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Embodied Pollution in Trade: Estimating the 'Environmental Load Displacement' of Industrialised Countries

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Abstract

The present paper sets out to aid in the development of "environmental load displacement" indicators. Developing the notion of the "environmental memory" of physical flows, we estimated embodied pollution in trade of 18 industrialized countries with a) the rest of the world and b) developing countries, from 1976 to 1994. We found that in the last years of analysis, total imports of Japan, USA and Western Europe have entailed, in general, larger air pollutant emissions than local exports. The balance of embodied emissions in trade (BEET) seems follow an inverted-U shape across time in Japan and Western Europe, and an N-shape in the US. In the period of analysis, Japanese and European environmental terms of trade with developing countries have "improved", whereas American environmental terms of trade with developing countries tended to "deteriorate" over time. Although there is no statistical trend between income and embodied emissions in imports in a cross-section analysis, there does seem to be a positive relationship between both variables at a national level. The results suggest that, despite many shortcomings, this type of assessment of embodied environmental pressures in inter-country physical flows may shed useful insights on the international aspects of sustainable development. Particularly, on the distribution of the environmental costs of trade and the relationship between economic growth and environmental degradation.

Keywords: Environmental terms of trade; Embodied Pollution, Ecologically unequal exchange; Environmental Kuznets Curve; International trade; BEET.

1. Introduction

The assessment of the environmental performance of any selected economic system requires us to specify the relevant spatial scales of analysis. This choice will depend on the assumptions adopted about (a) the interrelationship between the different ecological systems transformed by the economic activity; (b) the agents and institutions where environmental liability has to be assigned; (c) the economic driving forces of environmental transformation; and (d) the envisaged mechanisms of environmental policy (Grainger, 1999).

Undoubtedly, from an ecological point of view, the global scale would often be the most suitable level to address sustainability. However, since the planet is divided into political entities, environmental accounting is mostly referred to political (not ecological) territories, particularly to the country-level. National indicators of sustainability may have large leverage in guiding the environmental performance of societies because the country-level is still the scale where most of the environmental policies are implemented. Nevertheless, due to the existence of international environmental interrelationships, sustainability evaluations at a national level may face significant caveats in establishing ultimate causes of environmental transformation. Thus, to weigh up foreign environmental repercussions of local economic activities is crucial for understanding in a comprehensive way the economy-environment relationship. As well, local environmental changes caused abroad have to be considered in any integral sustainability assessment.

The present paper tries to aid in the development of indicators of inter-country environmental load displacement, estimating embodied pollution in physical flows in industrialised countries. Section One summarises the theoretical framework that justifies the assessment of the foreign environmental effects of a national economy, and then reviews some indicators of environmental load displacement already developed in the literature, thus introducing the concept of environmental terms of trade. Section Two describes data sources and analysis. Section Three summarises the most relevant results, followed by a discussion in section Four. Section Five is a short note on shortcomings and difficulties of the analysis. The paper ends with some brief concluding remarks.

1.1 Extending the framework: from production to consumption

Economy-environment interactions are mediated by land transformations and energetic-materials flows involved in the metabolism of the production process, as well by the final disposition of wastes and heat after consumption. In this sense, the scale and "quality" of the throughput are the main forces determining environmental change. In a free market economy, production is conditioned and determined by consumption patterns. Consequently, consumption is the "final cause" of human-induced environmental transformations. Consumption is perhaps not the driving force of the capitalist system, but it is (as Keynes diagnosed in the 1930s) a structurally necessary part of its dynamism. Increasing human inclination for diverse consumable goods and services seems to be a keystone requirement for innovation and economic growth. Inexhaustible willingness to consume is perhaps the most characteristic feature of current western civilisation.

Psychological reasons behind expenditures behaviour are complex and multiple. Explanations for rising consumption in industrialised societies are many and diverse, going from the "insatiable wants" to advertising manipulation (Røpke, 1999a). The environmental impacts of private expenditures are not necessarily related to their magnitude in monetary terms, but instead will depend on the size and quality of throughput. These features are determined by the level of consumption, the composition of the different categories of consumed commodities and by a technological factor. Even though technology can modify the relationship between a certain level of material consumption and its environmental pressures, there are constraints to reducing effluents, imposed by thermodynamic considerations. Material outputs must be always equal in mass to material inputs. What can be changed is the disposition of the output and its "quality" (toxicity for example). Equally, there are restrictions to recycling, imposed basically by energy availability and feasible pathways of transformation under terrestrial conditions (O'Connor, 1994; Craig, 2001). Hence, in the long term, it is practically impossible to de-link rising material use from environmental loads.

In the long run, sustainable increasing monetary consumption is only possible if resources substitutability or material stocks tend to infinite. In the short term, swelling private expenditures are compatible with improving environmental conditions if (1) resources-utilisation efficiency by unit of expenditure increases at least as much as the level of total consumption, or (2) technology allows to dispose of effluents in a more environmentally friendly way and to decrease environmental impacts in the different steps of the material extraction-processing-consumption chains. Given their power in guiding the economic system, consumers are supposed to play a key role in deciding between alternative production processes. Demanding a certain environmental quality of products, consumers may induce a particular development pathway.

Following the same line of reasoning, assuming consumers as agents where environmental liability has to be assigned, and therefore as a central target of sustainable development policies, can be justified with the Polluter Pay principle. If the costs of environmental externalities are incorporated into prices, as the polluter pay principle advises, final consumers will pay the ultimate environmental consequences of sustainable production of goods and services. Thus, the polluter pay principle can be equated to the "consumer or user pay principle" (Kox, 1993).

Sustainability issues have, in public policy, traditionally been appraised at a national level, evaluating the environmental performance associated with domestic production. However, if consumption is assumed as an important economic force "steering" environmental transformation, the assessment of the environmental performance of a national economy requires us to make the distinction between environmental costs-borne and costs-caused by a nation, and therefore, to expand the scale of analysis beyond the national political frontiers. From a consumption-centered perspective, local consumption is linked, through international production chains, to foreign environmental pressures. Similarly, local environmental transformations can be associated with foreign consumption patterns. Inter-country flows of good and services (trade) and transboundary flows of pollutants are the two main ways that international links can be established between local consumption and foreign environmental degradation, or vice-versa. Under this perspective, environmental loads related to consumption in the importing country, but suffered in the exporting country, can be conceived as displaced environmental loads. The next part of this section reviews some indicators dealing with the international aspects of sustainable development, from this consumption-centered viewpoint.

1.2 Indicators of environmental load displacement

A number of environmental indicators have been developed to estimate different sorts of supra-national environmental-pressures-transference of national economies. Muradian and O'Connor (2001) discuss the policy relevance of "environmental load displacement" adjustments to national aggregate (macro-economic) indicators for taking account of openness to the rest of the world. In general, inter-country environmental load displacement indicators can be classified in two categories:

a) Those that adopt a "weak sustainability" standpoint. These indexes intend to calculate (in monetary terms) the natural capital depletion caused by national resources imports.
b) Those adopting a biophysical or "strong sustainability" perspective. In this case, the strategy is rather to estimate foreign environmental physical pressures associated with national consumption.

An example of the first kind of approach is the indicator of weak sustainability for an open economy presented by Proops, Atkinson and others (see Proops and Atkinson, 1998; Proops et al., 1999). Using international input-output analysis, these analysts extended the indicator of weak sustainability for a closed economy introduced by Pearce and Atkinson (1993) to include foreign depletion of non-renewable energy and mineral resources caused by national imports. In this approach, the value of natural capital depletion occurring within a territory is accounted in the country where final consumption of these resources takes place. They found that in the period 1980-1990, global net capital savings are positive, and moreover, the capital stock has improved by an average of 8.5 % per year. In this study, all industrialized countries are sustainable in the "weak" sense.

