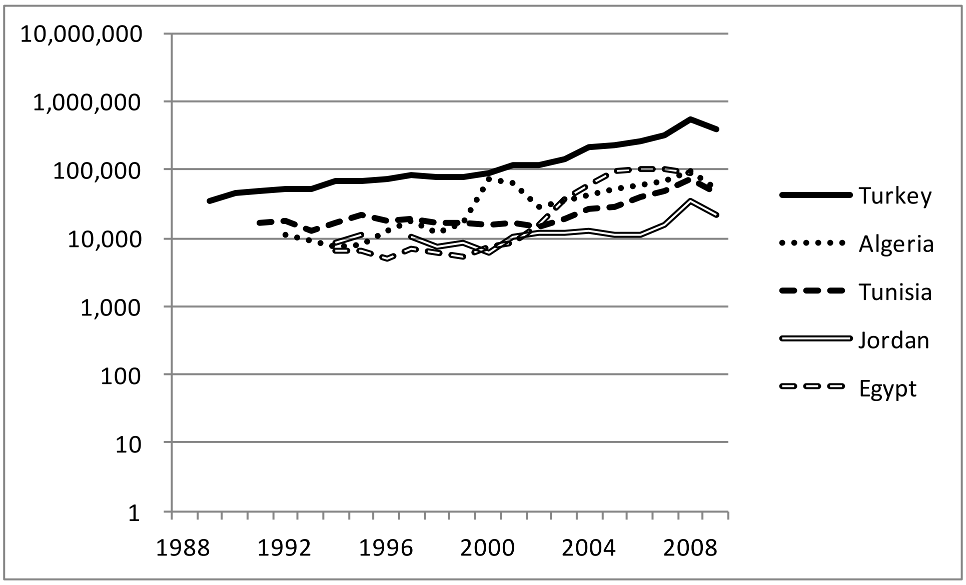


Figure 3-7-c. SO2 emission embodied in exports (Middle East)

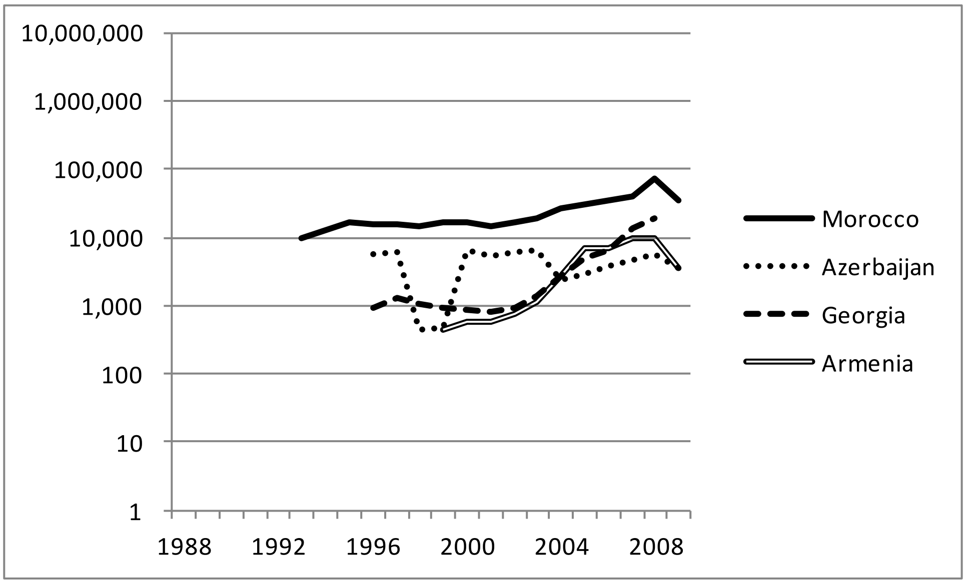


Figure 4. Pollution intensity of exports and imports by income country group

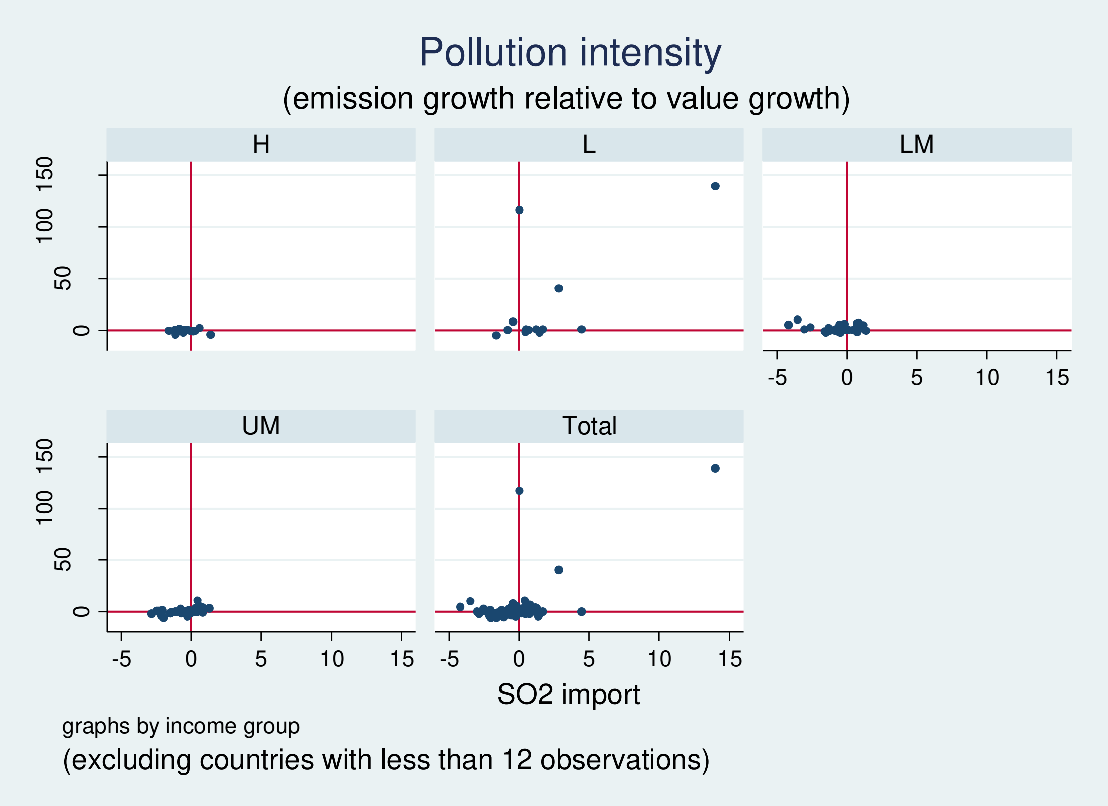


Figure 5-1-a: Export values and SO_2 emissions in Asia and Oceania

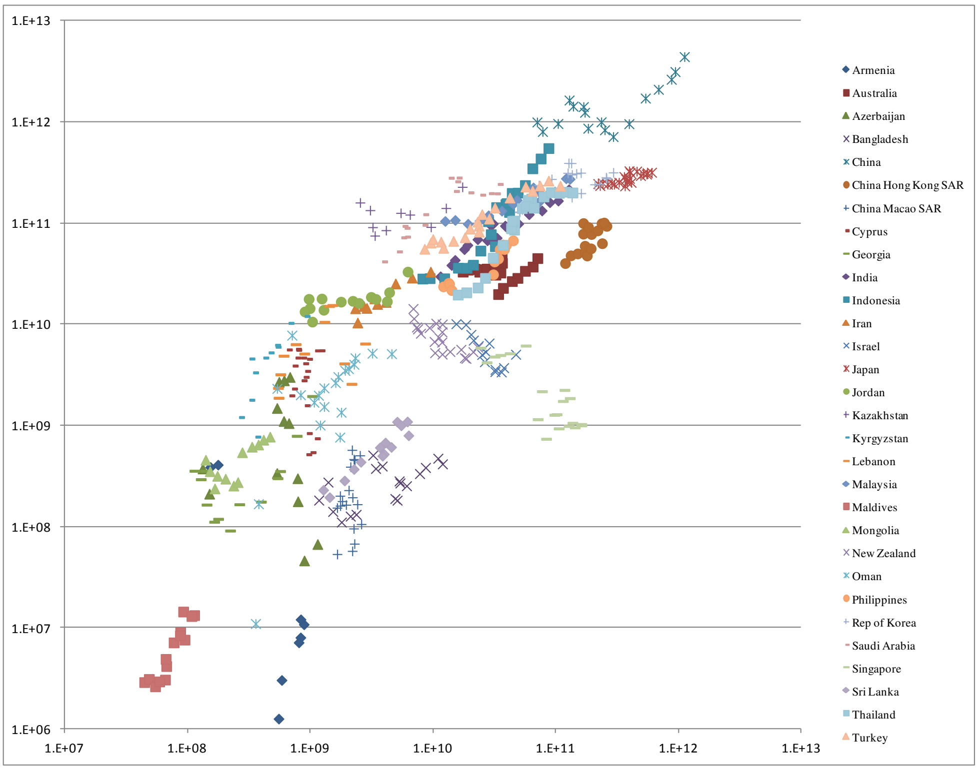


Figure 5-1-b: Export values and NO_2 emissions in Asia and Oceania

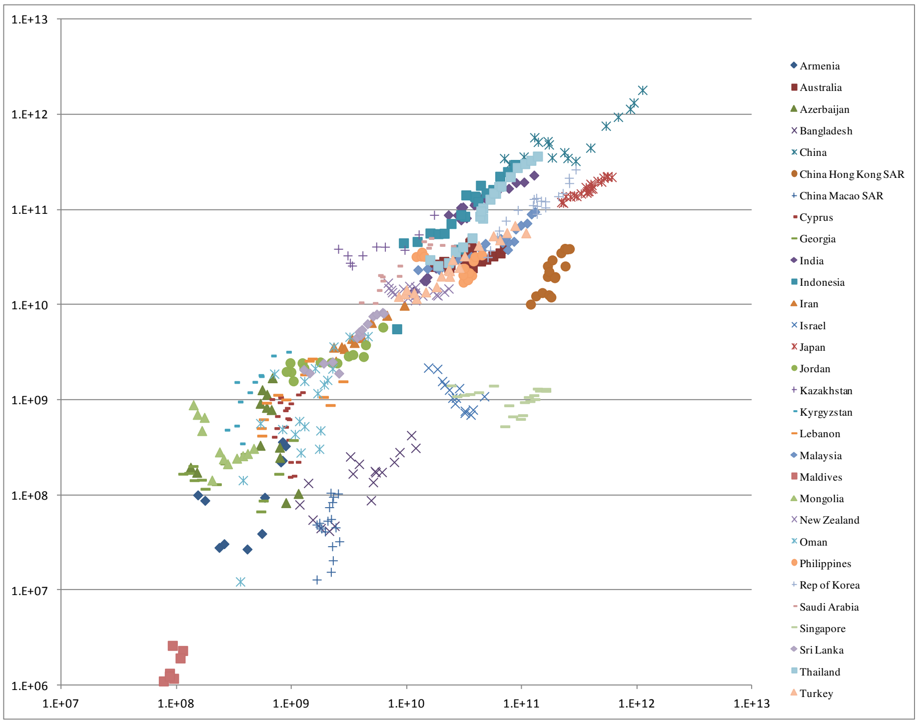
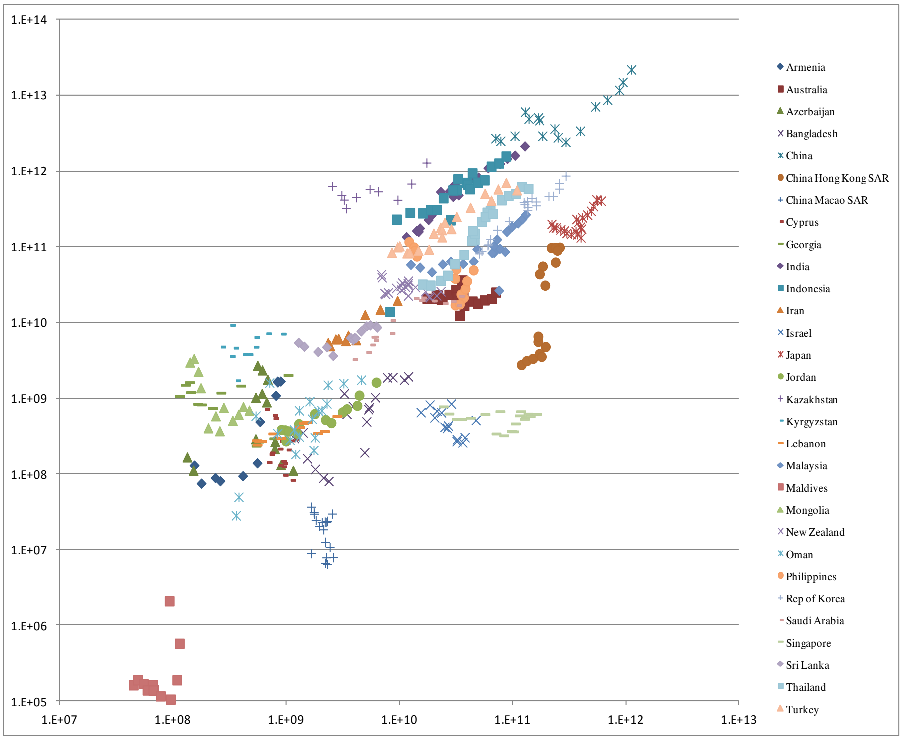


Figure 5-1-c: Export values and CO emissions in Asia and Oceania



Note: Horizontal axis denotes exported values and vertical axis denotes pollution emission. These values are scaled in the logarithm.

