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Do industries with emission constraints have legitimate competitiveness concerns?

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Abstract

The implementation of a carbon price leads to a uneven price increases across industries and countries. This is exacerbated when some industries or countries are excluded from carbon pricing. Uneven pricing has led to strong protests from vested interests, particularly the trade-exposed energy-intensive industries. These industries claim that carbon prices may force them to relocate production to countries without a carbon price and therefore increase global pollution. To avoid this, these industries claim they need concessions. Most studies to date find that *generally* these industries have little to worry about. This study extends the arguments to consider a wider range of industries and countries. It is found that *generally* the manufacturing industries have more competitiveness issues then the energy-intensive industries. Even though manufacturing industries have lower price increases, they are often highly competitive, trade-exposed, and mobile. The study concludes that politicians should ignore the negative cries of industrial competitiveness and instead focus on how to make industries competitive in a world with a carbon price.

Keywords:

Multi-region input-output analysis; Post-2012 climate policy; Competitiveness; Energy-intensive industry; Carbon leakage; Pollution haven hypothesis;

1 Introduction

The increased concern over global climate change has led several governments to impose legislation to encourage companies to mitigate their greenhouse gas (GHG) emissions. There is strong pressure from interest groups to use "market-based solutions" sparking the emergence of several emissions trading systems at the regional and international level. The European Union's Emission Trading System (EU-ETS) is the strongest measure implemented to date, but it may be trumped by the development of a US-ETS. Several countries are in the process of implementing ETS and the Kyoto Protocol contains an ETS at the international level. If current trends continue, it is likely that an ETS will be the core means of mitigating greenhouse gas (GHG) emissions in future climate regimes.

Currently, ETS cover primarily the emission intensive sectors and only relatively few countries participate. Consequently, some consumers and producers face mitigation costs, while others do not. In a globally integrated economic system with the relative free flow of goods this means that production may relocate to a region with lower mitigation costs. This has sparked intense politically lobbying on two fronts. First, industries with an emission cap will face increased costs and therefor be at a competitive disadvantage to other producers in less regulated regions. Such industries, usually "trade-exposed energy-intensive industries" intensely lobby for concessions to level the playing field with competitors (e.g. Grubb and Neuhoff, 2006). Second, if the competitive forces are adequately strong, then production may emerge in or relocate to regions with lower mitigation costs (e.g. Peters, 2008b). Limited coverage will therefor potentially increase *global* mitigation costs and reduce environmental effectiveness.

It is difficult to separate competitiveness rhetoric from protectionism and environmental concern. The underlying motive of an ETS—to change consumption and production behaviour to a low carbon society—is to avoid undesirable climatic change and this is put in jeopardy when industries or countries are excluded or given concessions. Over time elements of production and consumption will need major restructuring. Understandably, the ETS must allow time for this restructuring, but this time should not be a disguised form of protectionism. It can be convincingly argued that competitiveness concerns only exist at the firm level but not the national level (Krugman, 1994). There is also an increasing wealth of literature attempting to determine whether environmental costs cause industries or investments to relocate (e.g. SQW Ltd, 2006; Cosbey and Tarasofsky, 2007; Carbon Trust, 2008). The major challenge in assessing competitiveness concerns is to separate a companies decisions on environmental costs from the myriad of other economic and political costs.

To date, most of the competitiveness rhetoric has come from the trade-exposed energy-intensive industries (such as cement, iron and steel, etc). Several studies have attempted to determine whether in the past tighter environmental legislation has caused industrial relocations. Earlier studies found little evidence for relocation, but these studies have since been critiqued (see Cosbey and Tarasofsky, 2007, pp. 6, for an overview). A recent literature survey found that "...modelling suggests that regulations are unlikely to increase competitiveness (econometric models) and may adversely affect it (general equilibrium models)", but also that "...evidence seems consistently to be that the costs imposed by tighter pollution regulation are not a major determinant of trade patterns" and "...evidence on investment and locational patterns suggests that their determinants are complex and that the stringency of regulations must be regarded as one and often a modest one - amongst a variety of influences at work with more or less significance depending on other conditions" (SQW Ltd, 2006). Drawing a conclusion from this is difficult, but it seems fair to say that current environmental regulations are not a *major* factor in companies decisions.

Competitiveness concerns arise in many different situations. The two main situations are 1) an exporting industry may face increased costs and loose market share to international competitors; and 2) a domestic industry may loose market share due to increased competition from imports. Certain industries may also face different environmental costs and hence an industry may loose market share due to competing products. This is arguably the explicit long-term intention of climate policy and it should therefor not be protected against. It is important to emphasize than many industries already face competitiveness concerns *without* climate policy. In this case, it is not the role of climate policy to subsidize increased costs due to other existing economic forces. Thus while there are a variety competitiveness pressures caused by climate and economic policy, it is difficult to isolate *unwanted* competitiveness pressures from vocal interest groups.

If an industry does have legitimate competitiveness concerns due to climate policy it has several possible counter actions. First, the industry can lobby for weaker legislation or concessions. It is not possible to determine the overall environmental outcome of this action as it depends on how the industry actually behaves under different legislation. Second, the industry can restructure and improve its internal performance to counteract the higher costs. This is a good environmental outcome. Third, the industry may decide that to remain competitive it needs to relocate to a region where costs are lower. This is generally known as the "pollution haven hypothesis", industry relocates to a region with weaker environmental legislation. This is generally a bad environmental outcome. Fourth, the industry does not physically relocate, but rather, production expands in regions with weaker climate policy causing the global output of that industry to shift to new regions. This is generally the weak form of "carbon leakage" (Rothman, 1998; Peters and Hertwich, 2008a). This is generally a bad environmental outcome. The third and fourth points are particularly relevant and are expanded on in the following paragraphs.

The pollution haven hypothesis has been well studied empirically. While not all studies agree, it is generally found that the *physical relocation* of companies (SQW Ltd, 2006). There are many reasons for this, but most apparent is that environmental costs are not the most important cost in most industries (SQW Ltd, 2006). Even if environmental costs dominate, there are also disadvantages to relocation depending on a variety of geographical, political, social, economic, and other factors that may counteract the lower environmental costs. A combination of these factors is probably why EU industries have not relocated due to the imposition of the EU-ETS or the environmental costs of the EU-ETS are simply too small to have an effect. Given these factors, the increased costs due to climate policy will generally need to be non-marginal for climate policy *alone* to force industrial relocations.

A more alarming issue than the pollution haven hypothesis is the weak form of carbon leakage. This represents a systematic geographic separation of production from consumption (Rothman, 1998; Peters and Hertwich, 2008a). In this case the industry need not relocate or close down, but rather, increased consumption is met by increased production in a different geographic region. The evidence for weak carbon leakage is stronger (Peters, 2008b) and is reflected in the rapid growth of China's exports since joining the World Trade Organization (Weber and Matthews, 2007; Weber et al., 2008). This type of leakage is of more concern. The affected company might not close-down and may continue to grow. However, the company grows at a slower rate than competing foreign companies. As with the pollution haven hypothesis, weak carbon leakage is not necessarily driven by climate policy, but rather existing economic forces.

A weakness of previous studies on competitiveness concerns is that they primarily consider trade-exposed energy-intensive industries. The general argument is that energy-intensive industries have the highest cost increases due to environmental regulation. Consumers on the other hand, do not generally consume energy-intensive products, but rather consume manufactured products that may contain some energy-intensive materials or have energy-intensive materials used in their production (including capital investments). Thus, if the energy-intensive inputs into manufactured products are not trade-exposed (they primarily supply domestic companies) then they will not be identified as of concern. In addition, the bulk of global trade is not in energy-intensive products. This suggests that a focus on energy-intensive industries may be misleading. As an example, a considerable component of the global CO_2 footprint of Norwegian consumption is electricity generation in developing countries (Peters and Hertwich, 2006). If electricity is a high cost input into manufacturing then regulations on the electricity sector may effect the marginal investment decisions of non energy-intensive manufacturing. This suggests that assessment of competitiveness concerns must take a wider view than trade-exposed energy-intensive industries.