Despite the fact that weak-sustainability indicators are easy to interpret for policymaking, they suffer major methodological and conceptual difficulties (see Fauchaux and O'Connor, 2001). First, not all environmental values are measurable with a unique unit of value (O'Neill, 1997). Second, "monetization" of environmental externalities is a hard task when there is a high degree of uncertainty (Funtowicz and Ravetz, 1994). Third, prices are unable to reflect the long-term effects of critical natural capital depletion (Rees and Wackernagel, 1999). Fourth, evaluation of environmental externalities depends on the distribution of power and income (Røpke, 1999b). Hence, when environmental damage occur in poor and powerless areas, the costs tend to be lower by definition (Martinez-Alier and O'Connor, 1999).

A range of researchers, aware of the above-indicated problems with the weak sustainability viewpoint, have adopted a biophysical stance to evaluate the supranational environmental effects of local consumption. The best known of these biophysical approaches is the ecological footprint (EF). Using this index, Wackernagel et. al.(1999) arrived at an opposite conclusion about the degree of sustainability of the global economy. They estimated that the global ecological footprint (2.8 ha/cap) overshoots global biocapacity (2.0 ha/cap). They show also that most developed countries have an "ecological deficit", in the sense that national appropriation of land productive area is larger than local available biocapacity.

The major advantage of the EF approach is that it is relatively easy to understand and to implement. However, it has many shortcomings. First, no distinction between different quality of land uses is made and the possibility of multifunctionality (multiple potential uses) of the same land is not considered (van den Bergh and Verbruggen, 1999). Second, as it depends on biological productivity, some pollutant emissions may actually increase biocapacity. Third, the conversion scheme of energy consumption to land use is very controversial because the suggested sustainable energy scenario is not technically or environmentally feasible (Ayres, 2000). Fourth, the amount of land necessary for reforestation (to absorb CO_2 emissions) is calculated under a static perspective, which does not take into account neither time scales of forests growth dynamics nor final uses for the hypothetically produced wood (van Kooten and Bulte, 2000). Fifth, from an ecological point of view, the national borders are arbitrary as a spatial scale of analysis for the EF. These limitations mean that a substantial amount of pertinent information is lost (Costanza, 2000). Consequently, for some authors, it should be used to rank social alternatives or as a meaningful guideline for achieving sustainability (Opschoor, 2000).

The "environmental space" is a similar indicator to the EF. This concept is built on the notion that there are limits to the amount of environmental pressure that Earth's ecological systems can handle without suffering irreversible damage. The environmental services provided by these systems, for which there is a limited space, include both stocks (of renewable and non-renewable resources) and sinks to absorb wastes and pollution (Hille, 1997). This concept is related to equity issues because it is essentially concerned with the fairness of resource use in any one country, as measured relative to world average use. The ethical principle easily linked to this approach is "equality" understood as an equal global share of resources and pollution per capita (Moffat, 1999). The method used to implement the environmental space involves comparing global mean use of a given resource, expressed in per capita units, with national per capita consumption. Items of consideration include non-renewable raw resources, land, wood, water and energy (Hanley et al., 1999). According to the "Towards Sustainable Europe" report (Friends of the Earth, 1995), the European Union as a whole has raw materials (wood and non-renewable) consumption rates considerably higher than the world average. Europe is also a net importer of agricultural land and it has CO_2 emission levels by far larger than global average. Thus, according to this view, Europe occupies a disproportionate part of the available environmental space at a global level.

The general idea of the environmental space approach is to exemplify that the opportunity to expand resource use in countries occupying environmental space below world average is restricted by regions with high rates of stocks depletion and sinks utilization, such as Europe. This is clear for the case of greenhouse gases emissions. The environmental space has been used to set targets for resource reduction. However, this procedure has been criticized because global average of resource consumption is rather an arbitrary reference, given that actual stocks or sinks capacities are not being evaluated. The equality principle has been also criticized due to its political unfeasibility and difficult justification (Moffat, 1996).

Like the environmental space approach, the "material flow analysis" is mainly concerned with national physical flows. It is a relatively new technique (although the underlying concepts of mass accounting have a long history), that provides a numeraire that may be used to estimate indirect foreign environmental pressures linked to local consumption. It intends to characterize major resource flows at different scales of the society's metabolism (Fischer-Kowalski and Hutler, 1999; Haberl and Schandl, 1999). This approach allows estimating how dependent is a national economy on foreign resources. It takes into account not only direct material inputs to the economic systems, but also hidden flows, *viz.*, the proportion of the total material requirement that does not enter the economy, but it is necessary for the production of goods and services. Adriaanse et al. (1997) found that direct and hidden foreign inputs have, in general, increased in industrialized countries in the last decades. In the case of minerals, direct flows are related to pollutant emissions and hidden flows are usually associated with deforestation and habitat degradation. Therefore, they are indirect measures of environmental pressures. Nonetheless, in the material flow analysis no direct links between physical flows and specific environmental loads are established. Furthermore, very often materials flows are assessed in a unidimensional way, considering only the weight of the overall materials involved, not their qualitative differences.

Adopting a consumption-centred perspective, some authors argue that it is relevant for national environmental policy to examine the effect of the cross-country movement of goods that embody pollution (Suri and Chapman, 1998). One of the attempts to develop this approach is the work of Wyckoff and Roop (1994). They used a monetary input-output analysis and emissions data to estimate the amount of carbon dioxide emissions embodied in the imports of manufactured goods in six of the largest OECD countries. Their findings reveal that a significant amount, about 13 %, of total carbon emissions, is “embodied” in manufactured imports. They point out that this result suggests that standard measures of carbon emissions relying solely on domestic sources, such as annual carbon produced per unit of GDP or per capita, will be misleading if a real reduction of emissions is intended. This indicator is interesting because it is based on the measurement of specific environmental pressures (pollutant emissions). The main limitation of this method is that, due to prices variation, it is hard to link monetary values of imports to actual emissions.

Lee and Holand-Host (1993) have developed an indicator called the embodied effluent trade (EET), which is based on the idea that traded commodities embody an environmental service: the amount of pollution produced domestically when goods are produced for exports. This method generates an index of weighted aggregate effluent levels for a given composition of domestic production (in monetary terms), which is calculated using the Linear Acute Human Health index of the Industrial Pollution Projection System database (see below). The EET index measures the effluent potential of domestic output in units relative to the United States and it can be used to evaluate the implicit effluent content of trade. They use this indicator to study the "ecological terms of trade" between Japan and Indonesia. They found that, in 1990, Japanese imports from Indonesia are six times more effluent intensive than Indonesian imports from Japan. This approach is attractive because it emphasises explicitly the notion of "transfer of environmental costs". Nevertheless, its interpretation is not easy because no reference to actual emissions is made.

The next part of this section makes a brief development of the "ecological" or "environmental" terms of trade idea.

1.3 Environmental terms of trade

Monetary terms of trade assess the relationship between price indexes for imports and price indexes for exports, and its variation over time. It is a statistical tool for estimating the distribution of trade's profits. The notion of terms of trade has received a lot of attention during many years in the twentieth century. It constituted the central concept of the Singer-Prebisch thesis (Prebisch, 1950; Singer, 1950), which had a world-wide influence in development policies. This thesis postulates that there is a structural trend towards the decline of primary commodities prices relative to manufactures prices. They argued that this phenomenon lead to continuous terms of trade deterioration in developing countries, due to their specialisation in primary exports. According to this point of view, specialisation through comparative advantages could work as a poverty trap in the long term.