Figure 5-2-a: Export values and SO_2 emissions in Americas

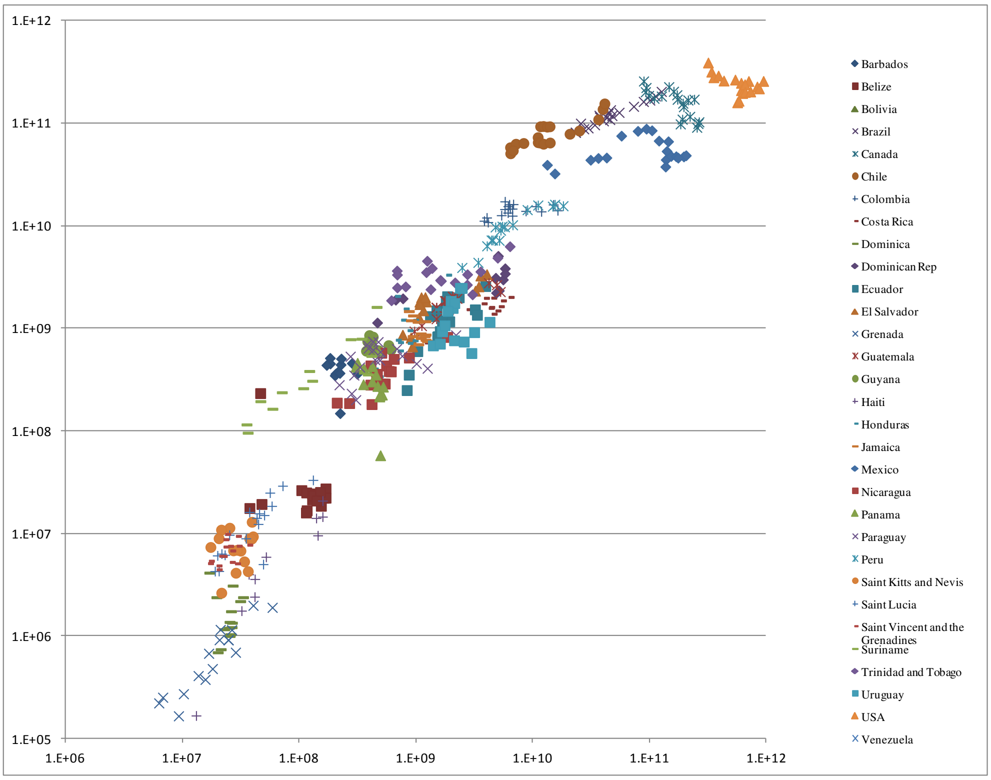


Figure 5-2-b: Export values and NO_2 emissions in Americas

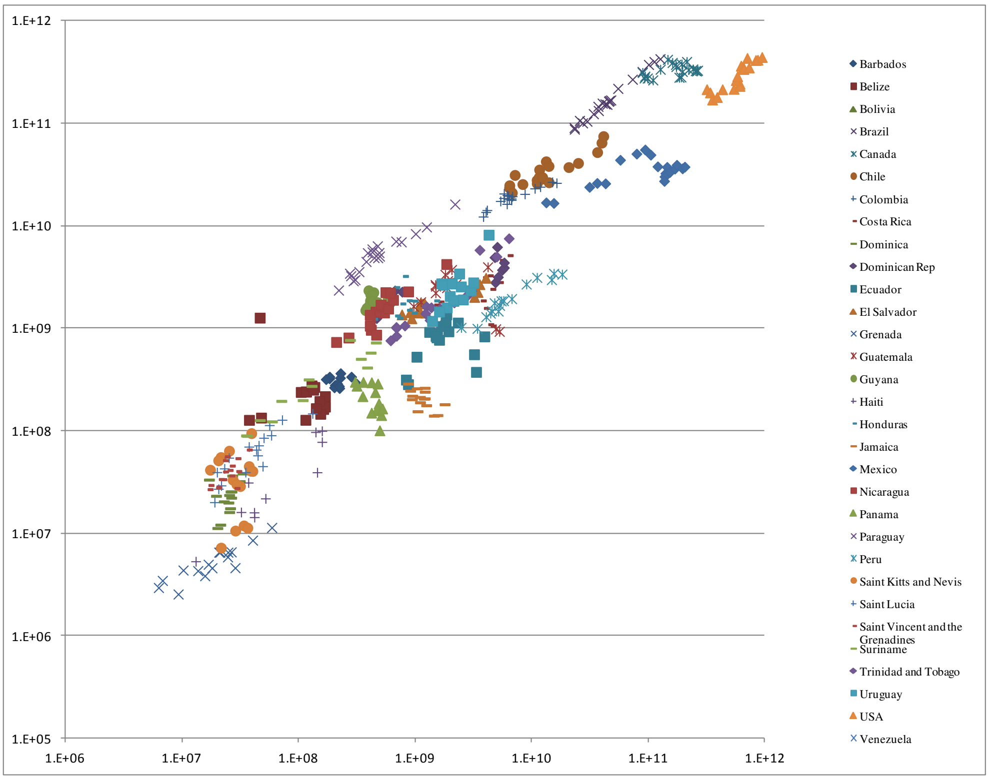
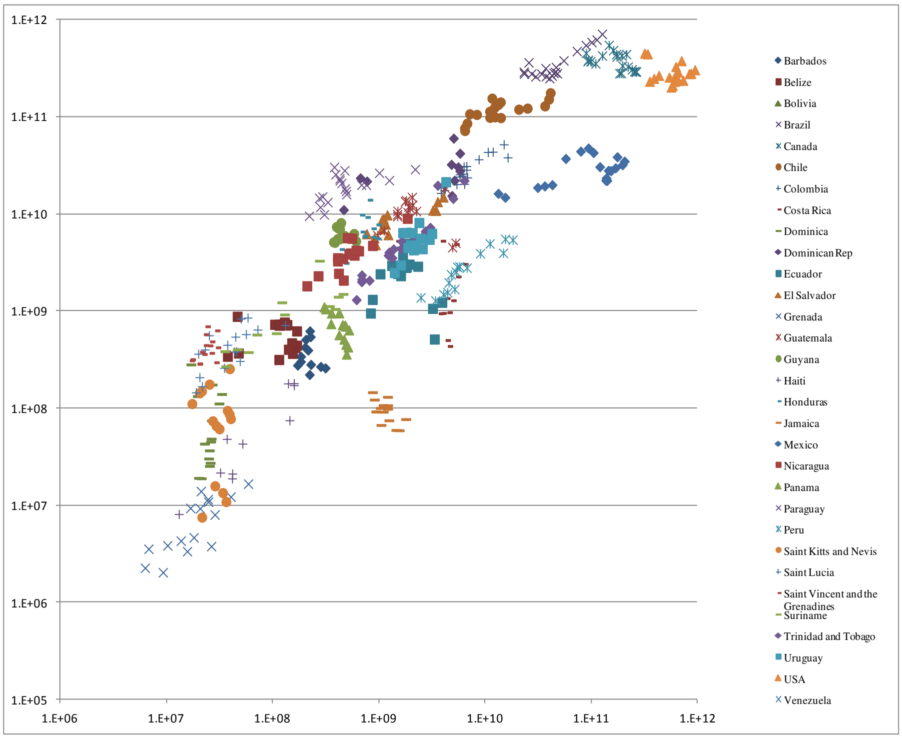


Figure 5-2-c: Export values and CO emissions in Americas



Note: Horizontal axis denotes exported values and vertical axis denotes pollution emission. These values are scaled in the logarithm.

Figure 5-3-a: Export values and SO_2 emissions in Africa

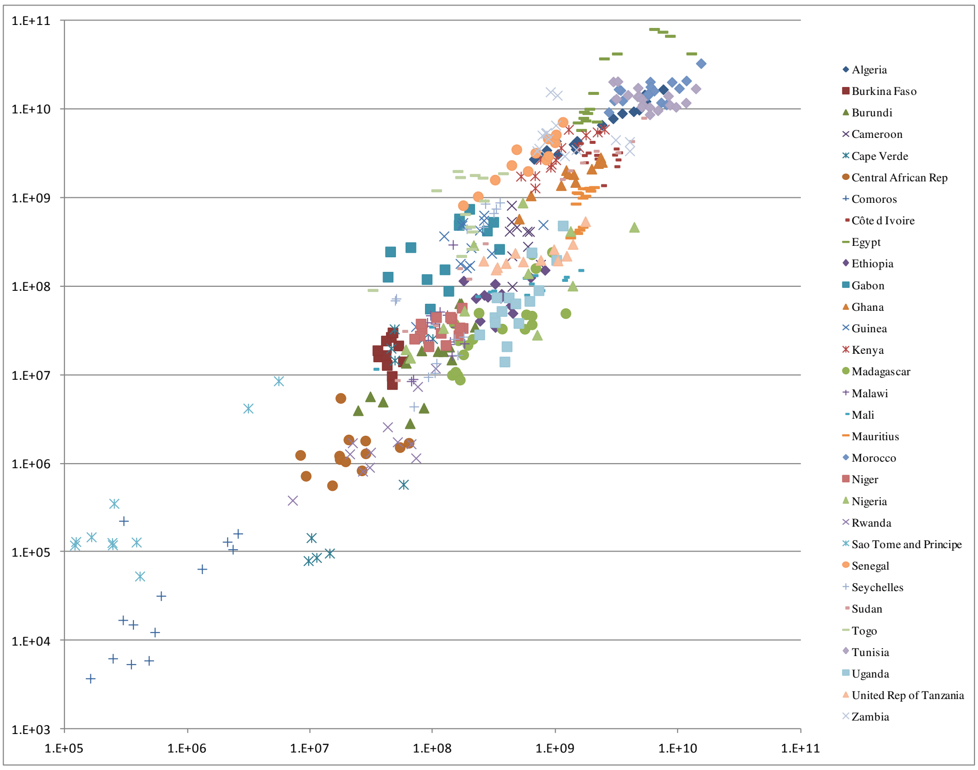


Figure 5-3-b: Export values and NO_2 emissions in Africa

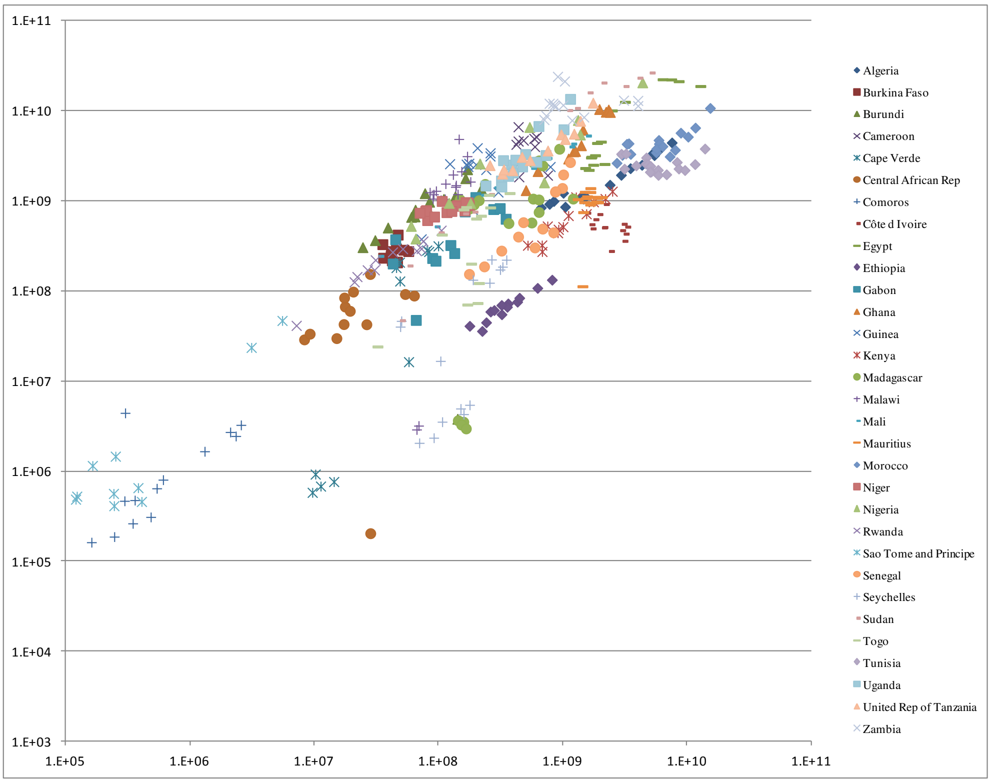
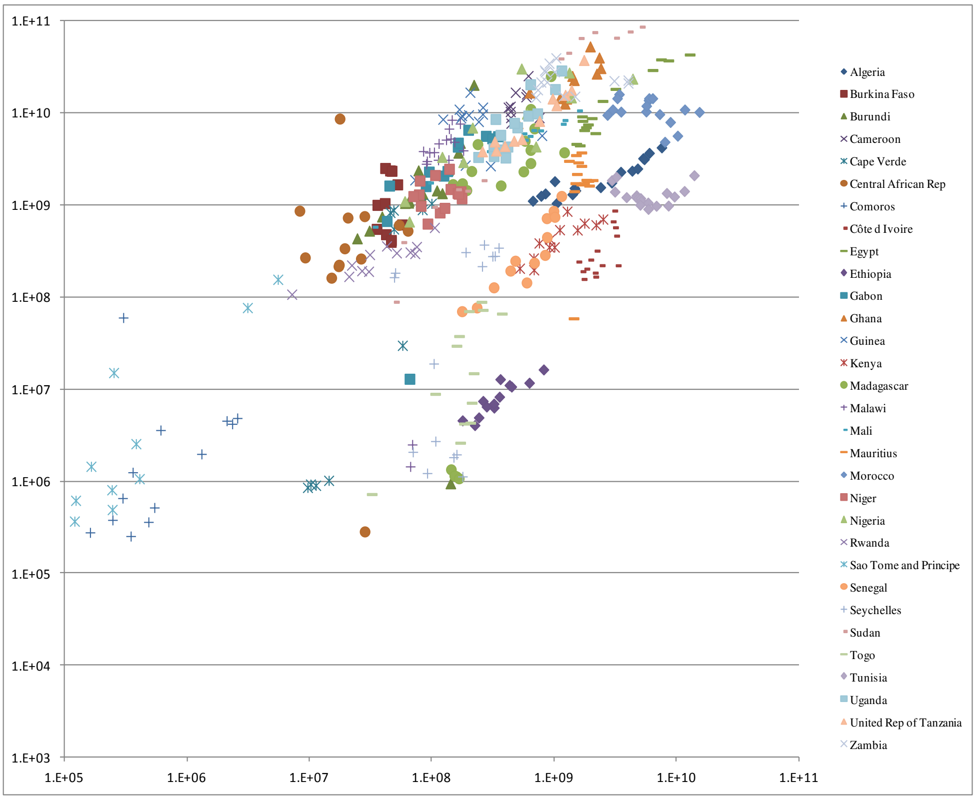


Figure 5-3-c: Export values and CO emissions in Africa



Note: Horizontal axis denotes exported values and vertical axis denotes pollution emission. These values are scaled in the logarithm.