Despite numerous studies on competitiveness concerns of climate policy, this paper makes several new insights. This study does not focus on trade-exposed energy-intensive industries as in most other studies. Significantly, this study considers the manufacturing sectors which are highly exposed to weak carbon leakage which is behind the current growth in Chinese production. For example, expanding Chinese production of cars might reduce the growth of the European car industry. While numerous existing economic factors may lie at the heart of this, the environmental consequences may be significant. Other advantages of this study include the broad coverage of countries and the consistent inclusion of international supply chain effects. Since this study takes a broad coverage, it consequently looses detail. Other studies find that specific product-lines and companies may have series competitiveness concerns even though the aggregated industry does not (Carbon Trust, 2008). The study also uses some strong assumptions to take a "worse-case" scenario. Overall, this study does not attempt to compete with other more detailed studies, but rather extend there coverage and scope.

The paper first considers aggregated results at the global level and then considers three case studies of relevant regions—the USA, EU, and Annex B countries. A discussion summarising the results then follows. The methodology is explained in the appendix.

This paper is a work in progress and should be considered a first draft of the analysis (Working Paper). Comments, both positive and negative, are welcome.

2 Results

The methodological details are given in the Appendix. As a quick overview, the paper applies multi-regional input-output analysis using the GTAP database version 6 with a base-year of 2001. This covers 87 countries and regions and 57 sectors. Only the results for CO_2 are given, although it is possible to expand this to non-CO_2. The methodology considers all the emissions in the domestic supply chain, but not the global supply chain. This is partly for simplicity and it is partly realistic (Peters, 2008a). The use of a full multi-regional model properly reflects price increases, but has a poor reflection of trade-flows as the trade to industry and final demand must be separated. Truncating the price increase at the domestic boundary assumes that the price increases due to imports are negligible. Both methods have advantages and disadvantages, but the simpler method was taken here. This is discussed further in the Appendix.

2.1 Global Overview

To begin, I give an overview of which industries may have competitiveness concerns at the global level. This is not adequate for regional specific issues, but gives an unbiased overview of affected industries. This global perspective then allows a realistic comparison of different methods and indicators. After this, we consider three case-studies which focus on different regions.

2.1.1 Which industries have the largest price increases?

Most studies suggest that industries that have the greatest price increase are the ones at greatest risk. Of course, other factors may be more important then price increases alone, such as, closeness to markets, trade-barriers, currency fluctuations, level of international competition, and so on. At least initially, it is worth ignoring these factors and focussing on the industries with the greatest price increases due to carbon pricing alone.

If all carbon costs are passed on, the industries with the largest price increase are the ones with the highest total emission intensity (direct plus indirect emissions, see Appendix). However, in the EU-ETS permits have been given for free which effectively means companies can choose not to pass on the costs. So far, only the electricity sector has taken full advantage of the opportunity costs. In this analysis, I separate the price increase into components that relate to the direct emissions in each sector, the electricity sector, the "energy-intensive" sectors which are largely covered in the EU-ETS, and the remaining sectors in the economy (non-ETS).

In Table 1, the first column is the direct (on-site) emission intensity. The yellow boxes are the ones with an emission intensity greater than the global average. The indirect emission intensity (second column) shows a greater share of sectors with an emission intensity greater than the global average. This picks up most of the main-stream energy intensive sectors, such as sectors 15-18 (mining), 31-36 (energy-intensive) and 43 (electricity). However, many other sectors also have a higher emission intensity than the global average. The next four columns break down the indirect emission intensity into four components: direct (on-site), electricity in the entire supply chain, energy-intensive sectors (31-36), and the remaining sectors. The yellow boxes represent when the share of a component is greater than 33%. For most industries, the electricity sector dominates, followed by the direct emissions. The "others" represent a small share of the emissions, but cover more sectors. The last three columns identify the price increase assuming that only the electricity sector passes on costs, next if direct and energy-intensive sectors pass on the costs, and finally, economy-wide price increases are included. The price increases are the percentage increase for a CO_2 tax of 20\$/tonne of CO_2; doubling the tax will double the price increase. The electricity sector is responsible for roughly half of the price increases and most is covered when the energy-intensive sectors are also included.

Overall, the results generally follow other studies. The industry with the greatest price rise is electricity (18%). After this at around 5% increase are the aggregated sectors of non-metallic products and ferrous metals, with non-ferrous metals and refineries following. Transportation sectors are important, but are not currently covered by ETS at either the regional or international level. Mining sectors are also important, but arguably, many types of mining have limited options for relocation. Most other sectors have around a 1% price increase. Interestingly, many sectors have a similar price increase of 0.5% if it is assumed that only electricity passes on costs. In addition, the non-ETS sectors have a relatively small impact on prices.

2.1.2 Which industries are trade-exposed?

Trade exposure is a little more difficult to measure. The Stern Review considered trade-exposure as the share of exports in final use (Stern, 2006, Chapter 11). The problem with this approach is that it ignores the fact that a considerable portion of domestic production is used domestically. A better measure would be to consider the share of exports in domestic output. However, output may not be easily compared across countries due to construction methods of input-output data (United Nations, 1993). Perhaps a measure of the CO_2 emitted in each sector for traded products measured against domestic output would be suitable.

Table 2 shows various measure of trade exposure. The first column shows the total price increase assuming full-coverage and pass-through of costs, from Table 1. The second column shows the trade exposure relative to final consumption and the third column related to output. Using output can greatly alter whether an industry is trade exposed or not. As an example, almost 100% of the final use of ferrous metals are exports, however, when considering total domestic output of ferrous metals, only 17% is exported globally. This significant difference changes ferrous metals from trade-exposed to not trade-exposed. By considering trade-exposure relative to domestic output, manufactured products become more important. To avoid comparability of output across countries, the fourth column shows the share of CO_2 emissions to produce exported products in each sector (for example, 15.7% of the global CO_2 emissions in paddy rice production are to produce products for export). Apart from mining, this approach puts more weight on the manufacturing sectors and less on the energy-intensive sectors, suggesting that energy-intensive sectors are often used as inputs into manufacturing. The final two columns show the global emissions embodied in exported products. The standard energy-intensive sectors (31-36) cover 39% of the emissions embodied in traded products with chemicals being the most important, followed by non-metallic products and primary metals production. However, the remaining 60% of traded emissions are important. The second most important group of sectors are manufacturing (27-30, 37-42) and cover 30% of global traded emissions.

It is evident that a consistent definition for trade-exposed may be difficult. Table 2 shows that depending on definition, different industries are trade-exposed. In some cases, the total traded emissions from manufacturing may be more important than the total traded emissions from the energy-intensive sectors. Energy-intensive industries may be important inputs into many domestic manufacturing industries which may be trade-exposed. In some cases, industries with modest price increases are not only trade-exposed, but also cover a a significant share of global emissions embodied in trade. Even with a modest price increase, these industries may be highly competitive and should be considered in competitiveness analyses. Overall, it is clear that a wide coverage of industries is needed to assess which industries are affected by carbon legislation.

2.1.3 Which industries have competitiveness concerns?

The screening analysis suggests that industries of most concern are the standard energy-intensive industries such as primary metal production, non-metallic products, refineries, and chemicals. Mining industries are important, but considering that mining is relatively concentrated in countries with natural resources, they may not be a sector under threat.

The screening analysis also identified various manufacturing sectors as causing concern. Together, manufacturing is an an important group of sector in total global emissions and many of the inputs into manufacturing are energy-intensive. If manufacturing relocates, then energy-intensive industries may follow. Likewise, if energy-intensive industries relocate, then manufacturing may also relocate. Manufacturing may also be at a greater threat to price competition and is arguably more mobile than energy intensive industries. Thus, any analysis should include non energy-intensive sectors.

