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*International material resource dependency in an international input-output framework**

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Abstract

Over the last decade an increasing awareness of resources embodied in traded products has resulted in attempts to track natural resource use along the international supply chain. An international input-output (IIO) model is the appropriate methodological framework to undertake this type of environmental accounting, because direct and indirect, domestic and international resource use is considered. However, an extensive IIO model capturing most of world trade has vast data requirements. As indicated by Wiedmann (2009) there is still room for improvements in data availability and quality. The EU-funded EXIOPOL project provides this opportunity through its environmentally extended international input-output database. This database, containing domestic and international trade flows of 43 countries, is essential for estimating the actual environmental impacts of international production and consumption. The project has an important role in delivering the desired improvements. In this study we analyze resource use and dependence among the 43 counties present in the EXIOPOL. Our focus will be on fossil fuel carriers, metals and mineral resource use.

Keywords: international input-output, environmental accounting, resources, dependency

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1. Introduction

Over the past decade environmentally extended input output tables (EE IOT) have received much attention due to their usefulness as data source for environmental accounting. Input-output tables and the related models allow for calculating the direct and indirect effects of an increase in final demand on total output. Extending input-output tables with environmental information results in a framework that is very suitable for analyzing the relationship between economic activities and the pressure on the environment caused by these activities. The incorporated environmental information can consist of, for example, pollution generated or resources used.

Many policy analyses based on input-output analysis are still performed using national tables. The implicit assumption made in these analyses is that the national structure may also be used to estimate the international spillovers of national measures. The vast data requirement of international input-output tables has been one of the main reasons for this practice. However, since the 1950s, international trade has been increasing steadily[1]. Within the European Union trade has expanded even more due to the internal market, which came into being in 1993 and the monetary union in which 16 European countries now participate. Over the years only few input-output tables have been constructed that include international trade flows among (the most important) trade partners. These are the European Union intercountry input-output tables (Linden & Oosterhaven, 1995), the Asian-Pacific international input-output tables (Inomata & Okamoto, 2006) and are the GTAP database (Dimaranan, 2006). Including international trade linkages is aimed at in order to be able to analyze international integration and the dependency of production. International input-output tables allow, for example, tracking the economic impacts of changes in final demand for products across borders.

The combination of environmentally extended input-output tables and international trade flows provides a strong basis for environmental policy analysis. Such an elaborate framework offers the opportunity to undertake environmental accounting in a complete economic transaction system. For example, it can be established whether the Japanese cars contain more or less material resources than cars produced in the United States. In addition, it can be investigated which countries actually mine these resources. Alternatively, it can be analyzed for how much CO_2 emission the Dutch government is responsible, compared to Dutch consumers – and whether these are emitted domestically or abroad, and where in the latter case.

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[1] A decline in trade flows occurred in 2009 due to the crisis.

An important application of international EE IOT is the accounting of pollution generated and resources used in terms of producer versus consumer responsibility. A national EE IOT only allows for calculating the environmental impacts due to production of domestic industries. The incorporation of trade flows in EE IOT makes it possible to track where products consumed in a country are produced and what are the related pollution generated or resources used. In this light, it is debatable whether China is responsible for the pollution it generates or the countries to which the products are exported to by China.

Important methodological work to incorporate EE IOT in the standard toolbox of environmental policy makers has been undertaken in various projects. Without exception, it is stressed in these projects that the database used for analysis has to include international trade flows. The final report of the EIPOT[2] project presents a methodological toolbox that is developed to assess environmental impacts through international trade (Wiedmann et al., 2008). The report indicates that the ideal basis for a suitable methodology in this context would be an environmentally extended multi-region input-output framework with close connections to the system of economic and environmental accounts as developed by the United Nations.[3] It includes very specific recommendations regarding the set up of the accounting framework. In an earlier project, a report was published to convey the data situation of EE IOT (Eder et al., 2006). In order to stress the importance of EE IOT in terms of availability and quality, the full potential of the tables is explored and principal application areas are discussed. In addition, given the analytical requirements of the applications, the technical specifications of the required data are defined and options for acquiring the data are given. In a review of the multi-region IOT used in environmental accounting (Wiedmann, 2009) concludes that further research is mainly needed in order to improve data availability, data quality, and accuracy of multi-region input output modeling. (Lenzen, Pade, & Munksgaard, 2004) compare the implications of using alternative trade models and of a reduction in detail in the sectoral disaggregation of the tables. It is shown that especially aggregation of high with low impacting sectors causes problems. In terms of trade relations, the study suggest that including direct import use coefficients is most important in correctly assigning environmental impacts of production of a specific country.