Figure 5-4-a: Export values and SO_2 emissions in Europe

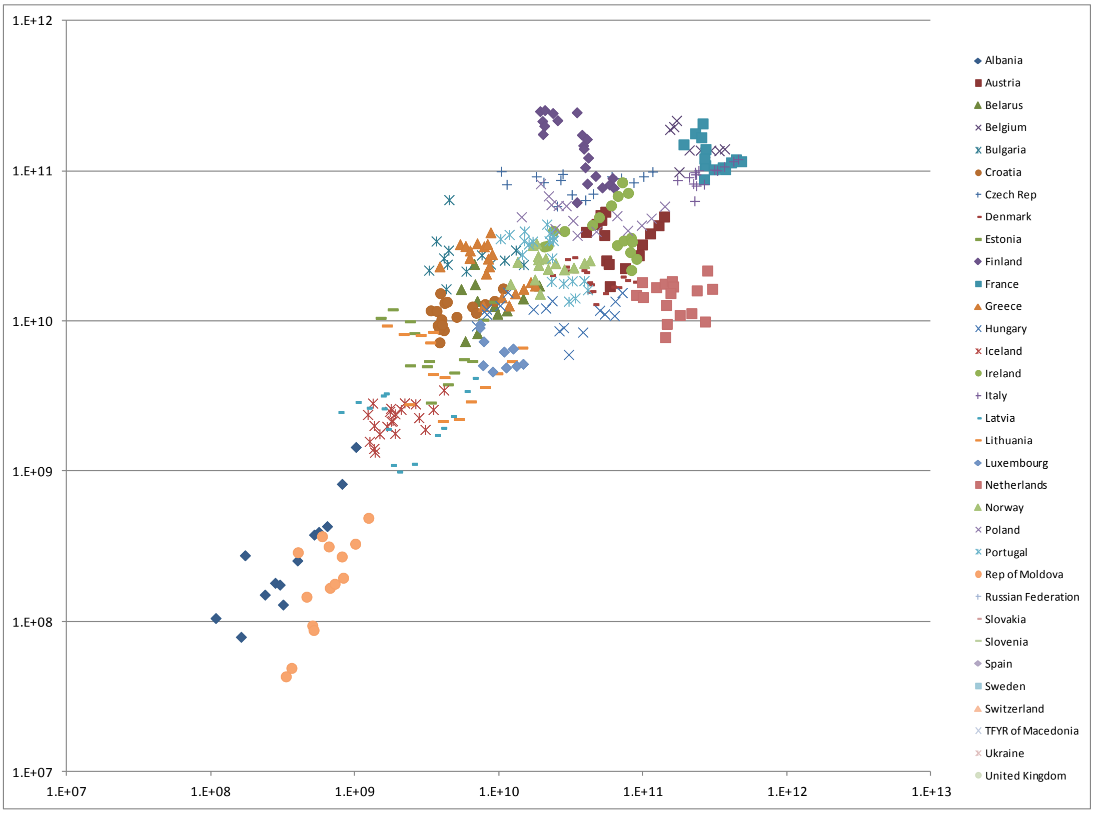


Figure 5-4-b: Export values and NO_2 emissions in Europe

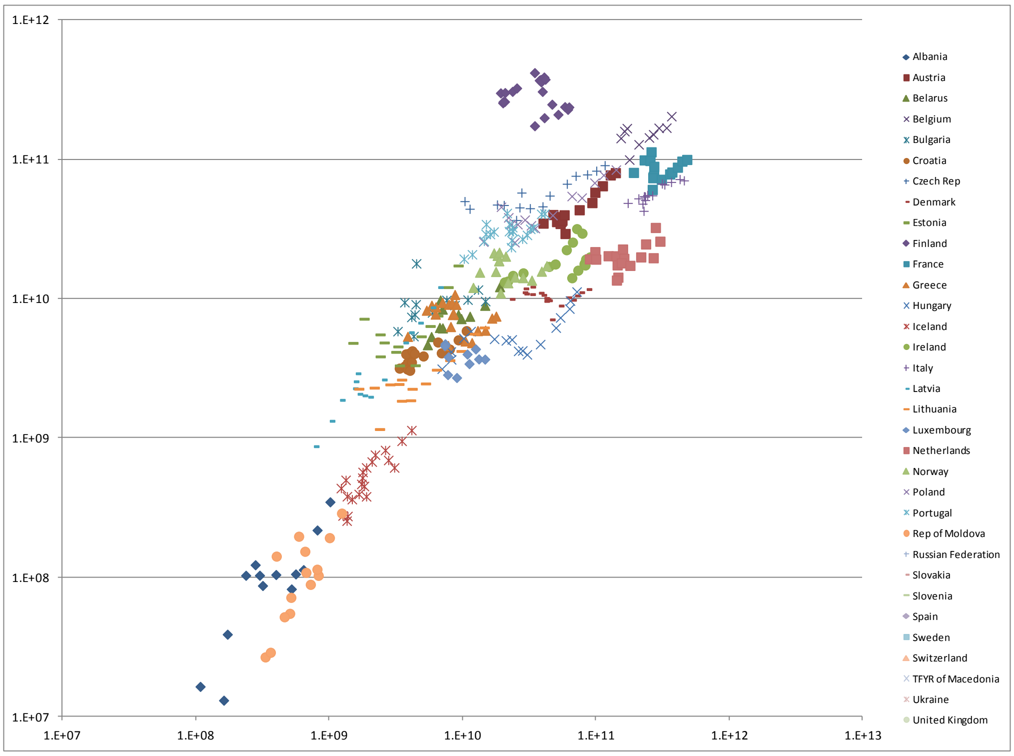
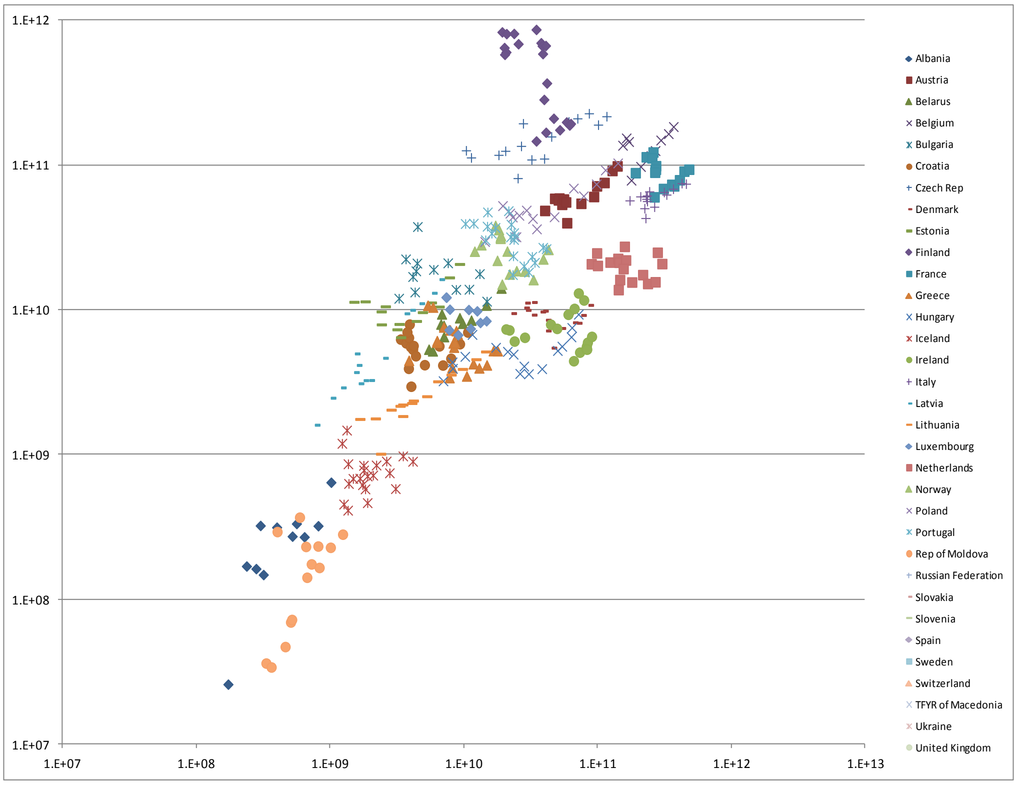


Figure 5-4-c: Export values and CO emissions in Europe



Note: Horizontal axis denotes exported values and vertical axis denotes pollution emission. These values are scaled in the logarithm.

Figure 6-1. Unadjusted and Adjusted SO_2 emissions of exporting countries (2000)

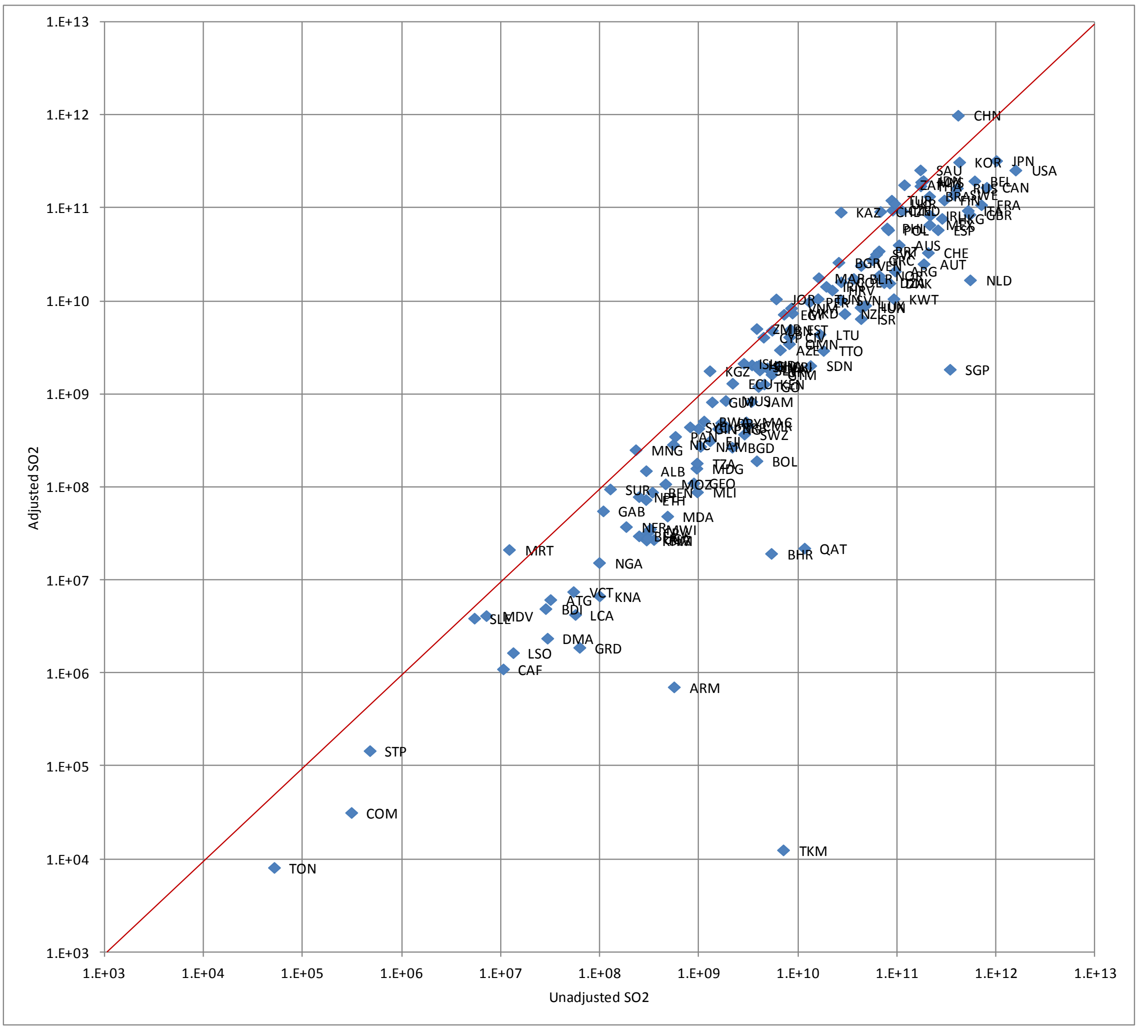


Figure 6-2. Unadjusted and Adjusted NO_2 emissions of exporting countries (2000)

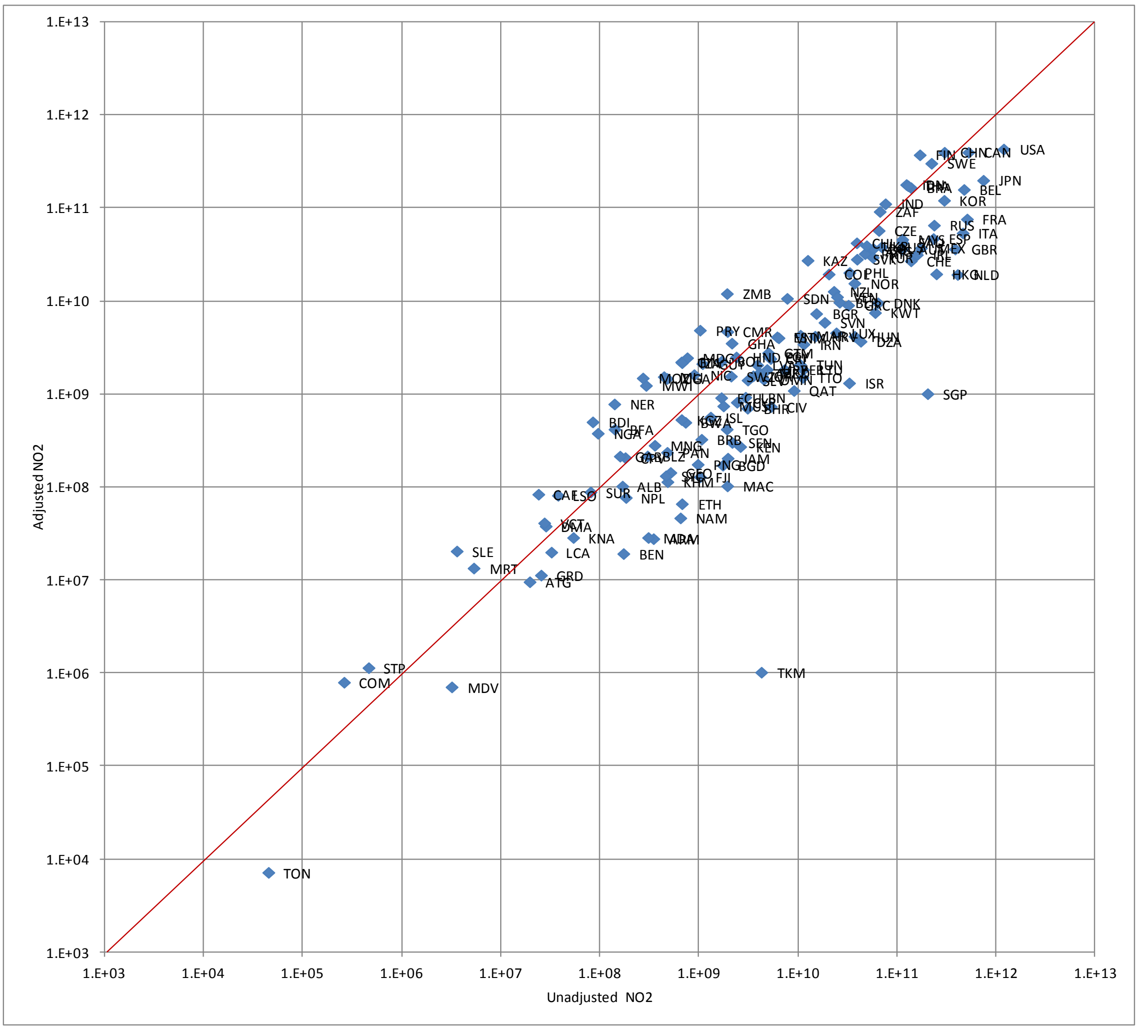


Figure 6-3. Unadjusted and Adjusted CO emissions of exporting countries (2000)

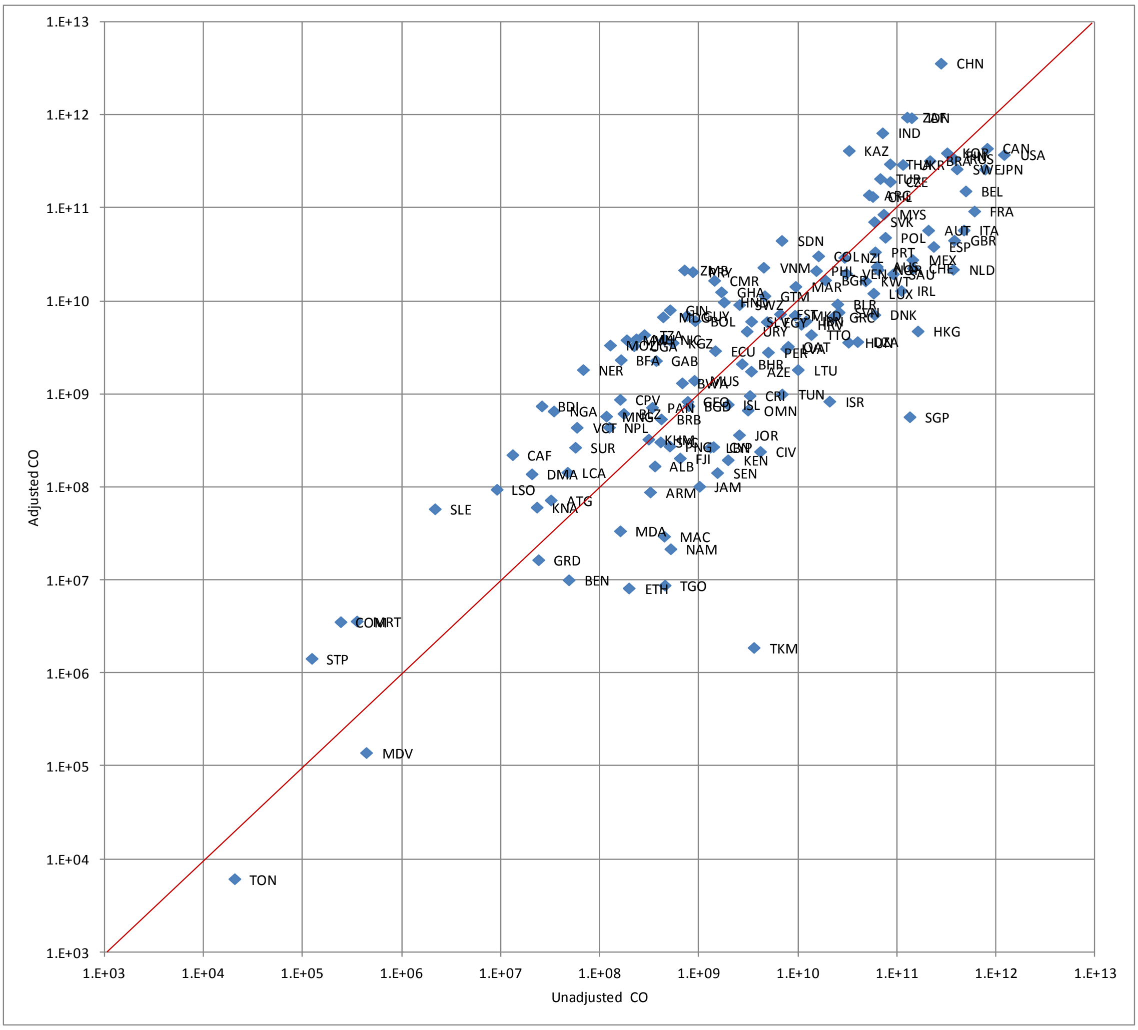


Figure 7-1. Unadjusted and Adjusted SO_2 emissions of importing countries (2000)