2.2 Case Studies

The screening analysis was only applied at the global level. Characteristics will differ at the regional level. I consider three case studies for relevant countries and regions—US, EU27, and Annex B. For each case a similar analysis is performed. This should reflect different regional characteristics, but still at an aggregated industry perspective. That is, while an aggregated industry may not have competitiveness concerns there may be companies and products within that industry that have competitiveness concerns.

Each case study will have the same data presented. Tables 3, 4, and 5 include the indirect emission intensity (covering domestic industries only), the price increase assuming total coverage of the economy and full pass-on off costs (an unlikely worst-case scenario), then the exposure of each sector to international trade from non-Annex B countries is shown relative to domestic output covering exports and imports separately and then total trade. For example, in the US 3.7% of the total output of paddy rice was imported from non-Annex B countries and 23% of domestic output was exported to non-Annex B countries. It is assumed that non-Annex B countries do not face a price increase due to carbon legislation while all Annex B countries do. Overall, this is a worst case scenario assuming full pass on of carbon costs in all Annex B countries and total coverage of the economy in each Annex B country. More data was used in the analysis, but the tables give a good overview.

Note that on occasion specific numbers are referred to. These come from the GTAP database and may not necessarily directly compare with the equivalent number in another data set. More details can be found in the Appendix. The figures come from another study (Peters, 2008b).

2.2.1 Case Study I: United States of America

Table 3 shows the industries affected by competitiveness concerns in the USA. The second column shows the price increases which are highest for the energy intensive industries. However, the industries with the largest price increases are not trade-exposed as a proportion of total output. The most trade-exposed industries are imports of oil, leather products, and manufactured products—these industries are not exposed to exports. The most trade-exposed export industries are agricultural products and more high-tech manufactured products. The trade-exposed industries generally have lower price increases, except from the agricultural products.

It is worth considering some examples of the trade-exposed industries. For example, in the database the US produced a total output of 15,894 million USD of leather products. A total of 1,931 was exported (1,245 to non-Annex B), but a total of 20,952 was imported. Thus, the majority of the US leather products are imported. Arguably, the worst case of a 0.7% increase is price due to carbon pricing may further increase imports and reduce domestic output. On the other hand, refined petroleum products have an increased cost of 3.9%, but compared to total domestic output of 145,800 million USD a total of 9,969 was imported from non-Annex B countries. In this case, which industry has the stronger claim of a competitiveness concern, the high-cost increase in the relatively low trade-exposed refined petroleum or the highly exposed and mobile leather industry? Of course, other factors come into play, such as the role of differing emissions intensity of the industries and counteracting is the difficultly of "relocating" some types of industries.

Figures 1 and 2 give a different view of the trade-exposed industries. It shows the share of CO_2 emissions embodied in global trade aggregated in the US to US (zero), US to non-US, non-US to US, and non-US to non-US. As expected, most trade is from the non-US to non-US and this has remained relatively static. However, over time the exports from the US to non-US has decreased while the exports from the non-US to US has increased. Most of the growth is due to the increased exports from China and the bulk of the emissions growth is due to various manufactured products. The energy-intensive industries account for a smaller portion of the total trade and changes are smaller.

Combining the information in Table 3 and Figures 1 and 2 suggests that most concern should be placed on the trade-exposed industries that are responsible for large flows of embodied emissions. Generally speaking, these industries have a smaller price increase than the energy-intensive industries. Given the price increase is based on total coverage with full pass through, it is likely that the price increase is lower than price changes due to currency fluctuations, material inputs, labour inputs, and so on. Thus, arguably, realistic price increases due to carbon legislation are unlikely to cause relocation issues over and above a business as usual situation. In addition, perhaps most problematic is the relocation of production of highly mobile manufacturing sectors and not the less mobile energy-intensive industries.

2.2.2 Case Study II: European Union

The results for the EU are follow similar trends to the US, Table 3. Again, the energy-intensive sectors have the largest price increase, but there are many sectors that have a price increase around 1%. Overall the price increases in the EU are slightly lower than the US due to a lower emission intensity. As for the US, most of the energy-intensive sectors are not that trade-exposed in relation to manufacturing sectors. The most trade-exposed sectors are generally manufacturing, but with a much lower price increase. The mining sectors exposure to imports is most significant, but this may reflect that a large share of natural resource is located outside of Europe. Agriculture is relatively trade-exposed to imports, followed by textiles and some manufacturing. Only a few manufacturing sectors are trade-exposed to exports. Air transport and plant-based fibres both have a relatively large price increase and trade-exposure.

Figures 3 and 4 shows that, as for the US, the energy-intensive sectors represent a small part of the emissions embodied in EU trade. In comparison to the US, the relative proportions of trade between regions and sectors is relatively constant over time. The EU to EU quadrant represents the trade between EU countries. The figure reflects that it is important is to keep track of the large aggregated sectors which are responsible for a large share of emissions, may have a larger trade-exposure, but a relatively small price increase. These sectors represent agriculture, textiles, clothing, and various manufactured products. As for the US, at the aggregate level the EU does not have significant competitiveness concerns.

2.2.3 Case Study III: Annex B countries in the Kyoto Protocol

Annex B countries follow a similar fate as the US and EU, Table 5. This is not surprising as the EU and US make a large share of Annex B emissions. The energy-intensive sectors are not trade-exposed except for some mining sectors heavily dependent on imports. More problematic is the import exposure of many agriculture and manufacturing sectors. As for the EU and US, there does not seem to be a significant competitiveness threat to the Annex B countries as a whole.

3 Discussion

It is worth initially pointing to the weaknesses of this study to allow an appreciation of its strengths. Other studies have found that competitiveness concerns are generally weak, but they can vary significantly at the sub-sector, product, and company level (Carbon Trust, 2008). Consequently, this study is only applicable to give a broad overview of where one may look further. Even in industrial sectors without competitiveness concerns at the aggregate, there may be companies and product lines that are greatly affected.

In addition, this study takes a worst case scenario for price increases by assuming full coverage of a carbon tax across all Annex B countries and total pass-through of costs. However, the point of this study is not to identify affected industries or product lines at the detailed level. Rather, the point is to invite the reader to view competitiveness concerns from a different point of perspective.

Generally, most studies of industrial competitiveness assume that the industries with competitiveness concerns are energy-intensive and trade-exposed. It doesn't seem as important that less energy-intensive industries are often more trade-exposed or that less energy-intensive industries are responsible for greater share of total emissions. Essentially, many articles fail to take a systems perspective as they pre-suppose which industries are affected (arguably, the ones that shout the loudest). A nice analogy is understanding why different studies find different reasons for animal extinctions (Pounds and Coloma, 2008). Thus, the goal of this study is to expand the analysis to cover all sectors and consider not only relative, but also absolute changes.

The first issue considered in this study was the implications of the full pass through of costs. Table 1 shows that if only electricity has a carbon price and passes on the costs fully, then it accounts for roughly 50% of the price increases compared to full coverage. This represents a global average and will differ marginally on a country by country basis. By additionally including the direct emissions and energy-intensive sectors, again with full pass-through of costs, then 80-90% of the price increases are covered. This suggests that first focussing a carbon price on the electricity sector and then on the energy-intensive sectors covers a substantial portion of emissions and price increases. This has several policy relevant implications. Focussing an ETS on energy-intensive sectors (the big emitters) covers most cost increases while keeping transaction costs relatively low. In terms of post-2012 policy, this also suggests that sectoral measures may be an efficient means of accounting for a significant share of global emissions and price increases.

The next issue discussed in this paper was how to evaluate trade-exposure. Many studies consider the share of that industries exports in terms of final consumption of that sector (GDP of that sector). This approach neglects that a substantial portion of many industries output goes to other domestic industries for inputs into production and are not exported. This changed perspective turned some industries from trade-exposed to not trade-exposed. Thus, when assessing an industries trade-exposure, it is imported to consider the share of trade as a proportion of total production (x) and not final consumption (y).

The third issue discussed was the distribution of global emissions embodied in trade across industries. The mainstream energy-intensive industries cover about 40% of the emissions embodied in global trade. Mining accounts for about 8%. This means that half of the global emissions embodied in trade cover a variety of industries with a higher level of processing (secondary and tertiary sectors). Arguably, these smaller industries are more mobile and warrant closer investigation despite the fact that they may have a lower price rise.