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[2] Environmental impacts of trade, see also the website www.eipot.eu where the final report can be downloaded, last accessed 27-04-2010

[3] See http://unstats.un.org/unsd/envaccounting/default.asp for more information.

The construction of a multi-regional EE IOT database that incorporates the recommendations made in the literature is undertaken in the EXIOPOL project.[4] The project has been set up to provide a new environmental accounting framework for policy analysis, using externality data and input-output tools. The objective of the project is to enable the estimation of environmental impacts and external costs of industry activities and consumption activities of countries in the European Union. These environmental impacts include greenhouse gases emitted, pollutants discarded, and resources used as inputs to production. Within the project methodologies are developed, valuation of externalities is undertaken, and an environmentally extended (EE) input-output (IO) framework is set up that the European Union can use for environmental policy analysis (Tukker et al., 2009). The EXIOPOL database, which has as core an environmentally extended IO framework, will contain satellite accounts for more than one hundred environmental factors. The focus on the environment also called for more detail in the sectors that are mostly involved in generating or using these environmental factors. Agriculture, food products, mining and energy have been disaggregated into multiple subsectors. By covering around 80 percent of world GDP, adding sectoral detail and the incorporation of bilateral trade, the EXIOPOL database caters directly for the need of harmonized and improved data for EE IOT analysis.

The EXIOPOL database is in its final stages of development. Although work is progressing steadily, the country SUT data is still under revision and not all environmental extensions are available yet. In this paper a first preliminary analysis is undertaken based on the data that is available at this point in time. The focus of the present analysis is on metals, minerals, and fossil energy carriers. In particular, we will first address for which countries and sectors an increase in final demand generates the most additional extraction of the three types of resources. This indicates the dependency of a sector on material resources. Second, we investigate the extent to which this additional demand is generated in other countries, which shows how dependent a country is on foreign suppliers of the material resources. Next, the concentration of the international dependency is analyzed as an important aspect of the factual dependency. A correlation analysis is undertaken to see to what extent these three measures are related for individual sectors.

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[4] EXIOPOL is the acronym for: a new environmental accounting framework using externality data and input-output tools for policy analysis. The project website is http://www.feem-project.net/exiopol/, last accessed 27-04-2010.

Unlike capital that can be accumulated or population that can increase, natural resources cannot be produced. In case a country is not endowed with natural resources, it will need to obtain the resources needed for production through international trade. This can be done by either importing the natural resources directly from another country or by importing intermediate inputs in which these resources are embodied. Unstable economic trade relations with a country that is a primary supplier of the natural resources needed to fulfill a country's final demand may be harmful to the economy. Fully depending on other countries for the supply of natural resources has been viewed as undesirable, especially after the two main oil crises of the 20th century and the increasing scarcity of fossil energy carriers. A strategy of diversifying imports over the countries which have natural resource endowments may decreases risks associated with natural resource dependency.

In the next sections the methods used are discussed followed by a description of the data available from the EXIOPOL database. Then, the first results on environmental resource dependency are presented. To conclude, the preliminary status of this paper is stressed by discussing the next steps that will be taken when the database is finalized.

2. Methods

The derivation of an input-output model from a SUT requires an explicit assumption regarding the production technology of secondary and/or by-products of industries, whereas this assumption is hidden in input-output tables. Different assumptions can be made and there is no definite answer to the question which of these is conceptually and practically the best. For the results calculated here the industry technology assumption has been used to create an industry by industry IOT.

$$\mathbf{A}_{ixi,\ ind\ tech} = \mathbf{V}\left(\hat{\mathbf{q}}\right)^{-1}\mathbf{U}\left(\hat{\mathbf{x}}\right)^{-1} \qquad \mathbf{1}$$

Where $\mathbf{V}$ is the transposed supply table, $\mathbf{q}$ is the total supply of products, $\mathbf{U}$ is the use matrix and $\mathbf{x}$ is the total output of domestic industries. The hat over the variables indicates a diagonalized matrix.