Studies testing empirically the Singer-Prebisch hypothesis arrive at mixed results, depending on data and the econometric model utilised (Athukorala, 2000; Bloch and Sapsford, 2000; Lutz, 1999; Muñoz and Sosvilla, 1993). So the debate is still open. Today, this question could be complemented with attention to environmental issues. Many developing countries are still specialised in primary and environment-intensive sectors, especially in Africa and Latin America. Non-renewable natural resources exploitation and processing head the list of the most polluting sectors (World Bank, 1998). Moreover, increasing exported volumes of renewable resources are usually associated with the expansion of the agriculture frontier in developing countries, which often affect very bio-diverse and valuable natural habitats. Finally, core-periphery displacement of pollution-intensive activities is likely because accounted environmental costs tend to be lower in the periphery. Environmental costs are lower in poor countries relative to richer areas because (1) the possibility for major producers and consumers to offload or ignore environmental damages is higher due to weaker institutions; (2) health-impairing pollution has a lower effect on the performance of poor economic agents (as measured in monetary terms, such as loss of earning capacity); and (3) Environmental externalities tend, when assessed in terms of monetary WTP, to have a lower value because income actually influences environmental valuation.

Starting from the idea that a country gains environmentally from trade in relative terms whenever its imported goods have larger pollution content than its exported goods, Antweiler (1996) introduced the notion of "pollution terms of trade". He designed an index to evaluate the environmental gains a country receives from engaging in international trade. This index measures the ratio of the pollution content by unit of monetary exports relative to the pollution content by unit of imports. Using input-output analysis, industry-level pollution data for the US, *monetary* trade flows, and a weighting procedure, he tested the index for 1987. He concluded that exports of highly industrialised countries appear to be more environment-intensive than are their imports, while the opposite holds for developing countries. Thus, according to these results, the environmental-periphery would not correspond to the income-periphery. The environmental loads of trade are larger in developed than in developing countries.

In the present work, we rather define environmental terms of trade in the simplest way. That is, as the total entailed environmental pressures in exports in relation to total entailed environmental pressures in imports. Our index of environmental terms of trade can be formalised as: ETT= (EEPx/EEPm) x 100, where EEPx is a measure of the embodied environmental pressures (pollution) in exports and EEPm the same measure for imports.

In order to avoid errors caused by prices variation, we prefer to use physical instead of monetary flows to estimate pollution content in international trade. If peripheralisation of environment-intensive activities from rich to poor regions of the world is occurring, this index should show a dropping trend across time in high-income countries trade with developing areas. If region "A" faces "deteriorating" ETT over time in trade with region "B", we can talk about ecologically unequal exchange between both areas (Andersson and Lindroth, 2001; Cabeza-Gutés and Martinez-Alier, 2001; Martinez-Alier and O'Connor, 1996), in the sense that the environmental effects of consumption in region "B" are consistently displaced towards its trade-partner.

2. Data source and analysis

The analysis of the terms of ecological exchange between different regions or countries can be very complex because international production-commercialisation-consumption chains are usually extremely intricate. Tracking environmental impacts in this kind of chains requires delimiting the number and sort of economic transactions to be considered. This implies always to lose information. Moreover, in these cases, data availability is an important source of constraints. Aware of these limitations, we decided to use existing pollution intensity factors for production outputs, in order to calculate embodied emissions in trade of the most polluting economic sectors.

The Industrial Pollution Projection System (IPPS) is a database developed by the World Bank (Hettige et al., 1994), which combines data from industrial activity with data on pollution emissions to calculate pollution intensity factors for many economic sectors. The IPPS has been used for a variety of research themes, including environmental assessments in developing countries (Dessus et al, 1994), estimation of abatement costs (Hartman et al., 1994), global patterns of industrial pollution (Hettige et al., 1992) and estimation of toxic pollution production in diverse countries (World Resources Institute, 1994). As regard air pollutants, pollution intensity indexes of the IPPS are published in terms of weight of emissions by unit of total value of output, value added or number of employees. These coefficients are based on U.S. production and pollution data from different years, up to 1989. Since prices, values added or labour intensities are highly variable from one country to another, as well as through time, we considered that pollution intensities expressed in terms of pollutant emissions by unit of production, both in *weight* units would be more reliable. In order to obtain this kind of factors, we transformed IPPS lower bounds air pollution intensity estimates from Kg of emissions by unit of total value ($ 1987) into kg of emissions per thousand metric tons of output.

For converting pollution intensities from monetary to physical terms, we used production data in weight outputs from the Industrial Commodity Statistical Yearbook (U.N.) and production data in monetary units from the International Yearbook of Industrial Statistics (U.N.). The transformation was made for each of the 11 most polluting economic sectors: Oils and fats, leather finishing, footwear, pulp, paper and paperboard, industrial chemicals, petroleum refineries, paints, varnishes & lacquers, iron and steel, non-ferrous metals, soap, cleaning preparations, perfumes & toilet preparations, and synthetic resins & plastic materials. This procedure was followed for 1985 and 1990. For each air pollutant, the new pollution intensity coefficient was calculated as the average value of the pollution intensities of US, Japan and Western Europe for these two years. With this method, we estimated emissions intensities of five air pollutants: SO_2, NO_2, CO, volatile organic compounds, fine particulates and total suspended particulates.

Embodied pollution in trade was calculated using the converted pollution intensity factors and trade data in weight units from the Commodity Trade Statistics (U.N.) for the above-mentioned economic sectors and the following countries: US, Japan, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, United Kingdom, Austria, Finland, Norway, Sweden and Switzerland. Calculations of embodied pollution were carried out for 1976, 1979, 1984, 1987, 1990 and 1994. Data was digitalised manually. Developing countries are defined here as low and middle income countries according to the World Bank classification (1998).

3. Results

3.1 Balance of embodied emissions in trade

We introduce here the concept of balance of embodied emissions in trade (BEET), which is defined as embodied emissions (EE) in imports minus EE in exports. Hence, a positive value means that entailed pollution in imports exceeds local emissions associated with exports. This could be seen as a measurement of "environmental deficit" or "environmental load displacement". Figures 1, 2 and 3 show the BEET for different air pollutants in the US, Western Europe and Japan respectively. In 1994, last year of analysis, Japan and the United States had positive values of BEET for all the considered pollutants. In the case of Japan, BEETs for all pollutants seem to follow the same trend over time, they increase until certain value and then they decrease. This can be described as an inverted-U trajectory through time. The US shows the same trend for BEETs of volatile organic compounds and total suspended particulates. In this country, SO_2, NO_2, CO and fine particulates firstly increase, then decrease and lastly they increase over time. This can be characterised as an N-shape trend, indicating a re-linking between the balance of embodied pollution and time. In 1994, Western Europe had positive BEET values for most of pollutants, except for NO_2 and CO. In this region, the BEET seems to follow an inverted-U pattern for most of pollutants.