The paper then moves on to discuss various relevant case studies which cover the US, EU27, and Annex B countries to determine which industries should be of most concern. In general, the industries most affected in a broader analysis are not energy-intensive, but trade-exposed agriculture and manufacturing. Mining was often trade-exposed to imports, but it is arguable whether this is an issue. In many cases, the low level of mining in the EU, US, and Annex B may reflect a lack of natural resource, particularly in relation to oil and gas. Additional analysis shows that most of the changes in trade flows since 1990 have occurred in manufacturing and not in energy-intensive sectors (Peters, 2008b). This is more prominent in the US compared to the EU, mainly due to the influence of China. The development of trade since 2002 should be closely followed to assess shifting centres of production.

One important reason that competitiveness concerns are low is that a significant share of global trade is between Annex B countries. This study only considered the trade-exposure to non-Annex B exports and imports. This assumes that all Annex B countries have similar carbon prices, even though in practice this is not the case. However, an implication of this is that the more countries and industries with carbon pricing will reduce potential competitiveness concerns.

Often, competitiveness rhetoric follows negative lines of argumentation. In many cases, it is assumed that migration of industrial production is bad. This is only the case, environmentally, when the new producer uses dirtier production than the original producer. This need not be the case, particularly, if cleaner technology migrates with the production. Also, the new producer may already have cleaner production. A good example, is Iceland. Iceland has increased GHG emissions due to aluminum production. From an environmental perspective, this is good since Iceland produces electricity with hydropower. If Iceland displaced production of aluminum from coal-fired electricity production, then this is a significant win for the environment. In contrast, economically it is a bad loss for Iceland as it increases its domestic emissions and increases mitigation costs.

The case of Iceland suggests that one should look for situations where trade and competitiveness can be used as a win-win situation and not viewed as a negative impact. In this light, policy makers should consider the concerns of industrial interests, but must not allow policy to conflict with the goals of climate policy. Policy should consider how trade can be used in a positive way and not to protect existing industries (Peters and Hertwich, 2008a,b). A degree of structural change in production and consumption is required to address climate change. Making too many concessions now will simply shift potential costs (and benefits) to a later date in the interests of short-term profit.

4 Appendix I: Methodology

Calculating the EET can become complex due to the need to enumerate the unique production system in individual countries to a reasonable level of sectorial detail and then to link this to consumption systems through international trade data. The most common methodology for this type of analysis is a generalization of environmental input-output analysis (IOA) Leontief (1970) to a multi-regional setting.

Using IOA there are two main approaches to modelling EET at a national level Peters (2008a). The simplest approach is to determine the domestic CO_2 emissions in each country to produce the bilateral trade with another country. This method is the most transparent, but does not assess the imports required to produce the bilateral trade. A more complex approach uses a multi-regional input-output (MRIO) model to determine the global emissions for an exogenous final consumption with global trade determined endogenously. Both methods give the same global emissions, but the national emissions differ in the method of allocating intermediate consumption Peters (2008a). In this article we employ the simplified version (EEBT) as we want to consider total trade flows and not only the trade flows to final demand. However, for the price increases we should really consider price increases on imported products using the MRIO. By using the EEBT we essentially assume that the price increase of imported products is negligible.

To explicitly model the EET requires a decomposition of the standard IOA framework into domestic and traded components. The total CO_2 emissions occurring in each region are

$$f_r = F_r \left(I - A_{rr}\right)^{-1} \left(y_{rr} + \sum_s e_{rs}\right) \tag{1}$$

where F_r is a row vector with each element representing the CO_2 emissions per unit industry output, A_{rr} are the interindustry requirements of domestically produced products demanded by domestic industries, y_{rr} are the products produced and consumed domestically, e_{rs} are the bilateral exports from region r to region s, and I is the identity matrix. Summing over all regions gives the total global emissions since bilateral trade is considered. In the full MRIO model the bilateral trade, e_{rs}, is decomposed into components for intermediate and final consumption Peters (2008a).

The linearity assumption of IOA allows (1) to be decomposed into components for domestic demand on domestic production

$$f_{rr} = F_r \left(I - A_{rr}\right)^{-1} y_{rr} \tag{2}$$

and the EET from region r to region s

$$f_{rs} = F_r \left(I - A_{rr}\right)^{-1} e_{rs} \tag{3}$$

Summation gives the total emissions occurring in the country $f_r = f_{rr} + \sum_s f_{rs}$. Direct household and government emissions—such as personal car use—can be included in f_{rr}. The total emissions embodied in exports (EEE) from region r to all other regions are,

$$f_r^e = \sum_s f_{rs} \tag{4}$$

and the total emissions embodied in imports (EEI) are obtained by reversing the summation,

$$f_r^m = \sum_s f_{sr} \tag{5}$$

The price increase is obtained using the price model. Since we assume full pass through of costs, the price increase is equivalently given as

$$\Delta p_r = \tau F_r \left(I - A_{rr}\right)^{-1} \tag{6}$$

where τ is the CO_2 tax.

The time-series analysis was based on another study (Peters, 2008b). Only time-series of data was available for the trade data and the data was valued in current prices.

Consequently, the emission intensities were used from 2001 and the results were normalized to reduce the effect of price changes. Overall, these results should give a good indication of how trade patterns have shifted between countries and sectors.

The data requirements for a multi-regional IOA are considerable, but most developed countries and many developing countries collect the necessary data. However, converting the country data to a consistent global data set is a considerable task. The Global Trade Analysis Project (GTAP) has constructed the necessary data for the purposes of CGE modelling and this data set can be applied for multi-regional IOA. The GTAP provides data for 87 countries and 57 industry sectors covering IOA, trade, protection, energy, and CO_2 emissions Dimaranan (2006). Version 6 represents the world economy in 2001. We only consider CO_2 emissions which covers over 70% of global GHG emissions CAIT (2007).

Whilst the GTAP database has impressive coverage, care needs to be taken with its consistency and accuracy. Generally, original data are supplied by the members of the GTAP in return for free subscription. The data are often from reputable sources such as national statistical offices. Unfortunately, due to the voluntary nature of data submissions, the data are not always the most recently available. Further, once the original data has been received "[GTAP] make[s] further *significant* adjustments to ensure that the I-O table matches the external macroeconomic, trade, protection, and energy data" Dimaranan (2006). These adjustments (or calibrations) are made for internal consistency in computable general equilibrium modelling and are of unknown magnitude. The key data challenges and adjustments we perform on the GTAP data in preparation for our analysis are described in the Supporting Information.