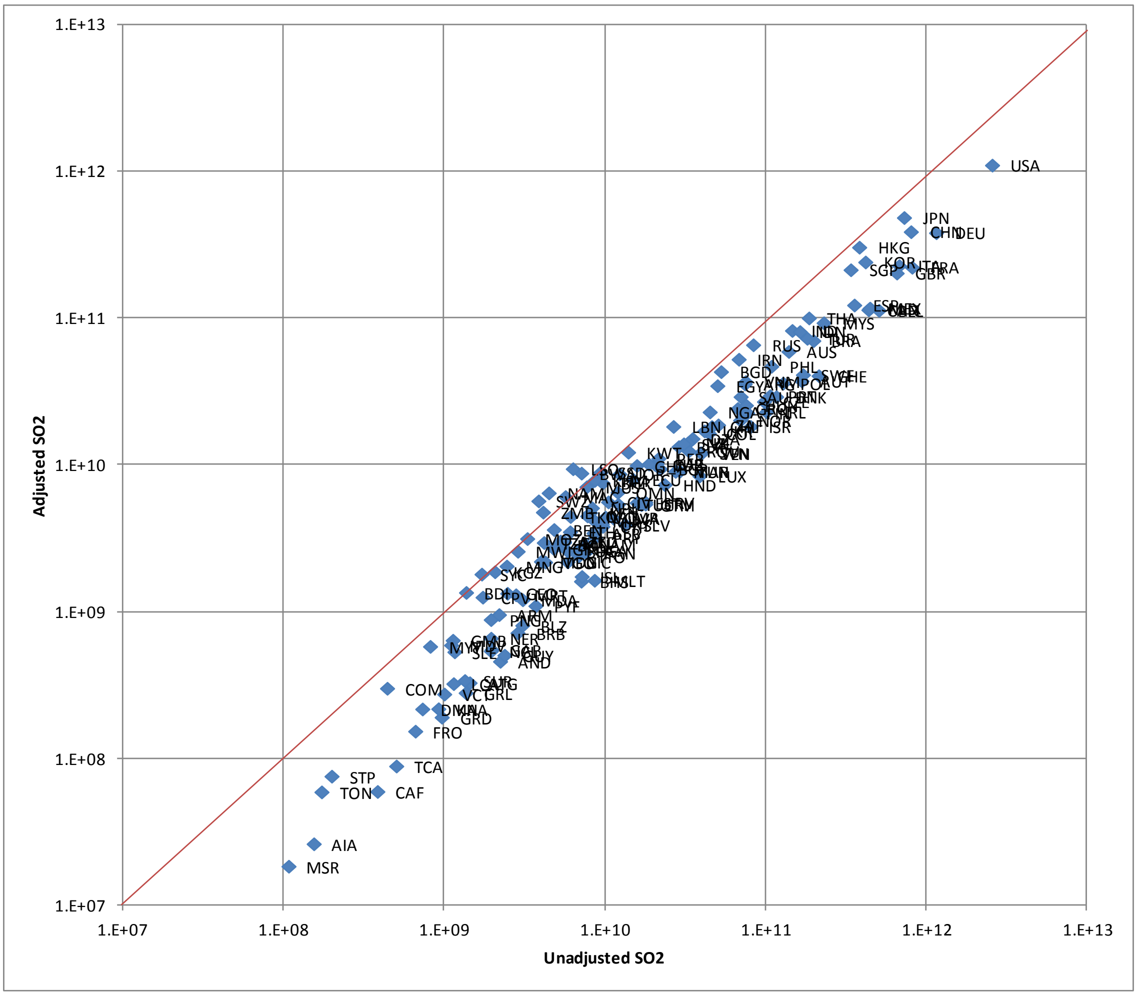


Figure 7-2. Unadjusted and Adjusted NO_2 emissions of importing countries (2000)

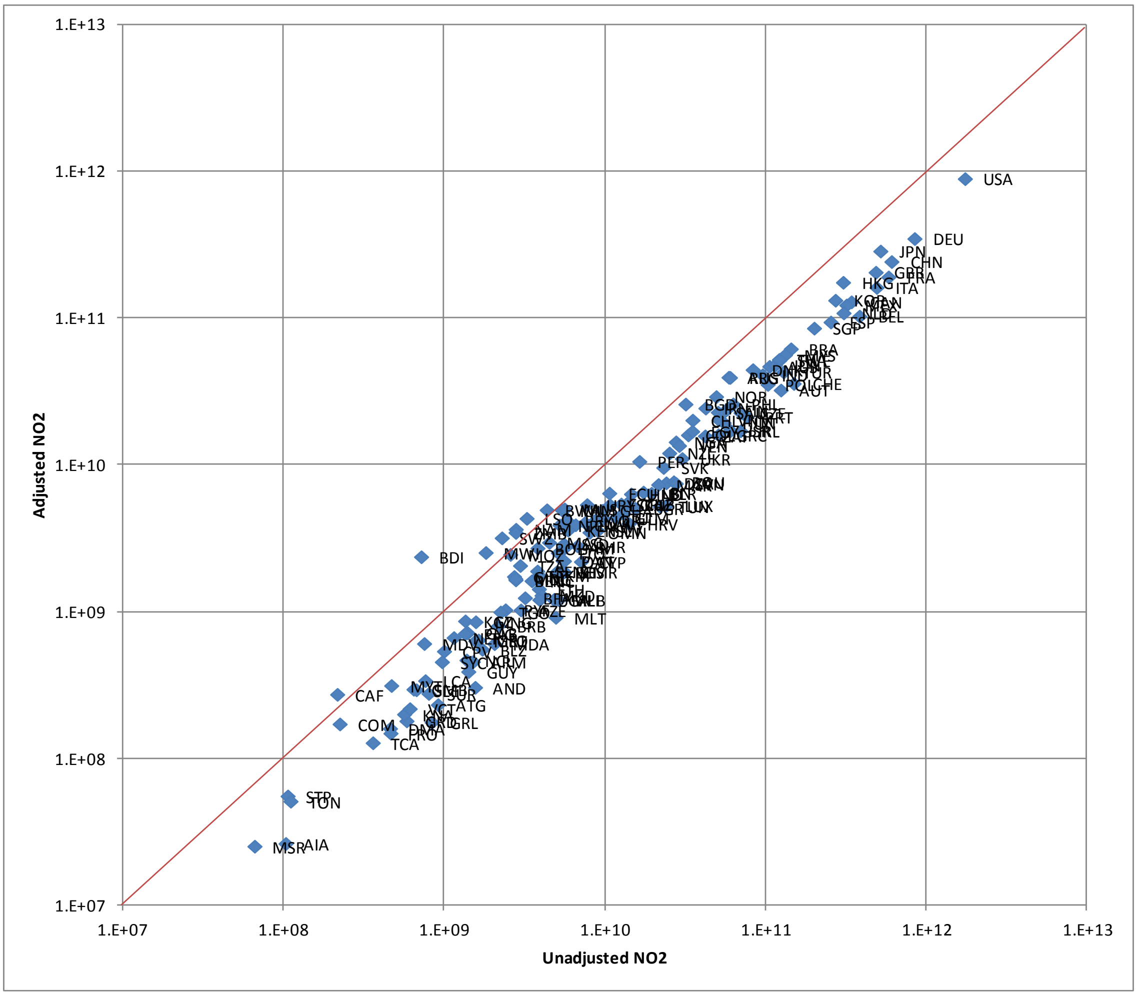


Figure 7-3. Unadjusted and Adjusted CO emissions of importing countries (2000)