Figure 1. USA. Balance of Embodied Emissions in Trade

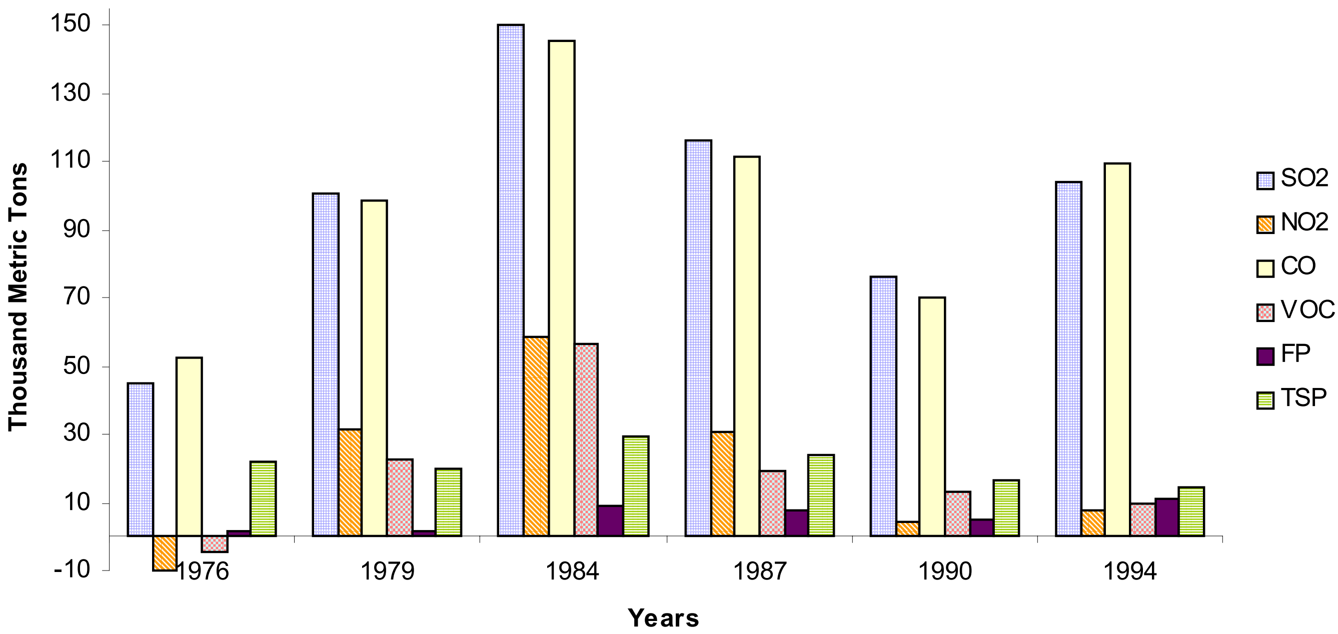


Figure 2. Western Europe. Balance of Embodied Emissions in Trade

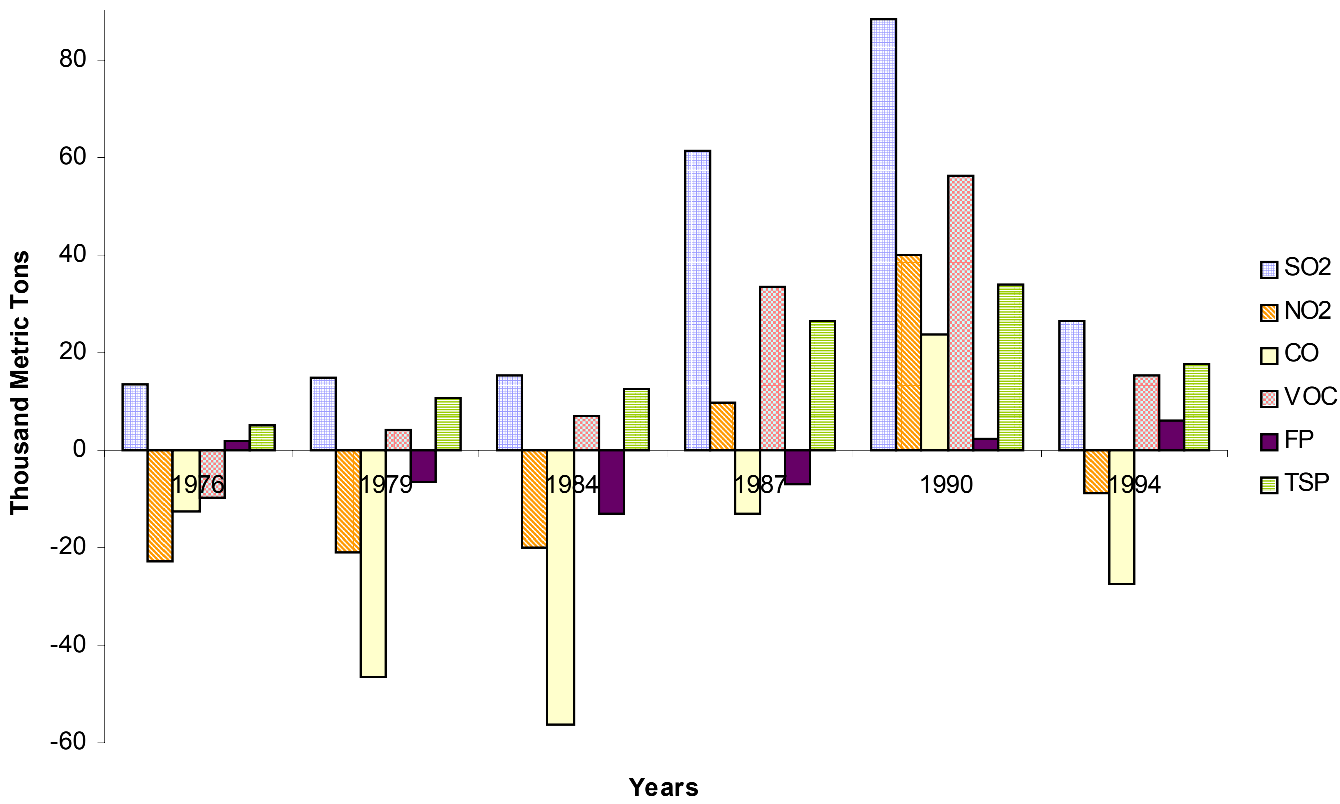
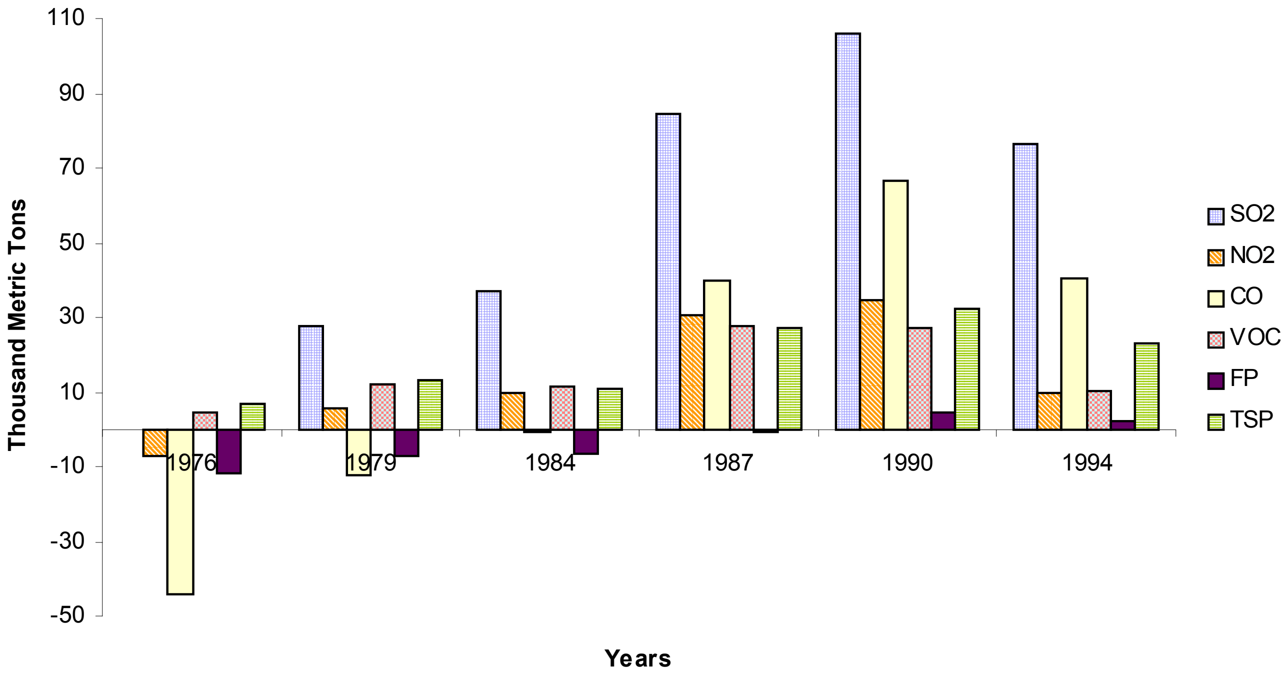


Figure 3. Japan. Balance of Embodied Emissions in Trade



Changes in trade flows of petroleum, iron-steel and non-ferrous metal products are the main factors responsible for large variations in the balance of SO_2 EE in the US and Japan. Significant shifts in the balance of SO_2 EE in Western Europe are rather linked to industrial chemicals and plastics trade. Trade variations in iron-steel products account for most of CO EE balance in Japan and the US. As regard Western Europe, BEETs of CO are rather associated with trade of paper and petroleum products. Paper, petroleum and plastic products trade accounts for most of the large changes in the BEETs of NO_2 in this region.