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		Global average	Emission intensity		Distribution of indirect emission intensity				Price increase		
			Direct	Indirect	Direct	Electricity	Energy Intensive	Others	If only elec passes on costs	If energy-intensive industry passes on costs	If complete coverage
				kg/$	%	%	%	%	%	%	%
		Global average	0.35	0.59					20	20	20
		Cut-off	0.35	0.59	33						
1	pdr	Paddy rice	0.11	0.32	35	31	17	18	0.2	0.5	0.6
2	wht	Wheat	0.26	1.06	25	53	10	12	1.1	1.9	2.1
3	gro	Cereal grains nec	0.28	0.74	38	32	14	16	0.5	1.2	1.5
4	v_f	Vegetables, fruit, nuts	0.19	0.49	40	35	13	13	0.3	0.8	1.0
5	osd	Oil seeds	0.29	0.72	41	35	12	13	0.5	1.3	1.4
6	c_b	Sugar cane, sugar beet	0.20	0.60	32	42	12	13	0.5	1.0	1.2
7	pfb	Plant-based fibers	0.39	0.94	42	34	13	11	0.6	1.7	1.9
8	ocr	Crops nec	0.24	0.55	43	31	11	15	0.3	0.9	1.1
9	ctl	Cattle,sheep,goats,horses	0.24	0.67	36	29	9	25	0.4	1.0	1.3
10	oap	Animal products nec	0.18	0.63	30	34	9	27	0.4	0.9	1.3
11	rmk	Raw milk	0.12	0.57	22	40	11	27	0.5	0.8	1.1
12	wol	Wool, silk-worm cocoons	0.16	0.55	30	30	11	29	0.3	0.8	1.1
13	frs	Forestry	0.73	1.01	72	10	5	12	0.2	1.8	2.0
14	fsh	Fishing	0.45	0.75	59	18	10	12	0.3	1.3	1.5
15	coa	Coal	0.59	1.35	44	42	6	8	1.1	2.5	2.7
16	oil	Oil	0.60	0.92	66	15	6	13	0.3	1.6	1.8
17	gas	Gas	0.87	1.18	74	17	3	7	0.4	2.2	2.4
18	omn	Minerals nec	0.43	1.41	31	47	8	13	1.3	2.4	2.8
19	cmt	Meat- cattle,sheep,goats,horse	0.06	0.58	10	39	10	41	0.4	0.7	1.2
20	omt	Meat products nec	0.05	0.56	9	42	10	40	0.5	0.7	1.1
21	vol	Vegetable oils and fats	0.14	0.65	21	38	11	30	0.5	0.9	1.3
22	mil	Dairy products	0.08	0.59	14	44	13	30	0.5	0.8	1.2
23	pcr	Processed rice	0.11	0.55	19	38	12	31	0.4	0.8	1.1
24	sgr	Sugar	0.15	0.66	23	37	10	30	0.5	0.9	1.3
25	ofd	Food products nec	0.10	0.57	18	40	13	29	0.5	0.8	1.1
26	b_t	Beverages and tobacco products	0.07	0.46	14	39	23	23	0.4	0.7	0.9
27	tex	Textiles	0.12	0.66	19	47	14	21	0.6	1.0	1.3
28	wap	Wearing apparel	0.03	0.39	9	49	14	29	0.4	0.6	0.8
29	lea	Leather products	0.04	0.41	11	45	17	28	0.4	0.6	0.8
30	lum	Wood products	0.05	0.56	9	45	15	31	0.5	0.8	1.1
31	ppp	Paper products, publishing	0.23	0.87	26	49	13	11	0.9	1.5	1.7
32	p_c	Petroleum, coal products	1.18	1.99	59	16	10	14	0.6	3.4	4.0
33	crp	Chemical,rubber,plastic prods	0.34	1.07	31	42	16	10	0.9	1.9	2.1
34	nmm	Mineral products nec	1.93	2.90	66	16	12	5	0.9	5.5	5.8
35	i_s	Ferrous metals	1.14	2.78	41	34	20	5	1.9	5.3	5.6
36	nfm	Metals nec	0.32	1.69	19	59	13	9	2.0	3.1	3.4
37	fmp	Metal products	0.10	0.92	11	43	35	11	0.8	1.6	1.8
38	mvh	Motor vehicles and parts	0.03	0.54	6	45	31	18	0.5	0.9	1.1
39	otn	Transport equipment nec	0.04	0.50	9	44	31	16	0.4	0.8	1.0
40	ele	Electronic equipment	0.02	0.36	6	48	28	18	0.3	0.6	0.7
41	ome	Machinery and equipment nec	0.04	0.53	7	45	33	15	0.5	0.9	1.1
42	omf	Manufactures nec	0.10	0.55	19	42	21	18	0.5	0.9	1.1
43	ely	Electricity	8.18	9.04	91	6	1	2	17.5	17.7	18.1
44	gdt	Gas manufacture, distribution	1.16	1.65	70	13	5	12	0.4	2.9	3.3
45	wtr	Water	0.13	0.88	14	69	8	9	1.2	1.6	1.8
46	cns	Construction	0.06	0.60	10	26	47	17	0.3	1.0	1.2
47	trd	Trade	0.06	0.35	19	49	11	22	0.3	0.5	0.7
48	otp	Transport nec	0.82	1.25	66	13	10	11	0.3	2.2	2.5
49	wtp	Sea transport	1.36	1.73	78	6	6	10	0.2	3.1	3.5
50	atp	Air transport	1.24	1.70	73	7	9	11	0.2	3.0	3.4
51	cmn	Communication	0.04	0.24	18	48	12	22	0.2	0.4	0.5
52	ofi	Financial services nec	0.01	0.17	8	53	12	26	0.2	0.3	0.3
53	isr	Insurance	0.02	0.22	7	52	13	28	0.2	0.3	0.4
54	obs	Business services nec	0.04	0.26	17	49	15	19	0.2	0.4	0.5
55	ros	Recreation and other services	0.06	0.37	17	53	11	19	0.4	0.6	0.7
56	osg	PubAdmin-Defence-Health-Educat	0.06	0.29	23	48	13	16	0.3	0.5	0.6
57	dwe	Dwellings	0.00	0.06	1	34	35	29	0.0	0.1	0.1

Table 1: A decomposition of the emission intensities and price increases (see text).

		Global average	Price increase If complete coverage %	Trade exposure y_exports/ y_total %	 y_exports/ x_total %	Share of CO2 emissions in each sector to meet export demand %	Emissions Embodied in Exports (Imports) Global Exports kt CO2	 Share of total %
		Global average	20	19.91	11.78	**26.0**		
		Cut-off		50	30.00	**33.3**		
1	pdr	Paddy rice	0.6	12.1	2.1	15.7	1077	0.0
2	wht	Wheat	2.1	39.4	17.0	41.3	15707	0.3
3	gro	Cereal grains nec	1.5	44.4	13.8	33.9	12027	0.2
4	v_f	Vegetables, fruit, nuts	1.0	16.2	10.8	19.9	24651	0.5
5	osd	Oil seeds	1.4	52.2	21.8	50.8	13846	0.3
6	c_b	Sugar cane, sugar beet	1.2	0.8	0.2	20.4	32	0.0
7	pfb	Plant-based fibers	1.9	52.2	20.9	37.5	10139	0.2
8	ocr	Crops nec	1.1	42.4	18.8	36.1	22415	0.4
9	ctl	Cattle,sheep,goats,horses	1.3	19.3	4.1	17.7	3986	0.1
10	oap	Animal products nec	1.3	12.2	5.1	21.0	11914	0.2
11	rmk	Raw milk	1.1	0.4	0.1	16.1	166	0.0
12	wol	Wool, silk-worm cocoons	1.1	43.3	16.2	60.0	1857	0.0
13	frs	Forestry	2.0	24.9	7.5	30.6	14038	0.3
14	fsh	Fishing	1.5	9.1	5.4	18.2	7007	0.1
15	coa	Coal	2.7	91.4	21.9	39.4	44674	0.8
16	oil	Oil	1.8	100.0	54.1	64.6	251637	4.7
17	gas	Gas	2.4	92.3	44.1	61.2	72496	1.4
18	omn	Minerals nec	2.8	91.2	15.5	52.8	78910	1.5
19	cmt	Meat- cattle,sheep,goats,horse	1.2	13.3	8.8	17.2	13162	0.2
20	omt	Meat products nec	1.1	14.5	10.4	19.3	18208	0.3
21	vol	Vegetable oils and fats	1.3	24.4	11.8	25.0	10846	0.2
22	mil	Dairy products	1.2	14.8	10.3	19.4	16225	0.3
23	pcr	Processed rice	1.1	5.3	4.4	7.0	3902	0.1
24	sgr	Sugar	1.3	13.4	6.6	16.1	6065	0.1
25	ofd	Food products nec	1.1	17.6	11.6	18.5	82452	1.5
26	b_t	Beverages and tobacco products	0.9	11.0	8.1	13.9	20591	0.4
27	tex	Textiles	1.3	58.4	25.3	52.8	147244	2.8
28	wap	Wearing apparel	0.8	36.3	30.7	43.1	86214	1.6
29	lea	Leather products	0.8	57.0	42.3	57.4	59228	1.1
30	lum	Wood products	1.1	42.3	20.2	37.0	83890	1.6
31	ppp	Paper products, publishing	1.7	44.1	12.1	31.7	124788	2.3
32	p_c	Petroleum, coal products	4.0	42.5	13.9	33.8	246415	4.6
33	crp	Chemical,rubber,plastic prods	2.1	63.9	25.8	42.0	663597	12.5
34	nmm	Mineral products nec	5.8	71.9	14.3	24.2	314856	5.9
35	i_s	Ferrous metals	5.6	97.2	17.4	43.9	393153	7.4
36	nfm	Metals nec	3.4	97.4	31.6	62.2	325267	6.1
37	fmp	Metal products	1.8	50.0	13.0	29.0	126846	2.4
38	mvh	Motor vehicles and parts	1.1	44.1	31.5	35.9	167690	3.2
39	otn	Transport equipment nec	1.0	55.4	40.3	48.3	80287	1.5
40	ele	Electronic equipment	0.7	65.4	47.6	56.3	258378	4.9
41	ome	Machinery and equipment nec	1.1	57.1	39.2	47.9	468814	8.8
42	omf	Manufactures nec	1.1	45.7	29.8	42.7	144431	2.7
43	ely	Electricity	18.1	7.3	2.1	21.8	131040	2.5
44	gdt	Gas manufacture, distribution	3.3	8.5	2.4	32.8	4521	0.1
45	wtr	Water	1.8	1.8	0.7	21.4	1387	0.0
46	cns	Construction	1.2	0.8	0.7	2.9	15058	0.3
47	trd	Trade	0.7	4.1	2.7	13.4	60215	1.1
48	otp	Transport nec	2.5	16.3	6.6	21.8	190126	3.6
49	wtp	Sea transport	3.5	20.5	14.0	22.9	79075	1.5
50	atp	Air transport	3.4	39.8	27.3	35.4	218409	4.1
51	cmn	Communication	0.5	9.1	4.1	19.8	9686	0.2
52	ofi	Financial services nec	0.3	8.1	2.5	20.7	7317	0.1
53	isr	Insurance	0.4	8.6	5.1	29.3	6819	0.1
54	obs	Business services nec	0.5	21.3	7.4	20.1	85970	1.6
55	ros	Recreation and other services	0.7	6.0	3.7	13.3	31079	0.6
56	osg	PubAdmin-Defence-Health-Educat	0.6	1.7	1.6	3.6	31411	0.6
57	dwe	Dwellings	0.1	0.0	0.0	0.8	0	0.0