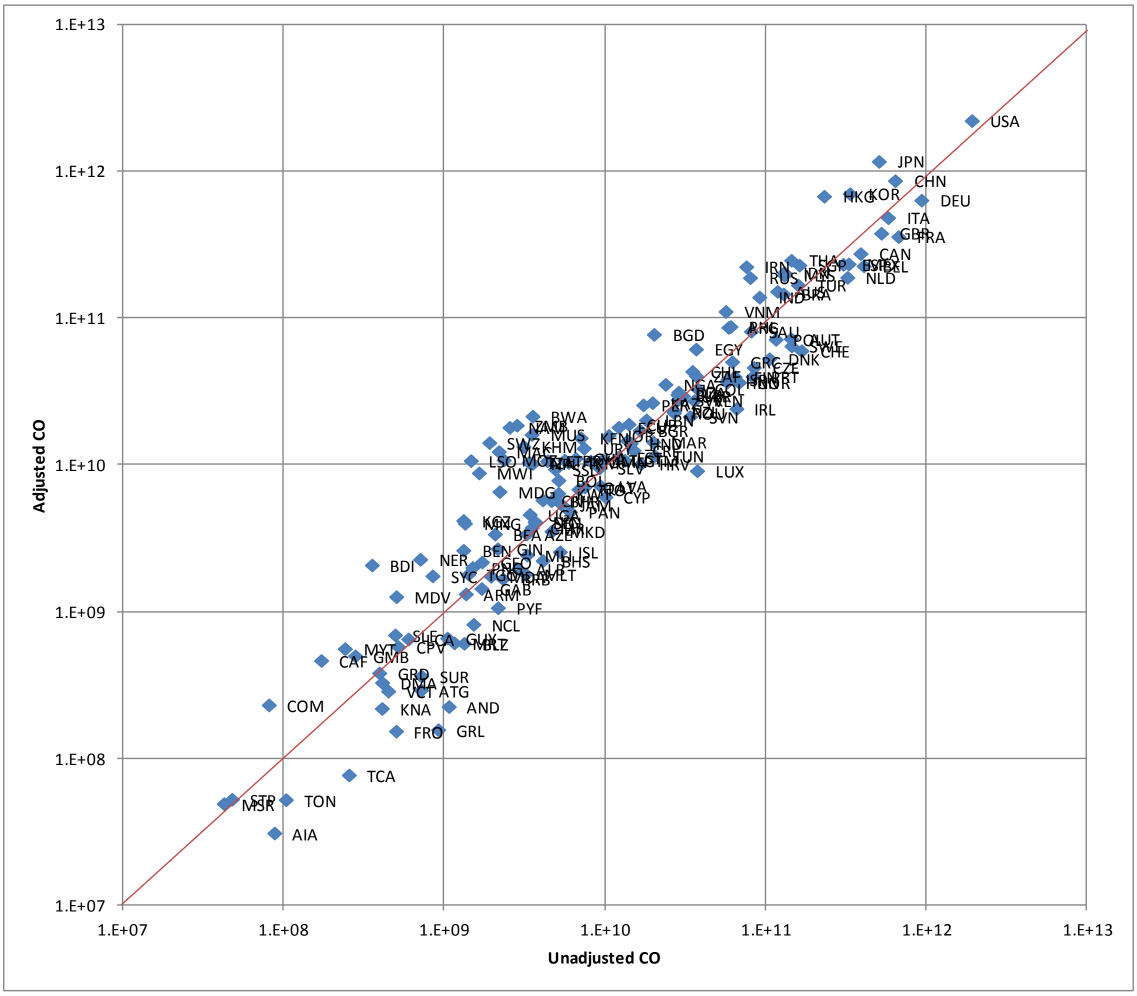


Figure 8-1. Brazil's export and its pollution emissions

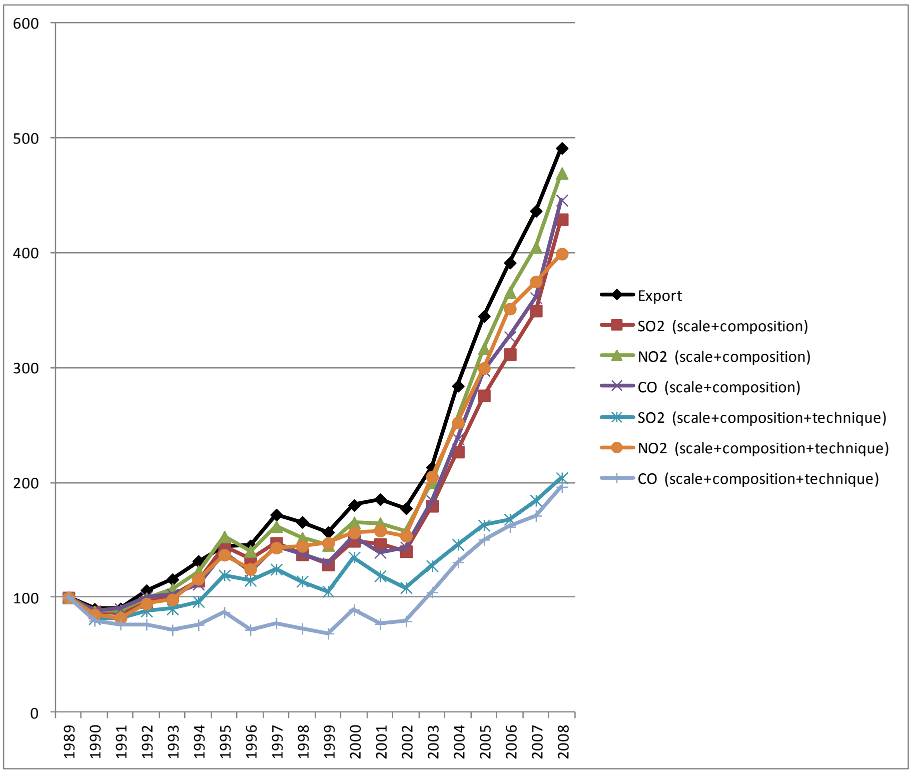


Figure 8-2. China's export and its pollution emissions

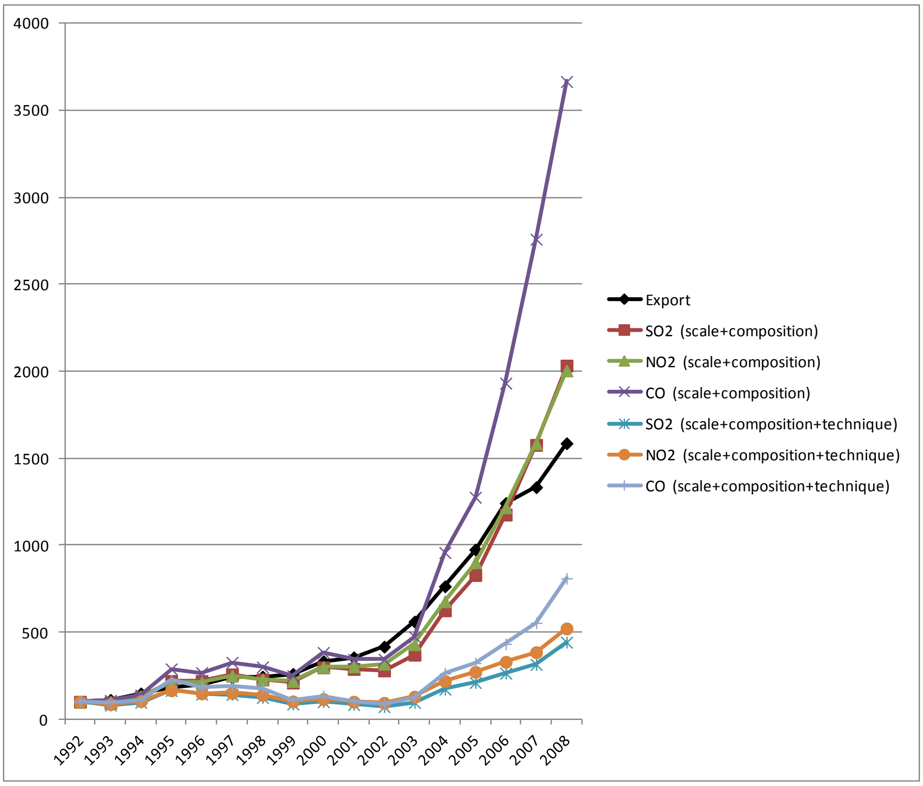


Figure 8-3. India's export and its pollution emissions

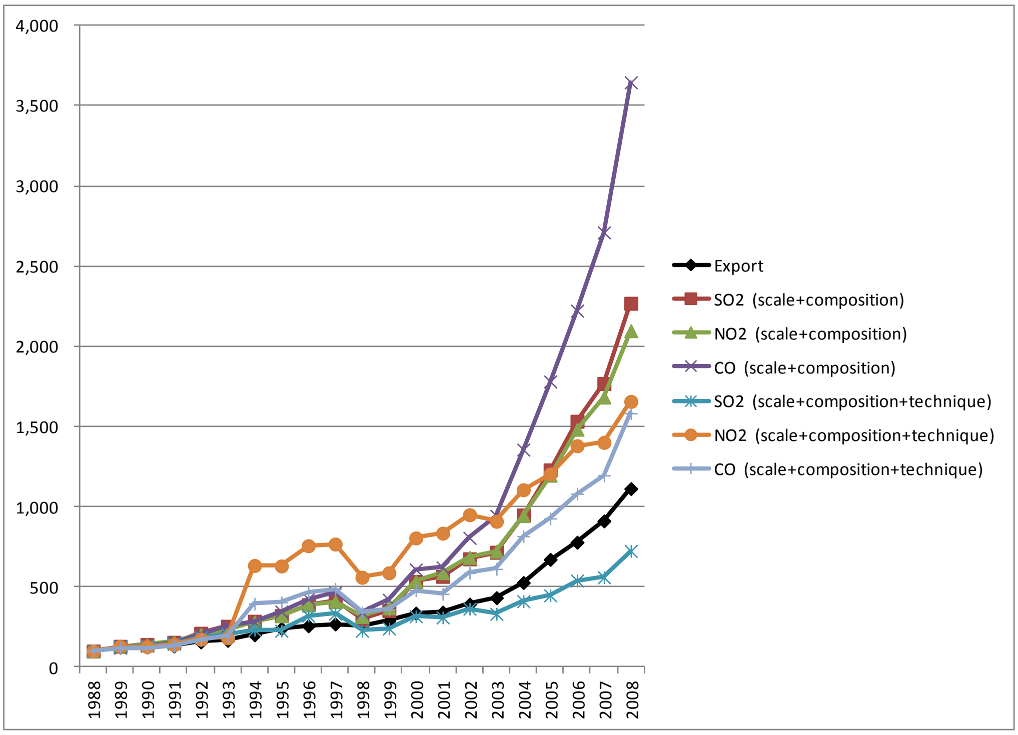


Figure 8-4. Russia's export and its pollution emissions

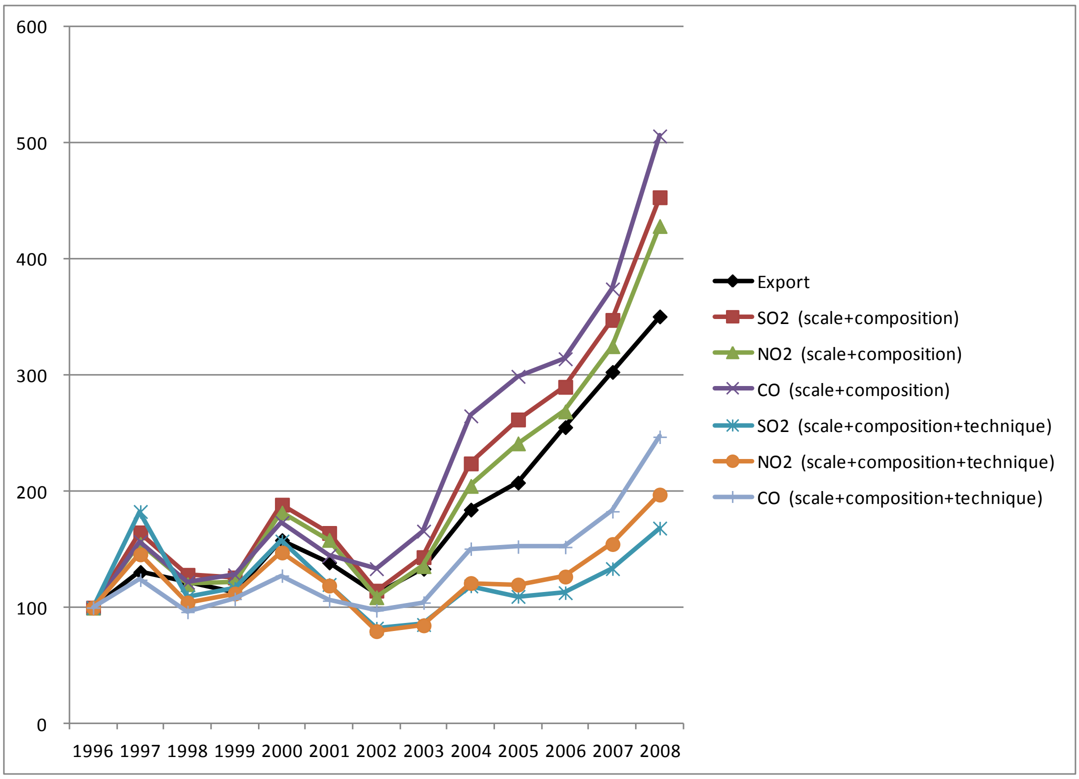


Figure 8-5. Japan's export and its pollution emissions

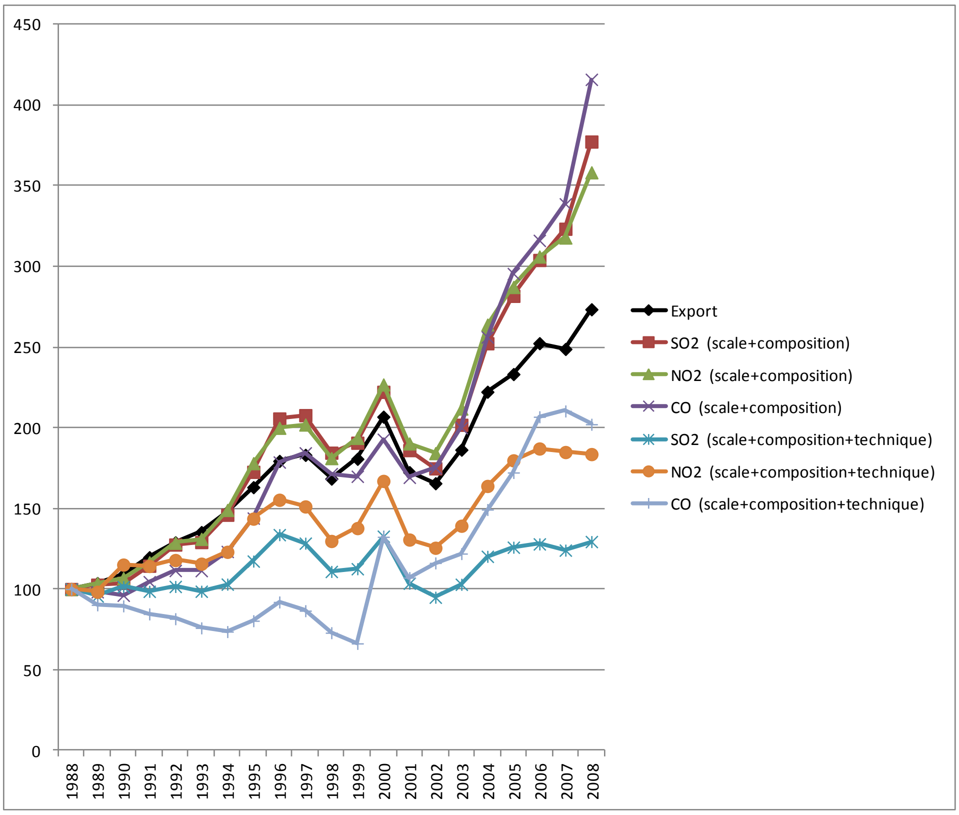


Figure 8-6. Mexico's export and its pollution emissions