3.2 Environmental terms of trade

In the present work, we define environmental terms of trade as ETT= (EEPx/EEPm) x 100 (see section 1.3). We say that the ETT "deteriorate" when EE in exports of a country or region increases more than EE in imports over time. We say that, on the contrary, the ETT "improve" when embodied pollution in imports increases more than EE in exports across time. If the ETT are lower than 100, embodied pollution of national imports from the specified countries is larger than entailed pollution in exports to the same countries.

Figures 4, 5 and 6 show the environmental terms of trade with developing countries for six air pollutants in the US, Western Europe and Japan respectively. With the exemption of fine particulates, there is a general trend towards "deteriorating" environmental terms of trade with developing countries for the US. However, in 1994, the American ETT for total suspended particulates, CO and SO_2 were still lower than 100. Western Europe shows an opposite trend. In this region, environmental terms of trade have "improved" from 1976 to 1990. In 1994, ETT were larger than in 1990 for all pollutants, although all of them were still below 100. Japan shows the same pattern as Europe: a general "improvement" in ETT with developing countries until 1990. In 1994, ETT were larger than in 1990 for all pollutants, but only ETT for NO_2 attained a value higher than 100.

Figure 4. U.S.A.
Environmental Terms of Trade with Developing Countries

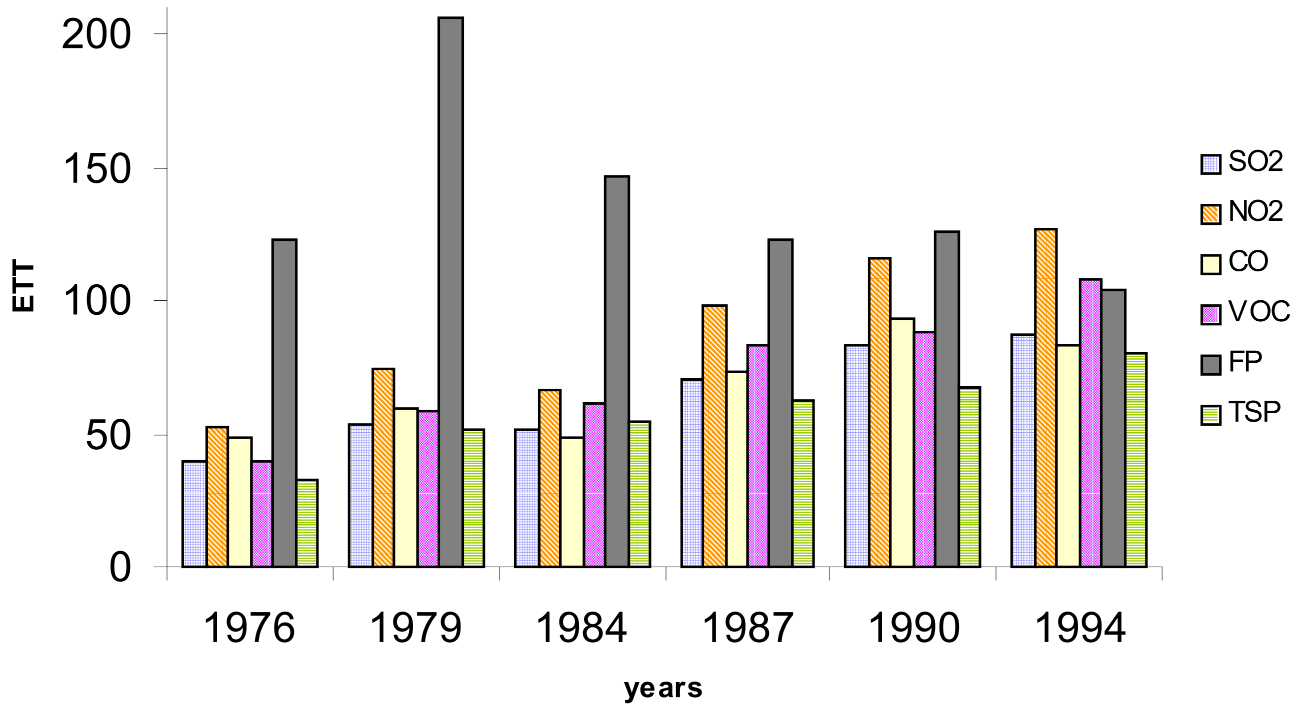


Figure 5. Western Europe
Environmental Terms of Trade with Developing Countries

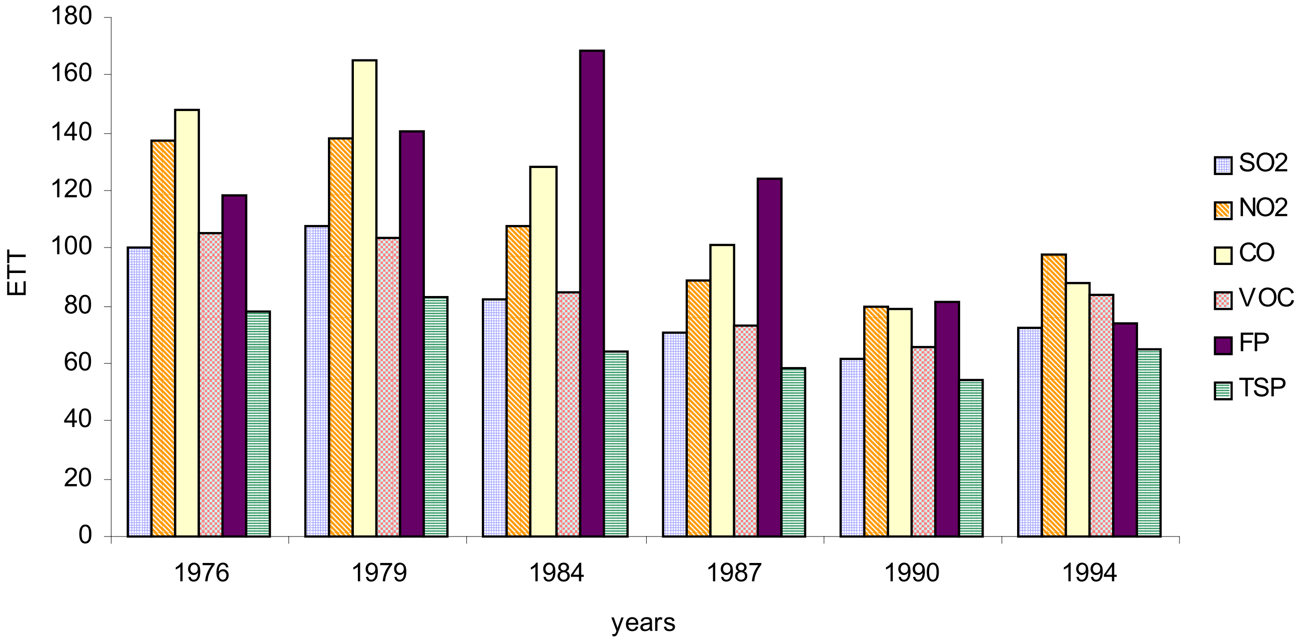
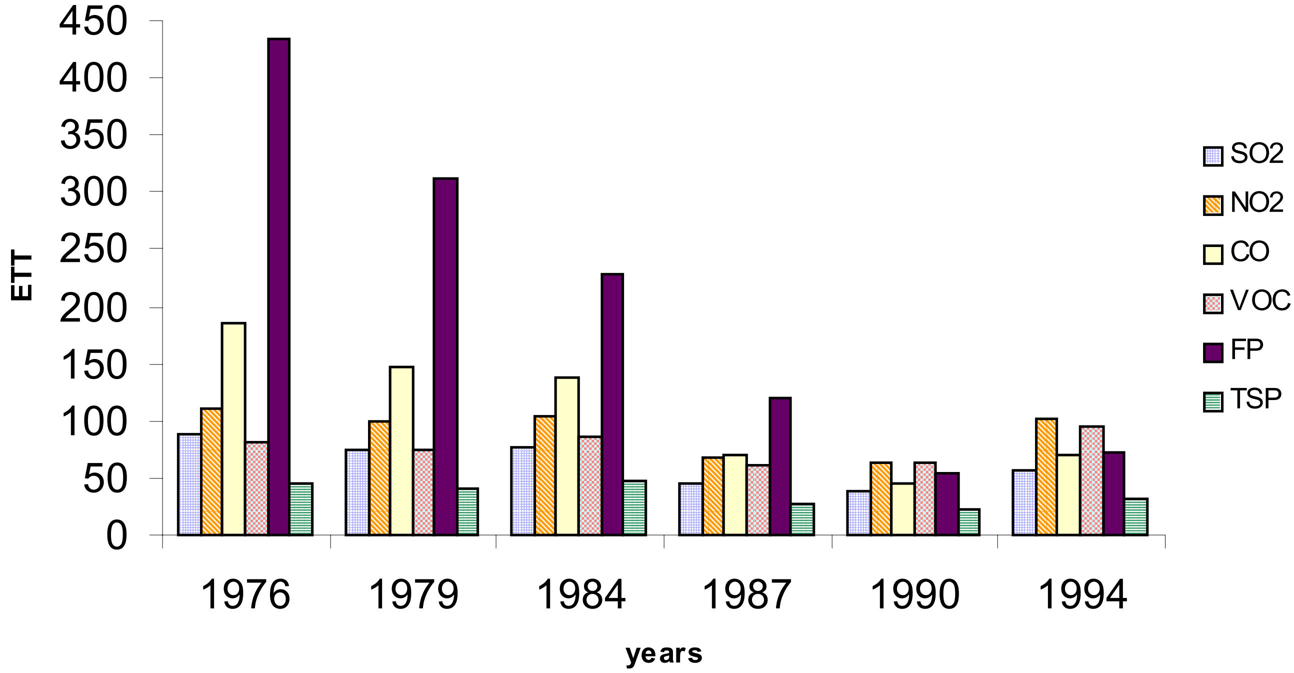