Table 2: Different measures of trade-exposure (see text).

			Indirect emission intensity kg/$	Max Price increase 20	Exports = y_exp_nB/ x_total %	Imports = y_imp_nB/ x_total %	Total Exposure = average Exp and Imp %
1	pdr	Paddy rice	1.94	3.9	23.0	3.7	13.3
2	wht	Wheat	1.10	2.2	47.0	0.4	23.7
3	gro	Cereal grains nec	0.80	1.6	18.5	0.6	9.6
4	v_f	Vegetables, fruit, nuts	0.62	1.2	6.5	21.3	13.9
5	osd	Oil seeds	1.05	2.1	27.8	0.8	14.3
6	c_b	Sugar cane, sugar beet	0.78	1.6	0.1	0.2	0.1
7	pfb	Plant-based fibers	0.77	1.5	27.1	0.9	14.0
8	ocr	Crops nec	0.27	0.5	3.4	15.4	9.4
9	ctl	Cattle,sheep,goats,horses	1.00	2.0	0.8	1.4	1.1
10	oap	Animal products nec	0.77	1.5	6.7	1.6	4.1
11	rmk	Raw milk	0.60	1.2	0.0	0.1	0.0
12	wol	Wool, silk-worm cocoons	0.79	1.6	2.7	11.7	7.2
13	frs	Forestry	0.43	0.9	1.1	0.4	0.7
14	fsh	Fishing	0.90	1.8	0.4	12.9	6.7
15	coa	Coal	0.64	1.3	1.4	1.4	1.4
16	oil	Oil	0.77	1.5	0.1	124.8	62.4
17	gas	Gas	1.52	3.0	3.6	11.8	7.7
18	omn	Minerals nec	1.64	3.3	1.5	4.0	2.8
19	cmt	Meat- cattle,sheep,goats,horse	0.69	1.4	1.9	0.4	1.1
20	omt	Meat products nec	0.59	1.2	2.6	0.3	1.4
21	vol	Vegetable oils and fats	0.93	1.9	3.5	2.0	2.7
22	mil	Dairy products	0.55	1.1	0.7	0.1	0.4
23	pcr	Processed rice	0.91	1.8	13.2	10.9	12.0
24	sgr	Sugar	0.64	1.3	0.5	2.0	1.2
25	ofd	Food products nec	0.58	1.2	2.1	3.1	2.6
26	b_t	Beverages and tobacco products	0.33	0.7	0.8	1.5	1.2
27	tex	Textiles	0.60	1.2	5.5	15.3	10.4
28	wap	Wearing apparel	0.36	0.7	3.3	38.5	20.9
29	lea	Leather products	0.35	0.7	7.8	111.2	59.5
30	lum	Wood products	0.45	0.9	1.2	7.2	4.2
31	ppp	Paper products, publishing	0.77	1.5	2.1	1.0	1.5
32	p_c	Petroleum, coal products	1.96	3.9	3.6	6.8	5.2
33	crp	Chemical,rubber,plastic prods	1.01	2.0	5.6	3.4	4.5
34	nmm	Mineral products nec	1.49	3.0	3.9	6.3	5.1
35	i_s	Ferrous metals	1.28	2.6	2.4	4.1	3.2
36	nfm	Metals nec	1.18	2.4	3.8	6.4	5.1
37	fmp	Metal products	0.59	1.2	2.0	4.2	3.1
38	mvh	Motor vehicles and parts	0.47	0.9	3.5	7.1	5.3
39	otn	Transport equipment nec	0.34	0.7	12.4	3.4	7.9
40	ele	Electronic equipment	0.27	0.5	17.2	34.6	25.9
41	ome	Machinery and equipment nec	0.35	0.7	8.8	9.8	9.3
42	omf	Manufactures nec	0.52	1.0	7.1	60.5	33.8
43	ely	Electricity	11.20	22.4	0.0	0.0	0.0
44	gdt	Gas manufacture, distribution	0.62	1.2	0.4	0.0	0.2
45	wtr	Water	0.26	0.5	0.1	0.1	0.1
46	cns	Construction	0.37	0.7	0.0	0.0	0.0
47	trd	Trade	0.32	0.6	0.2	0.5	0.3
48	otp	Transport nec	1.11	2.2	1.4	2.9	2.1
49	wtp	Sea transport	2.13	4.3	1.6	1.9	1.8
50	atp	Air transport	1.65	3.3	3.7	5.0	4.4
51	cmn	Communication	0.19	0.4	0.4	0.5	0.4
52	ofi	Financial services nec	0.14	0.3	0.3	0.1	0.2
53	isr	Insurance	0.13	0.3	0.6	0.4	0.5
54	obs	Business services nec	0.22	0.4	0.9	0.7	0.8
55	ros	Recreation and other services	0.40	0.8	0.7	0.4	0.5
56	osg	PubAdmin-Defence-Health-Educat	0.17	0.3	0.8	0.3	0.5
57	dwe	Dwellings	0.04	0.1	0.0	0.0	0.0

Table 3: Competitiveness concerns in the USA (see text).