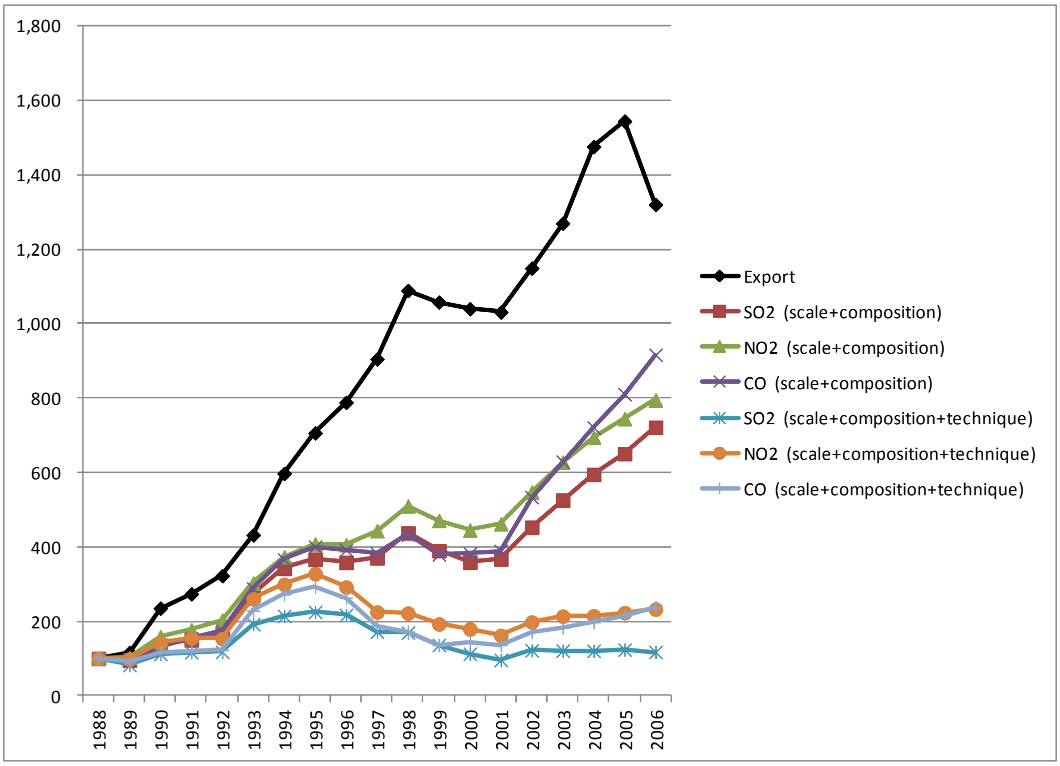


Figure 8-7. The US export and its pollution emissions

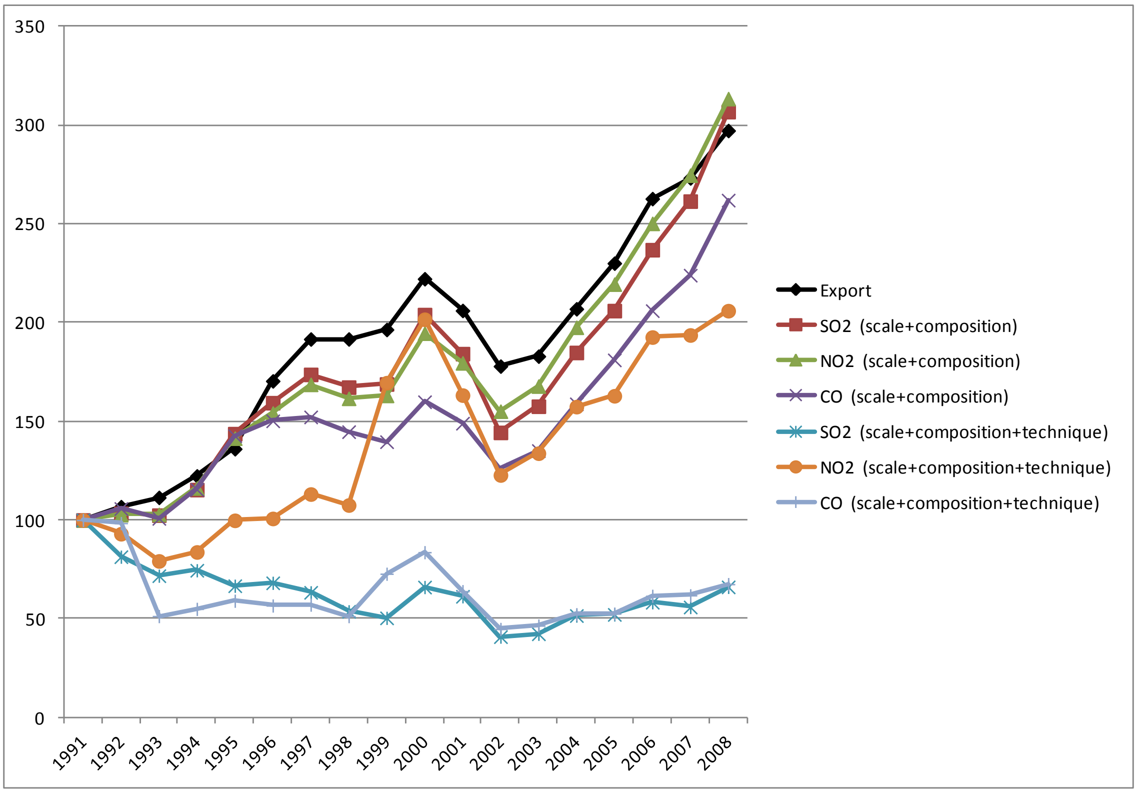


Figure 9-1. Brazil’s import and its pollution emissions

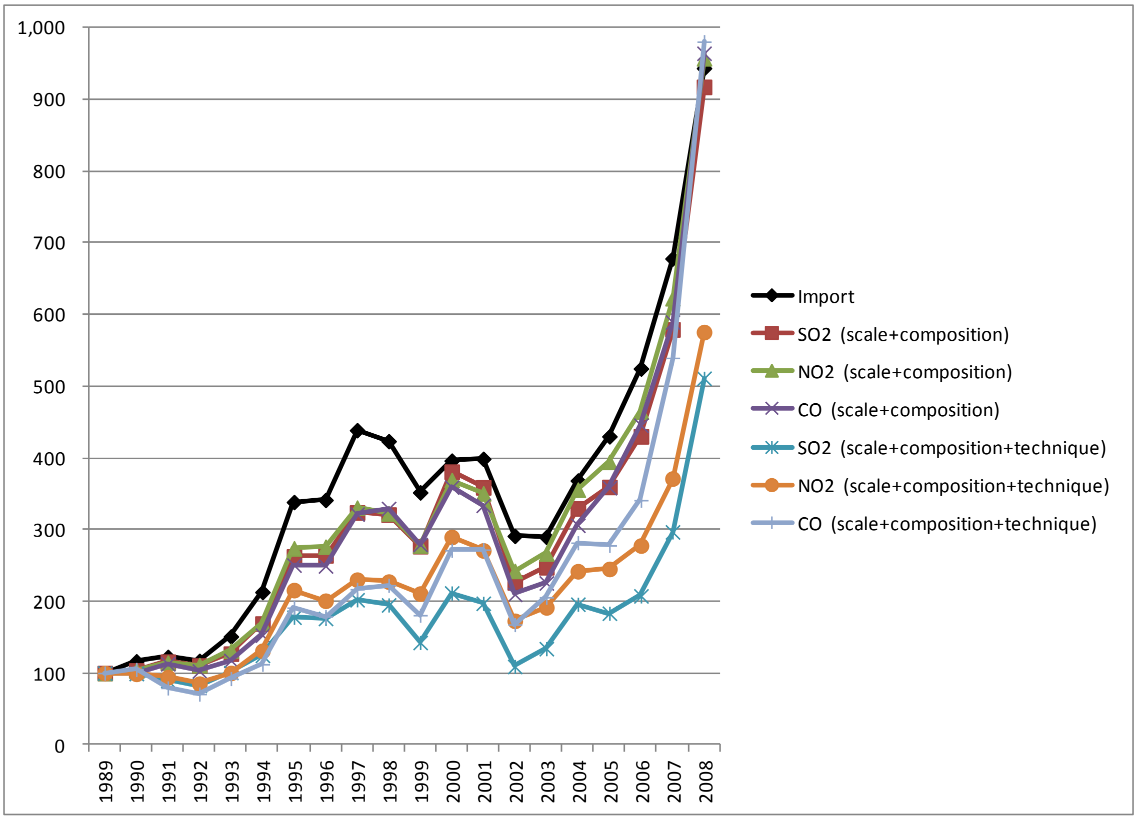


Figure 9-2. China's import and its pollution emissions

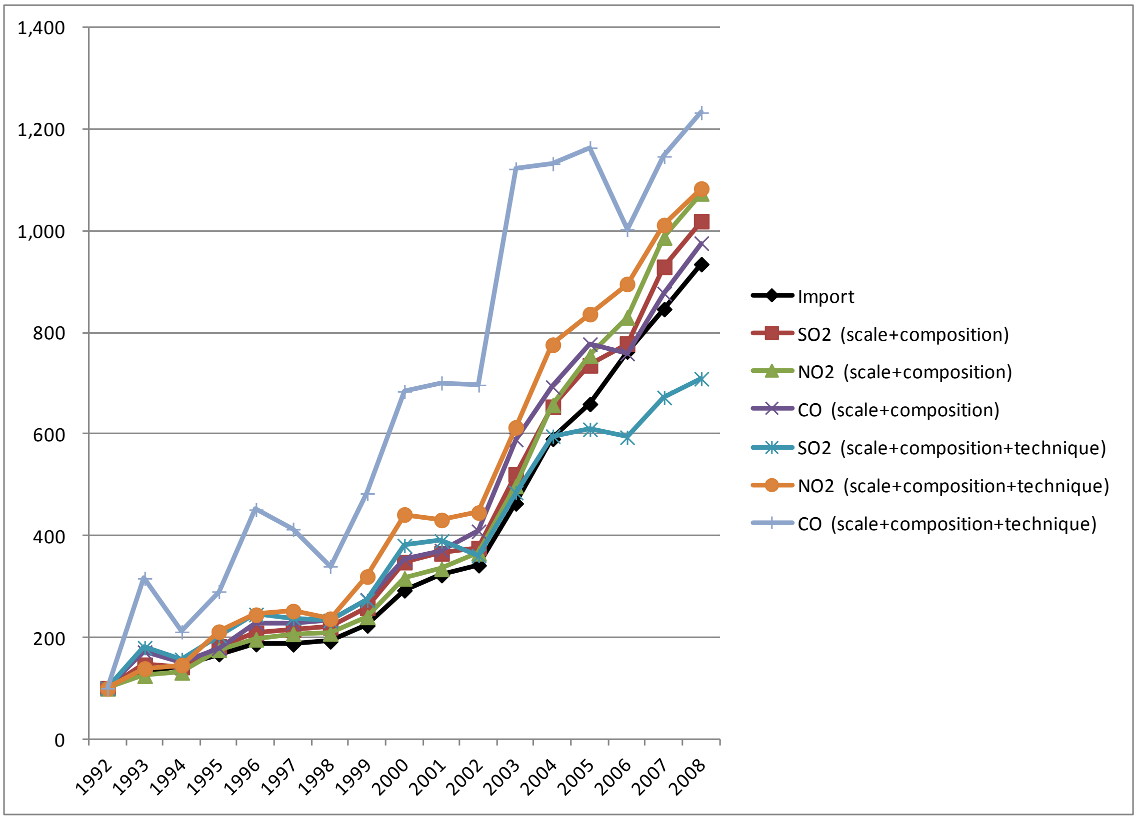


Figure 9-3. India's import and its pollution emissions

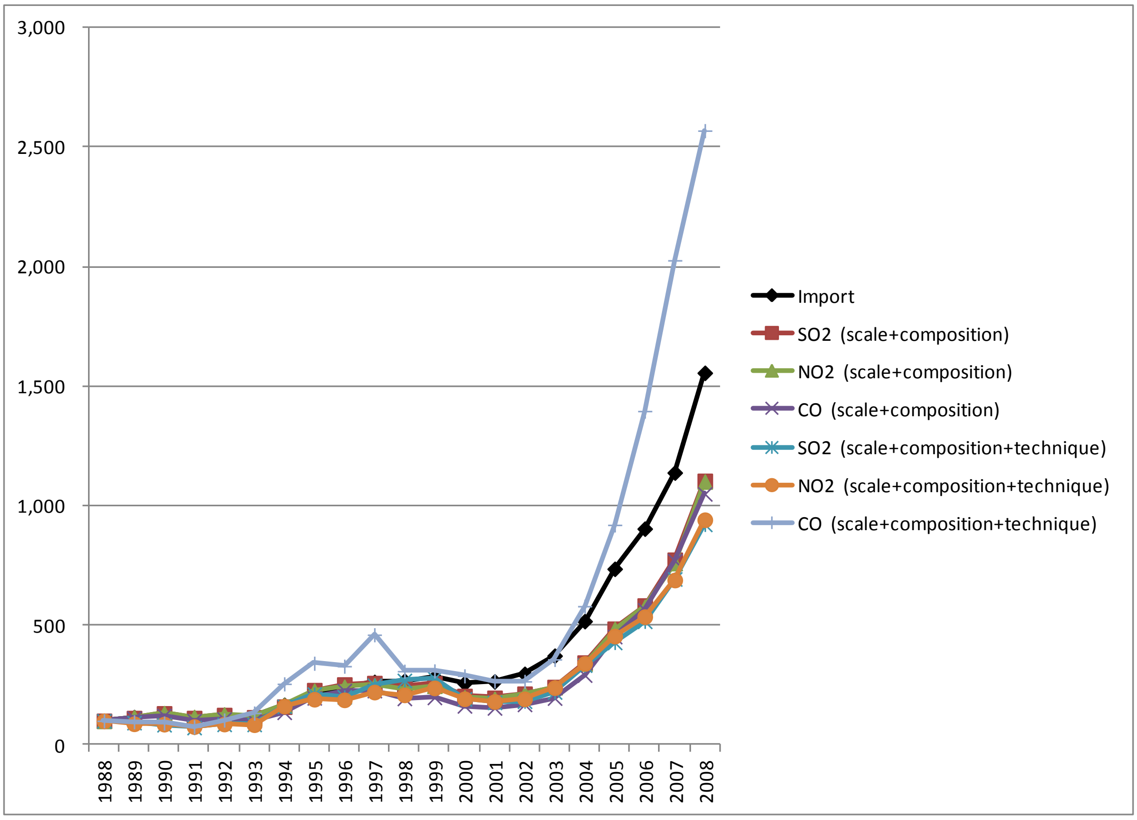


Figure 9-4. Russia's import and its pollution emissions

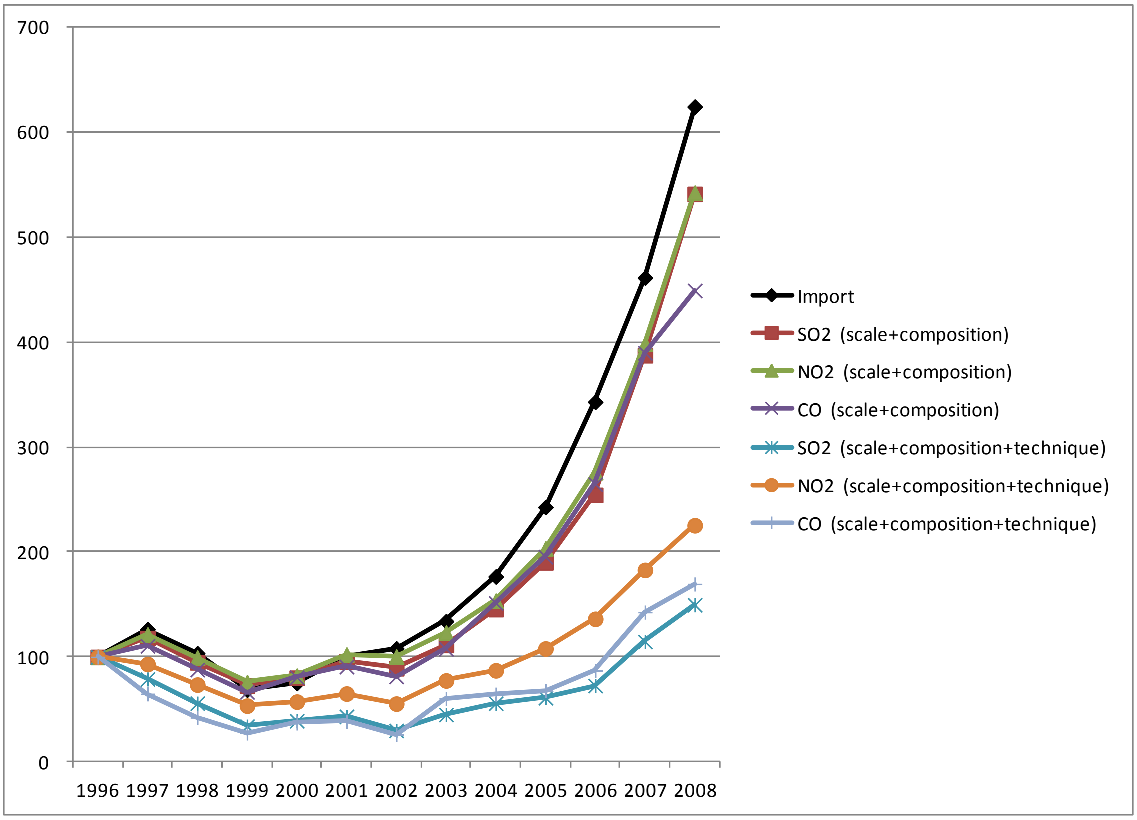


Figure 9-5. Japan's import and its pollution emissions