Figure 6. Japan
Environmental Terms of trade with Developing Countries

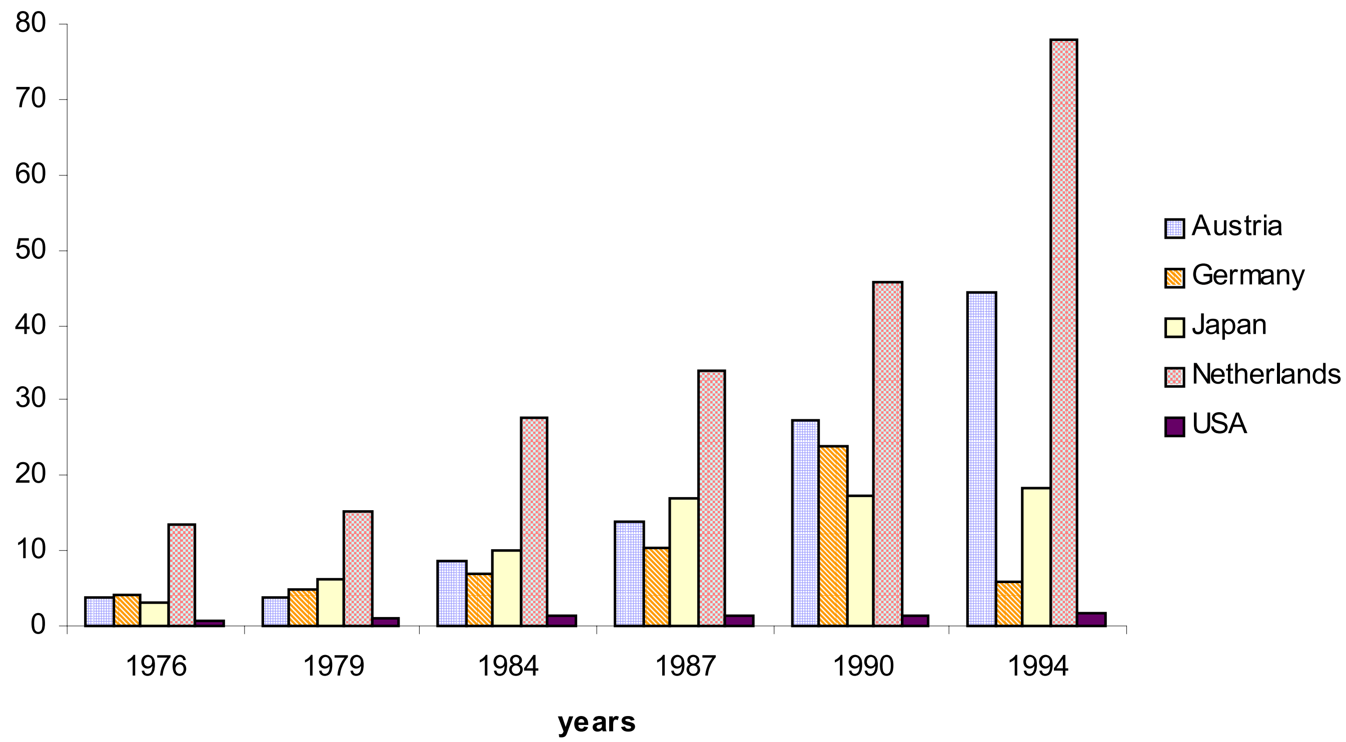


Iron-steel products trade with developing countries is responsible for most of the large variations in fine particulates ETT in the US and Japan. In the case of Western Europe, oils-fats and iron-steel products trade with developing countries accounts for most of the changes in ETT for fine particulates. Variations in the European ETT for CO is also mainly associated with iron-steel and petroleum products trade changes.

3.3 Foreign and local emissions

Figure 7 shows the percentage of SO_2 EE in imports to total domestic emissions of the same pollutant. National aggregated emissions data was taken from Matthews et al. (2000). The percentage of foreign to local emissions varies greatly across time and among countries. Whilst in the US it changed from 0.78 to 1.77 from 1976 to 1994, in the same period it shifted from 14 to 78 in the Netherlands. The percentage of embodied emissions in imports tends to increase in all the countries, except Germany. In this country, foreign emissions tended to rise relatively to domestic emissions until 1990. In 1994 it dropped, reaching less than a third of its value in 1990. This is probably a consequence of reunification.

Figure 7. Percentage of Embodied SO_2 Emissions in Imports to Domestic Emissions



3.4 EE in imports and income

Figure 8 was made plotting cross-section embodied emissions data and GDP per capita of Western Europe countries. Cubic regressions parameters are shown in Table One. R-values are not significant for any pollutant. There is not a clear trend between both variables described by cubic polynomials. Nevertheless, Figure 9 shows that when countries are considered separately, embodied emissions of SO_2 in imports tend to increase through time. We found the same tendency for all the pollutants. Since income is positively correlated with time in these countries, we could also assume a positive relationship between income and EE in imports at a national level. Data limitations do not allow testing statistically this relationship in the present work.