An input-output model describes how supply $\mathbf{x}$ follows demand with the following identity: $\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f}$. Where $\mathbf{x}$ is total output, $\mathbf{A}$ the matrix of direct input coefficients and $\mathbf{f}$ the vector of final demand. Solving the model for output gives $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$, where $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief multiplier matrix of direct and indirect industry output requirements per unit of final demand. In the Leontief quantity model, from which the backward multipliers are derived, the assumption is made that prices are fixed in the short term. Another assumption in IO modeling is that input coefficients do not change regardless of output, final demand, or other relevant changes. The structure of the economy is taken to be constant, at least in the short term.

The environmental extensions are given as a matrix of direct impact coefficients $\mathbf{D} = [d_{kj}]$, of which each element represents the amount (in physical units per dollar's worth of output) of the environmental factor *k* used in the production of sector *j*. These environmental extensions can be emissions, pollution, raw material, land use, water use, etc. The total requirement of environmental factors $\mathbf{x}^E$ can be calculated as:

$$\mathbf{x}^E = \mathbf{Dx} = \mathbf{D}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \qquad \mathbf{2}$$

For an international input-output table the same equation 2 holds, where **x** is now a vector of all individual country sub vectors $\mathbf{x}_R$, for all countries *R*. The matrix $\mathbf{D} = [d_{kj}^R]$ is the concatenated matrix of all individual country matrices $\mathbf{D}_R$. The matrix $\mathbf{A} = [a_{ij}^{RS}]$ is the input coefficient matrix of all domestic $\mathbf{A}^{RR}$ matrices and all bilateral matrices $\mathbf{A}^{RS}$, where *R* and *S* are the country indices and *i* and *j* are sector indices. The vector **f** is the stacked vecotr of all individual country final demand vectors $\mathbf{f}_R$.

The total requirement of environmental factors $\mathbf{x}^E$ signifies the dependency of a sector on material resource inputs. The requirements may be partially sourced domestically, but especially for the countries that do are not endowed with material resources, these requirements will be imported. The extent of dependency on foreign suppliers for material resources is measured by the requirement of imported environmental factors over the total requirement.

In addition, the Herfindahl index will be used to look at the concentration of the environmental requirements over the countries from which a sector imports. This highlights an important aspect of dependency; importing from multiple sources will make a country less dependent on one particular supplier. The index can be represented as given by equation 3, where *k* is the index representing the different resources.

$$H_{kj}^S = \sum_{R \neq S} \left(\frac{\sum_i d_{ki}^R l_{ij}^{RS}}{\sum_{i,R \neq S} d_{ki}^R l_{ij}^{RS}} \right)^2 \qquad \mathbf{3}$$

Each country has potentially 41 trading partners. For 41 observations, the value of the Herfindahl index would equal to 1/41 ≈ 0.02439 in case each of the environmental multipliers is exactly the same for each trade partner. This corresponds to full diversification over countries from which a particular country demands its imports and embodied resources. When a country only imports the embodied resources from one trade partner the value of the Herfindahl index will be equal to 1. The higher the value of the Herfindahl index the more dependent a country is on one, or a few countries, to fulfill its demand for embodied materials.

3. Data

The full EXIOPOL database consists of the supply and use tables (SUT) of 43 countries[5] and an aggregated 'rest of the world'. The supply and use tables maintained by Eurostat (referred to as the ESA-95 tables) are used as basis for the supply and use tables of the European Union countries. These tables have been disaggregated in industry and commodity classification to 129 industries and products, still in a squared set-up of the SUT. The tables are linked to each other via bilateral trade flows using a methodology that combines information on origin and destination of trade flows from trade statistics with the aggregated trade data in the SUT. In the process of regaining consistency after combining these two data sources, the data are also revalued from cost-insurance-freight prices of the purchasing country to basic prices of the producing country. (For a full description of the methodology see (Bouwmeester & Oosterhaven, 2008). It has to be noted that although several information sources are combined to construct a full international SUT, these tables do not represent full information. All supply and use tables are extended with satellite accounts of social and environmental variables. The database also contains input-output tables that have resulted from input-output modeling of the supply and use tables. See chapter 5 of Miller & Blair (1984), for an explanation of the assumptions that need to be made in IO modeling.