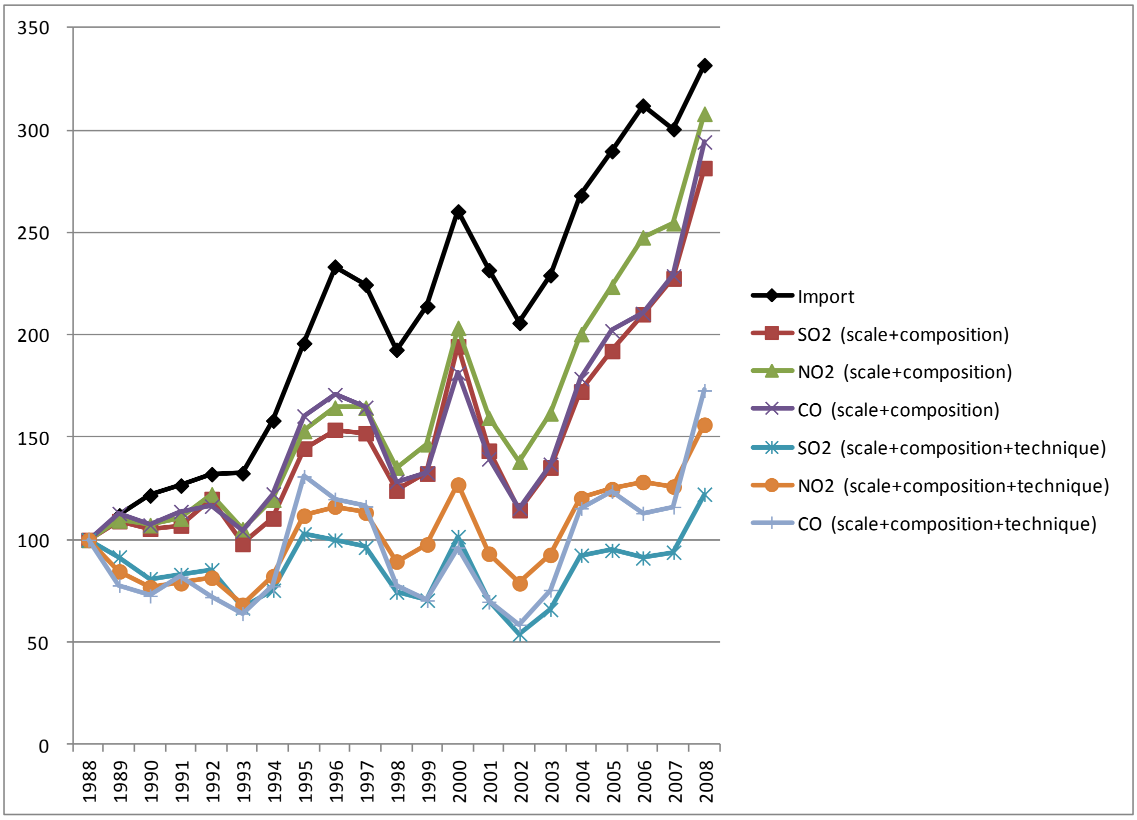


Figure 9-6. Mexico's import and its pollution emissions

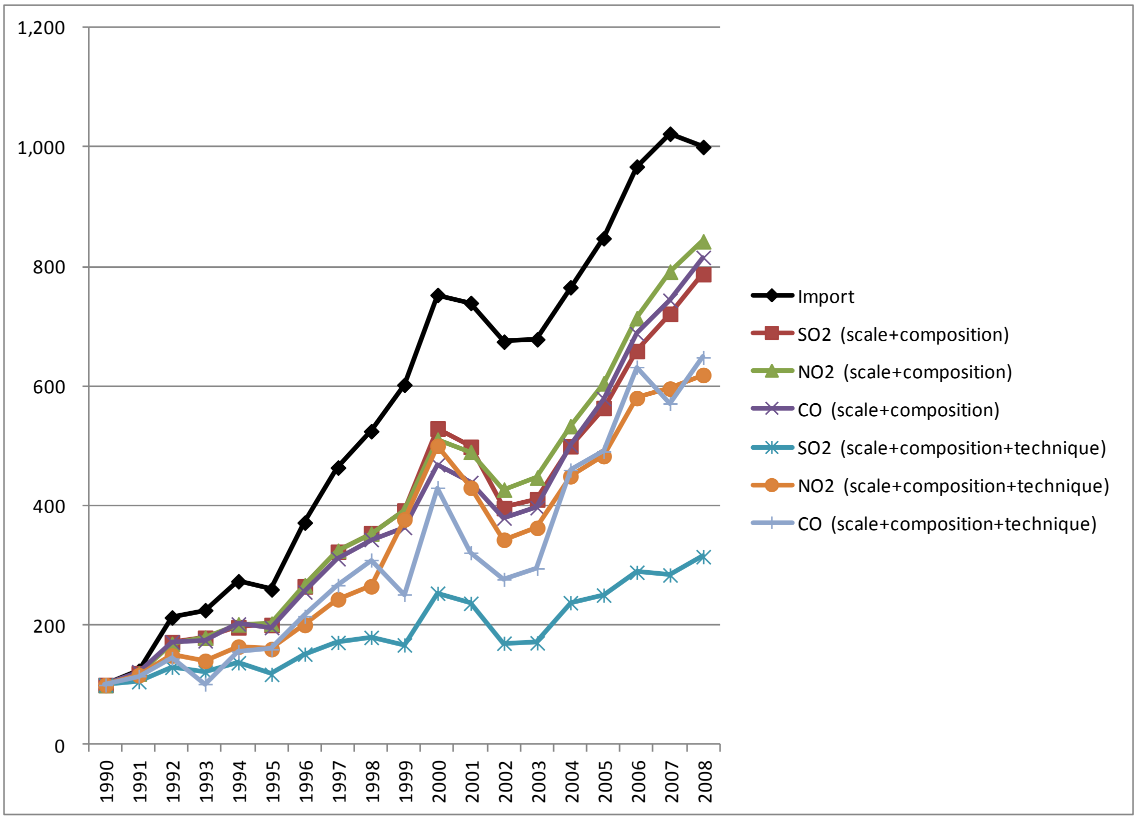
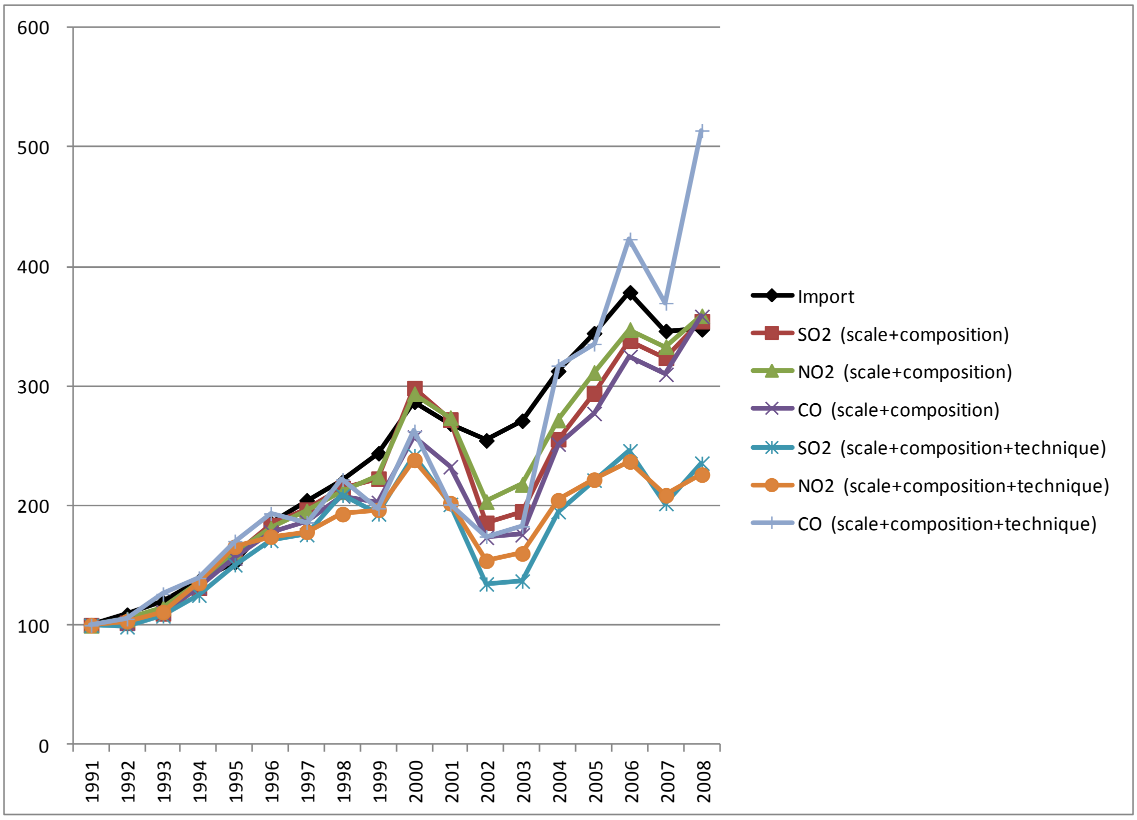
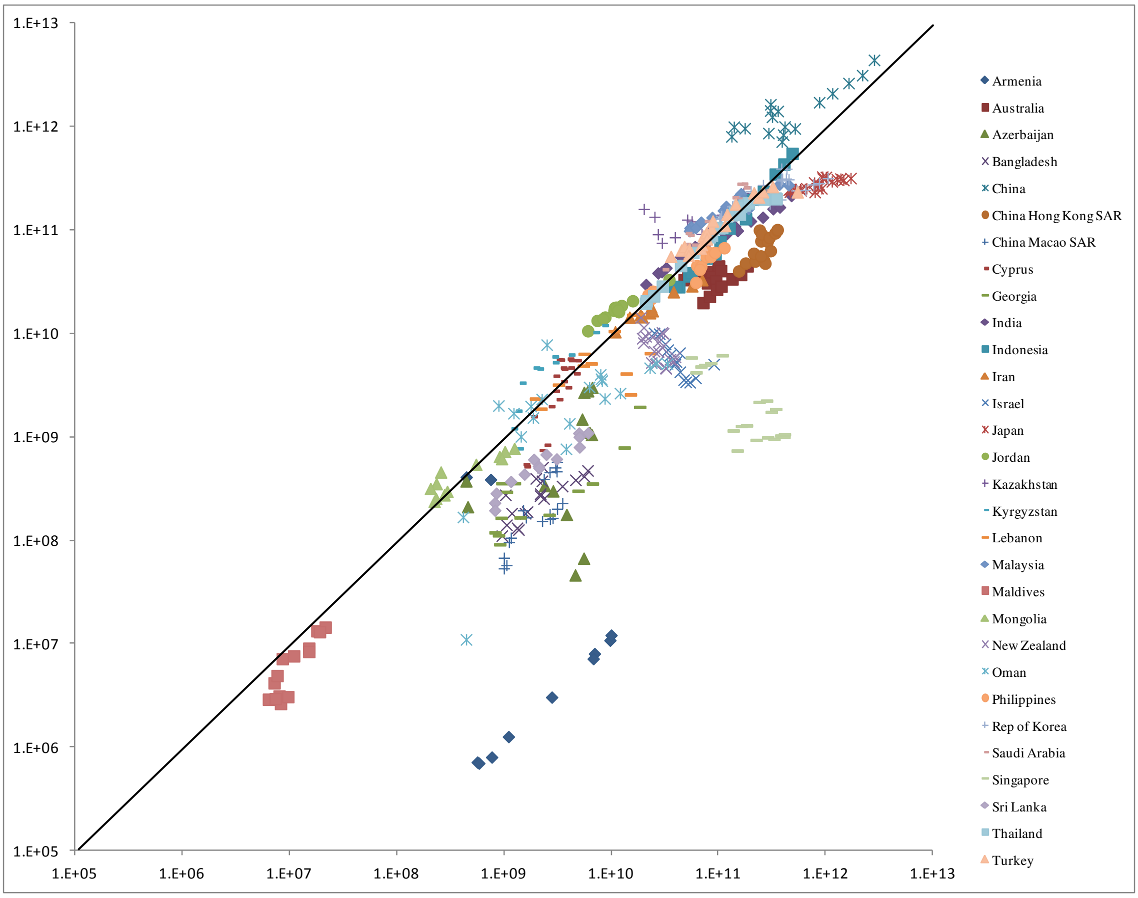


Figure 9-7. The US import and its pollution emissions



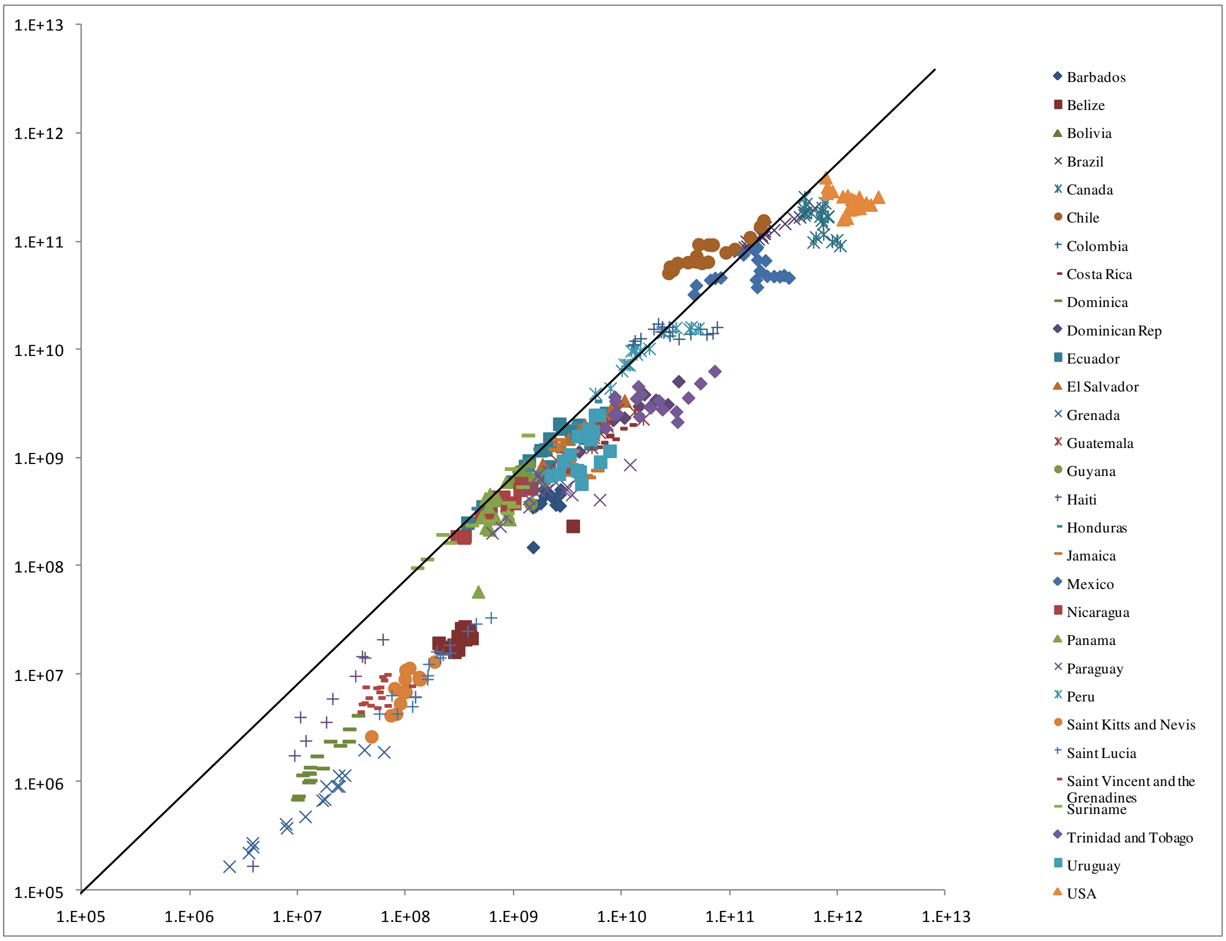
Appendix: Additional figures

Figure A1-a Unadjusted and adjusted SO_2 emissions by export in Asia and Oceania



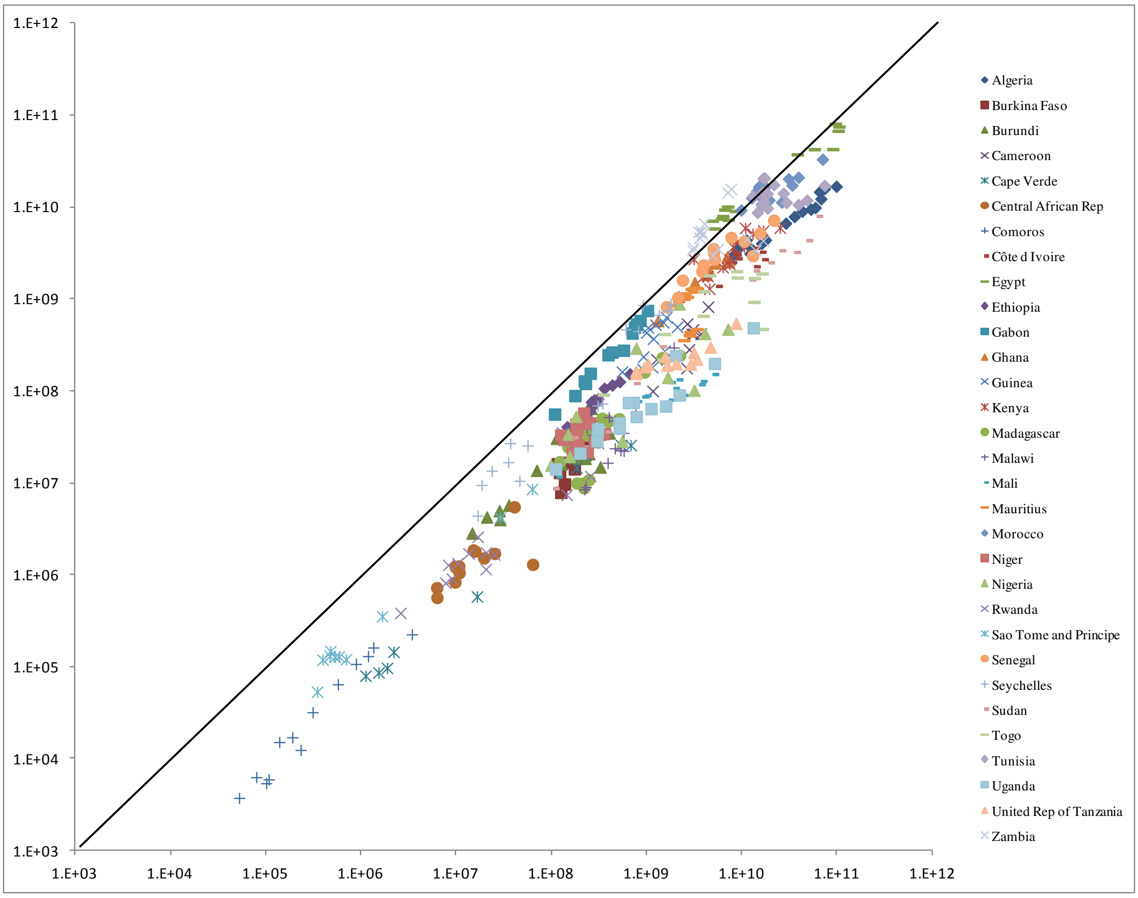
Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by export. These values are scaled in the logarithm.