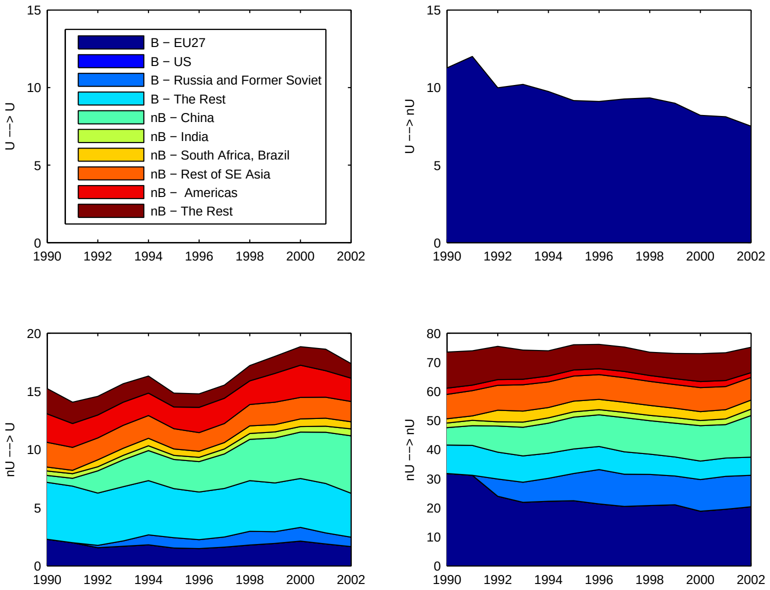

Figure 1: The development of emissions embodied in US trade from 1990 to 2002 by region (see text).

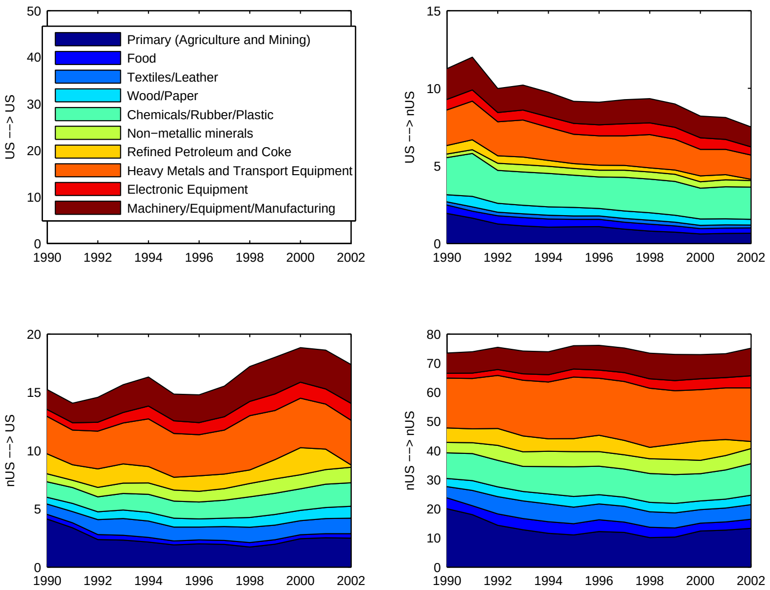

Figure 2: The development of emissions embodied in US trade from 1990 to 2002 by sector (see text).

			Indirect emission intensity kg/$	Max Price increase 20	Exports = y_exp_nB/ x_total %	Imports = y_imp_nB/ x_total %	Total Exposure = average Exp and Imp %
1	pdr	Paddy rice	0.72	1.4	1.0	23.2	12.1
2	wht	Wheat	0.55	1.1	8.5	0.6	4.5
3	gro	Cereal grains nec	0.60	1.2	4.8	2.3	3.6
4	v_f	Vegetables, fruit, nuts	0.53	1.1	1.2	13.6	7.4
5	osd	Oil seeds	0.55	1.1	3.1	35.8	19.4
6	c_b	Sugar cane, sugar beet	0.49	1.0	0.0	0.2	0.1
7	pfb	Plant-based fibers	1.18	2.4	19.9	46.4	33.2
8	ocr	Crops nec	0.64	1.3	1.7	16.0	8.9
9	ctl	Cattle,sheep,goats,horses	0.54	1.1	1.2	0.7	0.9
10	oap	Animal products nec	0.65	1.3	1.6	2.1	1.9
11	rmk	Raw milk	0.48	1.0	0.0	0.1	0.1
12	wol	Wool, silk-worm cocoons	0.49	1.0	4.6	23.0	13.8
13	frs	Forestry	3.31	6.6	1.2	3.7	2.4
14	fsh	Fishing	0.52	1.0	0.4	1.9	1.2
15	coa	Coal	1.45	2.9	0.2	25.7	13.0
16	oil	Oil	1.38	2.8	1.4	148.3	74.9
17	gas	Gas	0.55	1.1	0.1	81.9	41.0
18	omn	Minerals nec	1.44	2.9	3.7	24.4	14.0
19	cmt	Meat- cattle,sheep,goats,horse	0.44	0.9	0.9	1.7	1.3
20	omt	Meat products nec	0.46	0.9	1.4	1.3	1.3
21	vol	Vegetable oils and fats	0.39	0.8	1.4	3.0	2.2
22	mil	Dairy products	0.43	0.9	4.1	0.1	2.1
23	pcr	Processed rice	0.59	1.2	2.1	9.6	5.9
24	sgr	Sugar	0.57	1.1	1.1	4.7	2.9
25	ofd	Food products nec	0.39	0.8	2.5	4.4	3.4
26	b_t	Beverages and tobacco products	0.30	0.6	2.7	1.1	1.9
27	tex	Textiles	0.40	0.8	7.2	14.1	10.6
28	wap	Wearing apparel	0.21	0.4	3.7	24.0	13.8
29	lea	Leather products	0.24	0.5	6.7	22.0	14.3
30	lum	Wood products	0.47	0.9	3.1	4.8	4.0
31	ppp	Paper products, publishing	0.64	1.3	2.5	1.0	1.8
32	p_c	Petroleum, coal products	1.66	3.3	2.7	4.5	3.6
33	crp	Chemical,rubber,plastic prods	0.53	1.1	6.3	3.0	4.7
34	nmm	Mineral products nec	1.59	3.2	3.7	2.0	2.8
35	i_s	Ferrous metals	1.57	3.1	4.8	2.6	3.7
36	nfm	Metals nec	0.89	1.8	5.8	9.4	7.6
37	fmp	Metal products	0.39	0.8	2.7	2.3	2.5
38	mvh	Motor vehicles and parts	0.25	0.5	5.0	2.0	3.5
39	otn	Transport equipment nec	0.22	0.4	15.1	9.5	12.3
40	ele	Electronic equipment	0.18	0.4	10.3	15.4	12.9
41	ome	Machinery and equipment nec	0.23	0.5	12.4	4.6	8.5
42	omf	Manufactures nec	0.25	0.5	6.3	10.9	8.6
43	ely	Electricity	5.44	10.9	0.7	0.4	0.6
44	gdt	Gas manufacture, distribution	0.93	1.9	1.2	4.1	2.6
45	wtr	Water	0.62	1.2	0.3	0.4	0.3
46	cns	Construction	0.33	0.7	0.3	0.2	0.2
47	trd	Trade	0.22	0.4	1.1	1.7	1.4
48	otp	Transport nec	0.65	1.3	1.8	3.3	2.5
49	wtp	Sea transport	1.11	2.2	6.4	5.3	5.8
50	atp	Air transport	1.29	2.6	11.1	11.2	11.2
51	cmn	Communication	0.13	0.3	1.4	1.7	1.5
52	ofi	Financial services nec	0.11	0.2	0.9	0.8	0.8
53	isr	Insurance	0.15	0.3	4.3	1.4	2.9
54	obs	Business services nec	0.14	0.3	2.7	2.7	2.7
55	ros	Recreation and other services	0.13	0.3	0.8	0.7	0.8
56	osg	PubAdmin-Defence-Health-Educat	0.17	0.3	0.5	0.3	0.4
57	dwe	Dwellings	0.04	0.1	0.0	0.0	0.0

Table 4: Competitiveness concerns in the EU27 (see text).