Figure 8. Income and EE in Imports

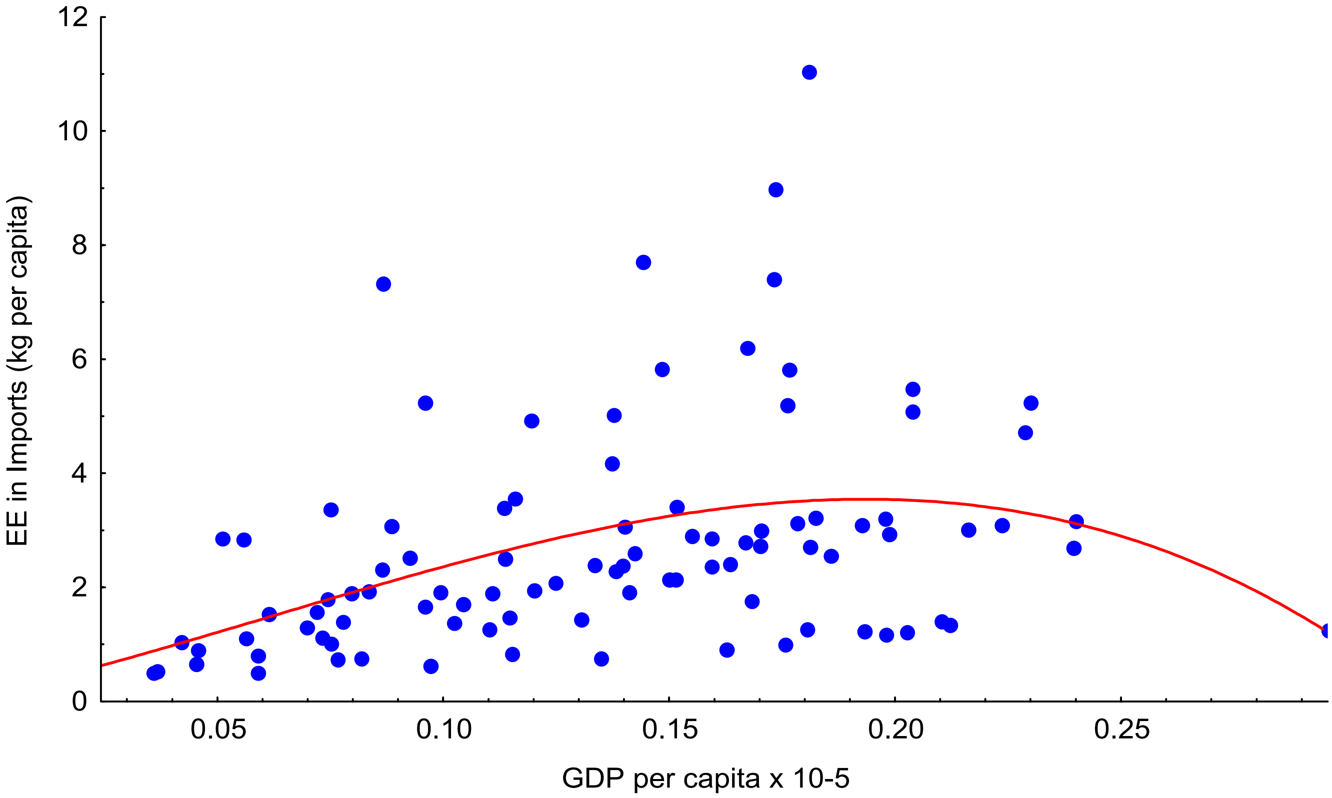


Figure 9. SO2. Embodied Emissions in Imports Over Time

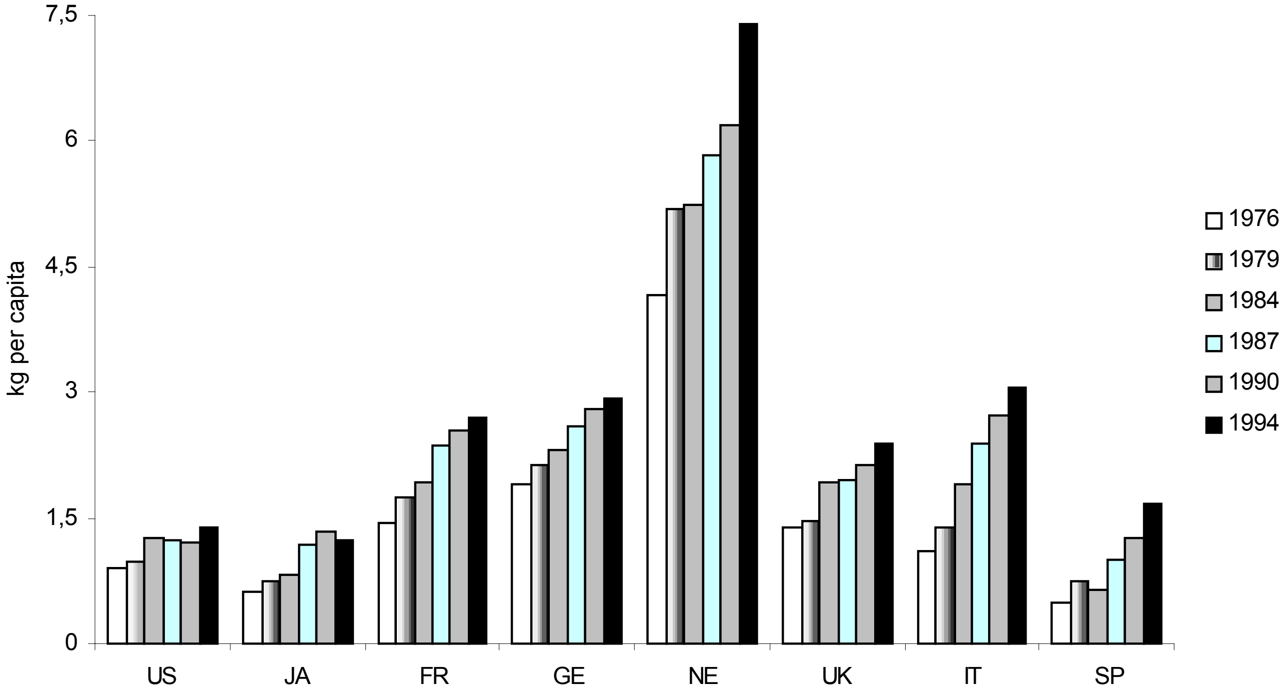


Table 1. Parameters of non-linear regressions. $Y = a + bX + cX^2 + dX^3$.

Y: EE in imports (kg per capita); X: GDP per capita (US$1987 x 10^{-5}).

	R	a	b	c	d
SO_2	0.4258	0.13	18.67	80.68	-444.41
NO_2	0.4089	0.14	11.46	72.05	-355.10
CO	0.4589	0.26	8.76	89.16	-375.35
Volatile Organic Compounds	0.3900	0.14	9.34	42.14	-242.90
Fine Particulate	0.4168	0.03	1.02	13.51	-53.71
Total Suspended Particulate	0.4062	0.01	6.54	15.66	-111.79

4. Discussion

The pattern of BEETs and their changes over time differ significantly between Japan, US and Western Europe. Our results suggest that both, Japanese and American imports, have systematically entailed larger pollution than the respective exports in the beginning of the 1990's. A positive BEET (when EE in imports surpasses EE in exports) can be interpreted as a net environmental load displacement towards the rest of the world. The pattern for European BEETs is less pronounced. In the same period, Western Europe had an "environmental deficit" for most of pollutant, except for NO_2 and CO in 1994, when the exports embodied larger levels of emissions than imports for these two pollutants. On the other hand, whereas Japanese and European environmental terms of trade with developing countries have "improved" from 1976 to 1994, American ETT with the same countries tended to "deteriorate" through time. It can also be seen ─not surprisingly─ that the importance of EE in imports relative to local emissions varies greatly from one country to another. In general, it tends to grow over time. However, this result may be an artefact of our analysis, which does not consider technological improvements. We also found that, although there is no statistical trend between income and EE in imports in a cross-section analysis, it seems to be a positive relationship between both variables at a national level.