FigureA1-b Unadjusted and adjusted SO_2 emissions by export in Americas



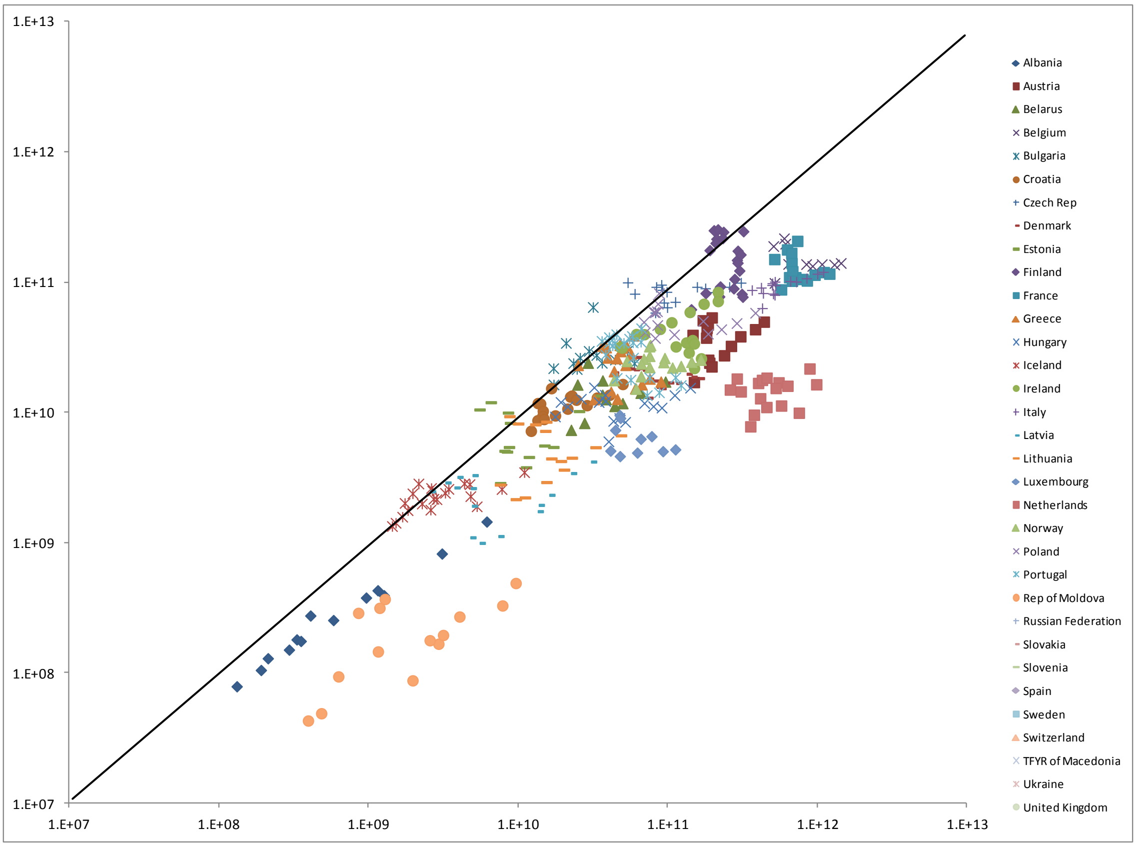
Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by export. These values are scaled in the logarithm.

Figure A1-c Unadjusted and adjusted SO_2 emissions by export in Africa



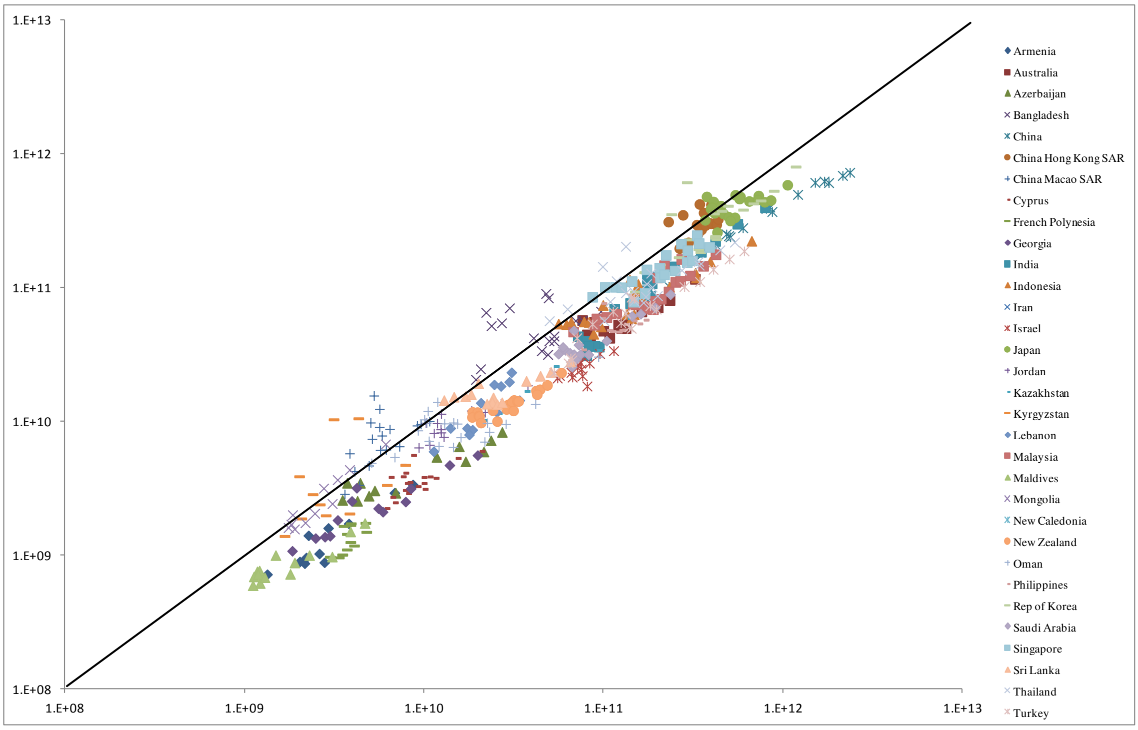
Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by export. These values are scaled in the logarithm.

Figure A1-d Unadjusted and adjusted SO_2 emissions by export in Europe



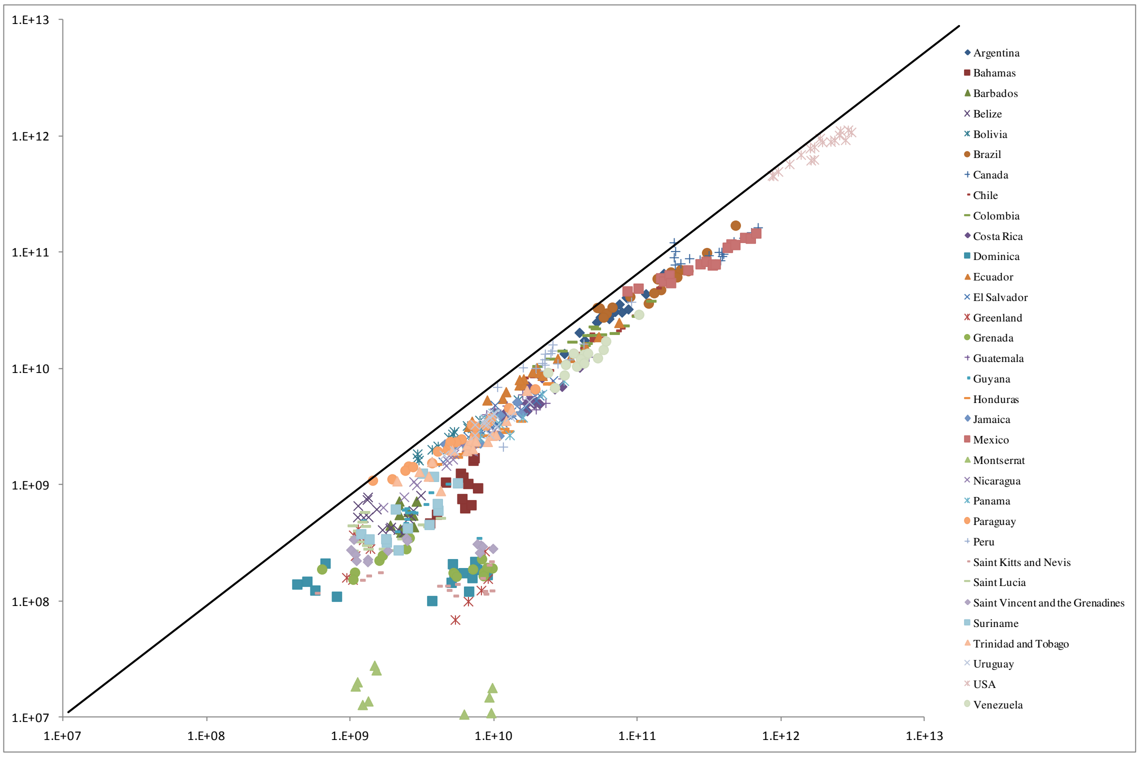
Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by export. These values are scaled in the logarithm.

Figure A2-a Unadjusted and adjusted SO_2 emissions by import in Asia and Oceania



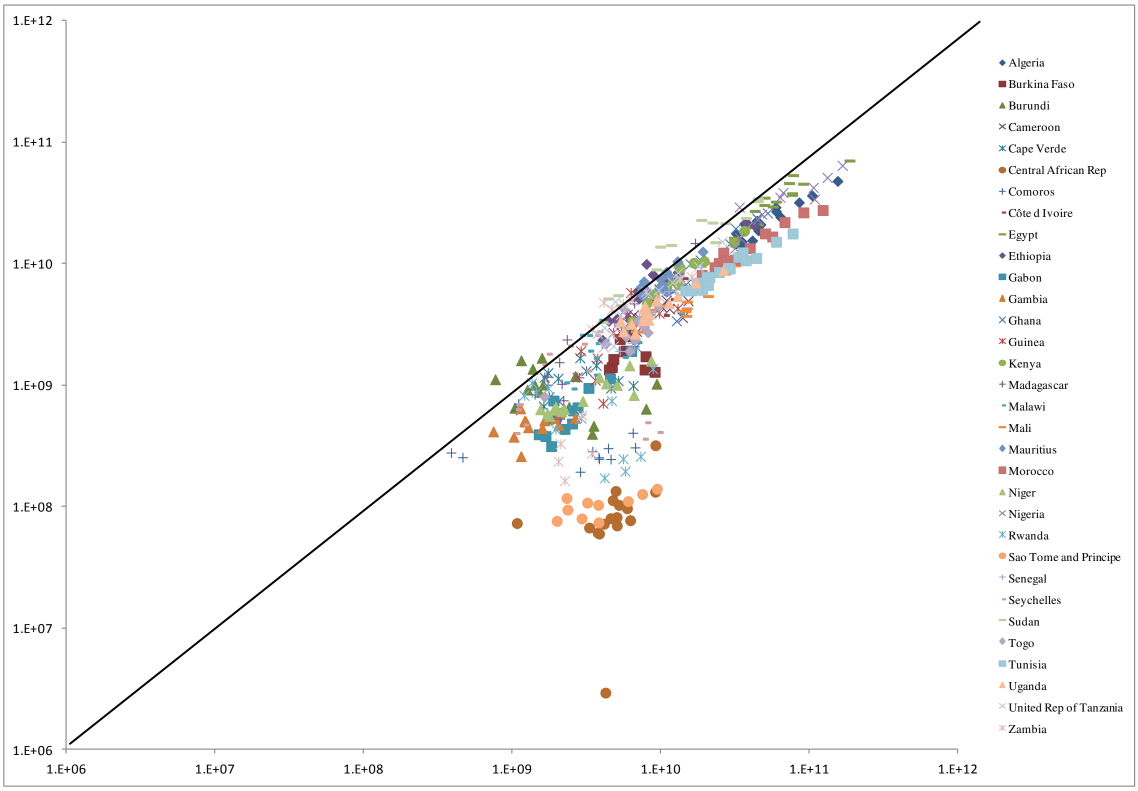
Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by import. These values are scaled in the logarithm.

FigureA2-b Unadjusted and adjusted SO_2 emissions by import in Americas



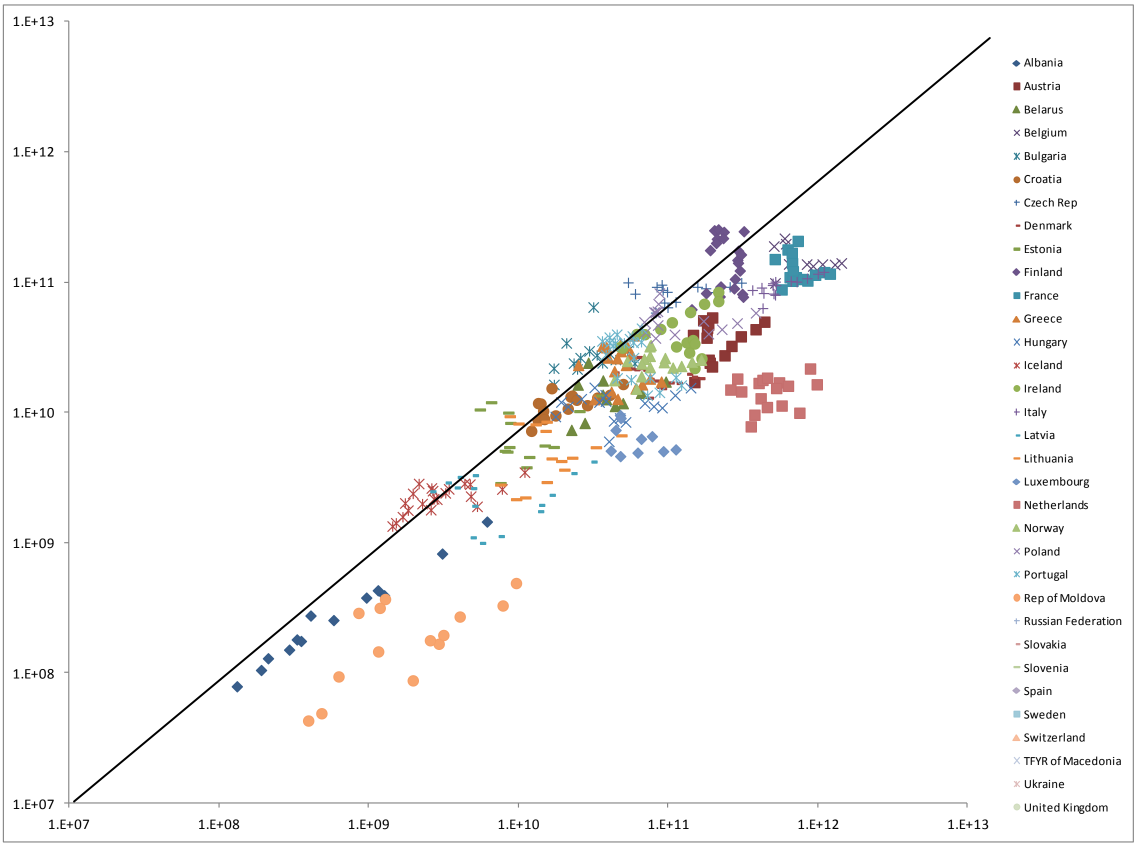
Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by import. These values are scaled in the logarithm.

Figure A2-c Unadjusted and adjusted SO_2 emissions by import in Africa



Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by import. These values are scaled in the logarithm.

Figure A2-d Unadjusted and adjusted SO_2 emissions by import in Europe



Note: Horizontal axis denotes unadjusted SO_2 emission and vertical axis denotes adjusted SO_2 emission by import. These values are scaled in the logarithm.