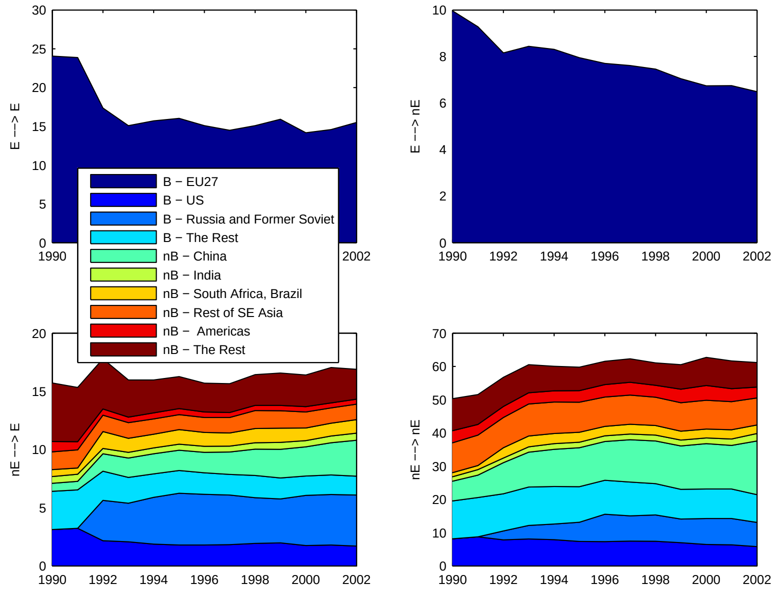

Figure 3: The development of emissions embodied in EU27 trade from 1990 to 2002 by region (see text).

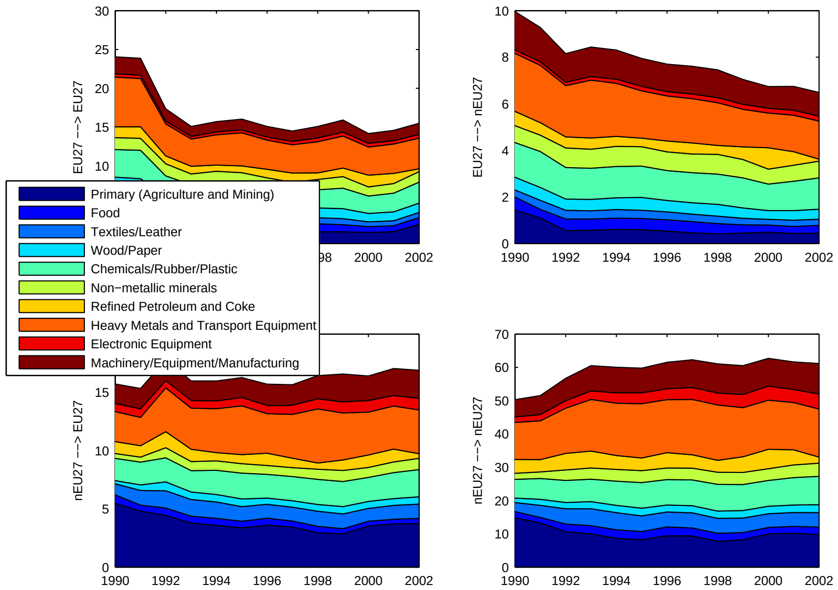

Figure 4: The development of emissions embodied in EU27 trade from 1990 to 2002 by sector (see text).

			Indirect emission intensity kg/$	Max Price increase 20	Exports = y_exp_nB/ x_total %	Imports = y_imp_nB/ x_total %	Total Exposure = average Exp and Imp %
1	pdr	Paddy rice	0.35	0.7	5.5	1.4	3.4
2	wht	Wheat	0.83	1.7	17.5	0.5	9.0
3	gro	Cereal grains nec	0.83	1.7	9.7	1.6	5.7
4	v_f	Vegetables, fruit, nuts	0.58	1.2	2.6	11.5	7.1
5	osd	Oil seeds	0.86	1.7	17.7	12.6	15.1
6	c_b	Sugar cane, sugar beet	0.62	1.2	0.0	0.2	0.1
7	pfb	Plant-based fibers	0.85	1.7	24.7	6.6	15.7
8	ocr	Crops nec	0.62	1.2	1.9	14.1	8.0
9	ctl	Cattle,sheep,goats,horses	0.78	1.6	1.4	0.8	1.1
10	oap	Animal products nec	0.75	1.5	3.3	1.8	2.6
11	rmk	Raw milk	0.64	1.3	0.0	0.1	0.0
12	wol	Wool, silk-worm cocoons	0.57	1.1	23.8	4.9	14.4
13	frs	Forestry	1.50	3.0	2.2	2.0	2.1
14	fsh	Fishing	0.68	1.4	0.6	3.1	1.8
15	coa	Coal	0.87	1.7	5.3	8.0	6.7
16	oil	Oil	0.91	1.8	2.8	73.8	38.3
17	gas	Gas	0.77	1.5	2.5	17.4	9.9
18	omn	Minerals nec	1.46	2.9	4.3	10.4	7.3
19	cmt	Meat- cattle,sheep,goats,horse	0.57	1.1	2.0	0.9	1.5
20	omt	Meat products nec	0.54	1.1	1.7	1.8	1.8
21	vol	Vegetable oils and fats	0.58	1.2	1.9	2.9	2.4
22	mil	Dairy products	0.54	1.1	3.5	0.1	1.8
23	pcr	Processed rice	0.52	1.0	1.3	2.4	1.8
24	sgr	Sugar	0.59	1.2	1.1	4.6	2.8
25	ofd	Food products nec	0.49	1.0	2.1	4.1	3.1
26	b_t	Beverages and tobacco products	0.35	0.7	1.5	1.1	1.3
27	tex	Textiles	0.50	1.0	7.3	14.5	10.9
28	wap	Wearing apparel	0.30	0.6	2.8	29.8	16.3
29	lea	Leather products	0.32	0.6	6.2	39.3	22.7
30	lum	Wood products	0.51	1.0	1.9	6.9	4.4
31	ppp	Paper products, publishing	0.72	1.4	2.2	1.0	1.6
32	p_c	Petroleum, coal products	1.70	3.4	2.7	5.6	4.1
33	crp	Chemical,rubber,plastic prods	0.79	1.6	6.4	3.2	4.8
34	nmm	Mineral products nec	1.71	3.4	3.8	3.2	3.5
35	i_s	Ferrous metals	1.99	4.0	6.3	2.6	4.4
36	nfm	Metals nec	1.29	2.6	7.7	7.7	7.7
37	fmp	Metal products	0.66	1.3	2.4	3.1	2.7
38	mvh	Motor vehicles and parts	0.41	0.8	4.6	3.5	4.1
39	otn	Transport equipment nec	0.36	0.7	13.8	5.0	9.4
40	ele	Electronic equipment	0.29	0.6	13.1	20.1	16.6
41	ome	Machinery and equipment nec	0.36	0.7	12.0	7.0	9.5
42	omf	Manufactures nec	0.40	0.8	5.9	18.6	12.2
43	ely	Electricity	7.59	15.2	0.3	0.2	0.2
44	gdt	Gas manufacture, distribution	0.88	1.8	0.7	1.0	0.8
45	wtr	Water	0.61	1.2	0.1	0.2	0.2
46	cns	Construction	0.39	0.8	0.1	0.1	0.1
47	trd	Trade	0.27	0.5	0.5	1.0	0.7
48	otp	Transport nec	0.96	1.9	1.3	2.5	1.9
49	wtp	Sea transport	1.42	2.8	4.3	4.1	4.2
50	atp	Air transport	1.51	3.0	6.7	7.4	7.1
51	cmn	Communication	0.18	0.4	0.8	0.9	0.8
52	ofi	Financial services nec	0.13	0.3	0.5	0.3	0.4
53	isr	Insurance	0.18	0.4	1.9	0.9	1.4
54	obs	Business services nec	0.20	0.4	1.6	1.5	1.5
55	ros	Recreation and other services	0.28	0.6	0.7	0.6	0.7
56	osg	PubAdmin-Defence-Health-Educat	0.21	0.4	0.5	0.3	0.4
57	dwe	Dwellings	0.04	0.1	0.0	0.0	0.0

Table 5: Competitiveness concerns in the Annex B (see text).