Establishing links between local consumption and foreign environmental pressures can be useful in assessing the relationship between economic growth and environmental quality. However, most of the environmental Kuznets curve studies (for a review see Ekins, 1997 or Barbier, 1997) miss this point, taking into account only local indicators of environmental performance (Rothman, 1998). The lack of a clear cross-section trend between embodied pollution in imports and income probably is due to differences in the composition of production among countries. Increasing embodied emissions in imports over time at a national level shows that the consumption-centred approach here adopted may shed some new light on the relationship between economic growth and environmental pressures. If embodied pollution in imports overcomes local emissions drop, the environmental Kuznets curve would not reveal a real de-coupling between economic growth and environmental degradation, but instead it would be the outcome of increasing transfer of environmental loads abroad as countries become richer. The magnitude of entailed emissions in imports relative to local emissions can be very important in some countries but irrelevant in others, as Figure 7 shows. Further research is needed in testing the extent to which local emission reductions can be achievable in part due to international environmental loads reallocation through trade.

When embodied pollution in exports is taken into consideration, an inverted-U evolution of BEET across time in Japan and Western Europe is found. This may suggest that local economic growth may be de-coupled from environmental load displacement. However, in the last year of analysis, local consumption in both regions still entailed a net environmental load (measured in terms of embodied emissions) on the rest of the world (except for NO_2 and CO in Europe in 1994). A re-linking between income and abroad environmental pressures "transference" is also possible, as seems to have occurred in the US.

The balance of “embodied emissions” in trade, by stressing the idea of “environmental memory” of traded products, could be a good metaphor for dealing with the international aspects of sustainable development, especially the assessment of the spatial distribution of environmental loads. Estimations of embodied pollution in physical flows can shed some doubts on the common assumptions about the environmental effects of international division of production. For example, analysing monetary exports-imports ratios for the most polluting sectors in low, middle and high income countries, the World Bank (1998) found that industrialised countries are net exporters of pollution-intensive products, while developing countries tend to be net importers for this kind of products. According to these results, international specialisation of production concentrates environmental loads, in high-income countries. However, our findings suggest instead that affluent countries consumption implies a net "transfer" of pollution to the rest of the world.

We think that the environmental effects of trade specialisation are most meaningfully addressed through evaluating the “environmental rucksack” of physical flows. Nonetheless, while embodied pollution assessments are very relevant for the above-mentioned issues, their use in environmental policy is not straightforward. Targets or compensatory measures do not arise automatically from a BEET analysis. In this kind of approach, there is not an *a priori* sustainability benchmark to be accomplished. Embodied emissions in trade are only an indirect and very rough index of environmental pressures because no reference to actual impact on ecosystem or human health is made. Given the difficulties in evaluating concrete environmental transformations along complex and long international production-consumption chains, the BEET analysis can,however, be an appealing tool to make people aware that their consumption behaviour has environmental consequences beyond the national level. From a consumption-centred environmental policy perspective, it is then also pertinent to study particular international product chains, in order to 1) inform consumers about the environmental consequences of alternative production chains for the same product and 2) envisage possible institutional frameworks for setting compensatory measures between consumers and those populations who suffer the environmental loads of consumed goods.

The "improving" European and Japanese environmental terms of trade with developing countries are mainly explainable by non-renewable resources trade. In Japan and Western Europe, the weight of iron-steel imports from developing countries increased 11 times and twice respectively from 1976 to 1994. In these regions, non-ferrous metals imports from developing areas increased also substantially in this period (4 times in Japan and twice in Europe). "Deteriorating" environmental terms of trade with developing countries in the US are mostly explained by American increasing weight of exports of non-ferrous metals, petroleum products and plastics, which increased by 4,56 and 5 times respectively.

The notion of environmental terms of trade is a key for understanding the distribution of trade benefits. There can be a feedback between monetary and environmental terms of trade. Deteriorating monetary terms of trade may force countries specialised in non-dynamic and pollution-intensive products to export ever-increasing volumes in order to maintain revenues. Rising volumes of exports likely entails enlarging local environmental impacts and deteriorating environmental terms of trade. As it was stated before, non-renewable resources extraction and processing are typically among the most polluting sectors and the agricultural frontier expansion usually involves lost of bio-diversity. Hence, if there are actually structural conditions keeping natural resources prices relatively low across time, countries specialised in natural resources exports may face both monetary and environmental terms of trade deterioration in the long run. This is especially pertinent for those developing countries, notably in Latin America and Africa, where exports are still very resource-intensive. If increasing resources exploitation means rising environmental pressures, a poverty-environmental-degradation trap can be created.

Based on monetary terms of trade considerations, Prebisch and Singer argued that international division of production might lead to maintaining development gaps between different regions of the world. We can now add that it may also produce and preserve uneven distribution of environmental loads at a global level. It could create a new dimension of the old core-periphery division. If some countries specialise in low dynamic and environment-intensive sectors, the income and environmental peripheries may coincide geographically. However, our data indicates that there is no a single pattern of environmental exchange between industrialised and developing regions of the world. Whereas Japan and Western Europe have increasingly ecologically unequal exchange with developing countries (unfavourable for the latter), the US tends rather to suffer "deteriorating" ETT with developing areas. As it was pointed out before, these results are explained by differences in non-renewable resources trade, especially of ferrous and non-ferrous metals and petroleum products. Japan and Europe are highly dependent on foreign natural capital due to relative local lack of non-renewable resources.

5. Limitations of the present analysis

The results here presented have to be taken carefully. They have to be considered as a first approximation on the subject. There are many steps of measurement, aggregation and statistical averaging along the way to the estimation of embodied emissions in trade.

Therefore, several issues associated with data availability and the statistical conventions for attributing emissions determine the quality of the results. Some of them are:

(1) The IPPS database has been adopted here as a blackbox. There could be substantial errors in the pollution intensity coefficients developed by the World Bank.
(2) The IPPS database was made using production and pollution data collected in the 1980's. Therefore, the technological component (very important in determining pollution intensities) is not considered in the current study. Pollution intensity factors may be underestimating actual emissions before the 1980's and overestimating emissions in the 1990's. This is a major shortcoming of our analysis.
(3) Trade and production data are not published using the same classification codes. Trade flows are classified according to the Industrial Standard Trade Classification (SITC), whilst production data is categorised following the International Standard Industrial Classification (ISIC). Even though conversion between the two schemes is possible, it is probable that trade and production sectors do not correspond exactly. This could introduce some errors in converting pollution intensities from production to trade categories.
(4) Classification codes for trade have changed slightly in the period of analysis. Thus, trade categories were not exactly the same for all the years for which calculations have been made.
(5) Only the 11 most polluting sectors were considered in the analysis.
(6) US pollution intensity factors may be underestimating actual emissions in developing countries.

6. Concluding remarks

Our results show that, in the 1990s, the industrialised world has had an "ecological deficit", in the sense that embodied emissions in imports tend to be larger than EE in exports. What we have reported can be considered an empirical estimation of environmental load displacement from Japan, USA and Western Europe to the rest of the world. Our results also reveal a positive relationship between EE in imports and time at a national level. This suggests that estimating the "environmental memory" (embodied emissions) of imported products provide appealing insights for re-evaluating the environmental Kuznets Curve hypothesis — that is, of decreasing pollution intensity as income per capita increases. Furthermore, we found that

Europe, Japan and the US differ in their environmental terms of trade with developing countries. In the period of analysis, American EE in imports from developing countries have increased more than American EE in exports to the same areas, whereas the opposite holds for Japan and Europe. This means that there is not a single pattern describing the evolution of environmental terms of trade between industrialised and developing areas of the world.

Notwithstanding certain limitations of our analysis due to the quality and availability of data, we think that the approach here has a strong heuristic value. It stresses the importance of taking into consideration the "entailed" pollution associated with inter-country trade when the environmental performance of a national economic system is to be evaluated. However, if this sort of analysis is to be made the basis for calculation of "trade-adjusted" indicators of national economic and environmental performance, much more research is still needed in ameliorating and expanding data collection and analysis[1].

[1] Some perspectives for future research are developed in Muradian and O'Connor (2001).

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