All data used in this analysis is taken from the preliminary versions of data that will be part of the EXIOPOL database. Due to some remaining problems in the sectors that have been disaggregated up to this point, the SUT have been aggregated back to the 59 sectors as represented in the ESA-95 tables. In addition, due to problems with the data of Estonia this

[5] See the appendix tables for a full list of the countries included.

country is removed from the dataset. For some sectors environmental extensions are present for a certain sector, while there is no output in the SUT. These environmental extensions are therefore disregarded in the analysis. The environmental extensions used in this study are: 1) domestic extraction of metal ores[6], 2) domestic extraction of non-metallic minerals[7], and 3) fossil energy carriers[8][9].

4. Results and discussion

In this section an analysis is presented of the dependency of countries on trade partners to fulfill their demand for embodied materials. First, we will have a closer look at the countries that supply resources. Next, to focus the discussion of the results, we selected the industries that on a world scale demand the most additional resources per € of output. For this purpose we have created a world weighted average supply and use table and a vector with the total material use per 'world' sector. For these selected industries we computed the share of the international environmental multiplier in the total environmental multiplier as a measure of dependency on trade partners to fulfill the demand for embodied resources. Next, we also look at the Herfindahl index of the international multipliers to determine the concentration of dependency. Finally, a correlation analysis is undertaken to see whether higher international dependence of countries is related to a higher concentration of international dependence. This would indicate that the sector may be very vulnerable to the effects of increasing scarcity of material resources.

Not all countries are suppliers of material resources. It may be that the materials are not present at all in the soil on a country's territory. Alternatively, it may be that there are material resources, but only in a limited amount or hard to retrieve, making it economically uninteresting to mine the materials. For fossil fuels, the following countries do not mine coal or extract oil or gas; Belgium, Cyprus, Ireland, Luxembourg, Malta, Portugal and Switzerland. Metals are not mined in the countries: Austria, Belgium, Czech Republic, Denmark, Germany, Latvia, Lithuania,

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[6] Which consist of: iron ores, bauxite and aluminum ores, copper ores, lead ores, nickel ores, tin ores, zinc ores, precious metal ores and other metal ores. Note that uranium and thorium ores have been excluded, because their nature deviates from the other metals; these ores are mainly used as fuel.

[7] Which consist of: chemical and fertilizer minerals, clays and kaolin, limestone, gypsum, chalk, dolomite, salt, slate, other industrial minerals, building stones, gravel and sand, other construction materials

[8] Which consist of: hard coal, lignite/brown coal, crude oil, natural gas, natural gas liquids, peat for energy use.

[9] Unused domestic extraction related to these materials is not included in the analysis.

Luxembourg, Malta, Netherlands, Slovenia, Switzerland, Taiwan and United Kingdom. For minerals only Poland has no reported output for the mineral sector, however, the environmental extensions do report a large amount of minerals extracted, so this may be a flaw in the supply and use tables. Summarizing; 35 countries extract fossil fuels, metal ores are mined in 28 countries and 41 countries report output for their mineral sector. In Table 1, the top three of countries with the most domestic extraction used, as well as the top three of countries with the most material use per million € output are represented.[10] Invariably, the United States is the largest extractor of materials, however its ranking in terms of the use of materials per euro demand is for fossil fuel 13th,, for metals 6th and for minerals 12th.

Table 1: Domestic extraction used

Fossil fuel carriers		million tonnes
1	United States	1692
2	China	1361
3	Russian Federation	958
Metal ores		
1	United States	560
2	Australia	490
3	Indonesia	443
Minerals		
1	United States	5743
2	China	1339
3	Japan	1309

Fossil fuel carriers		kilogram per € output
1	Hungary	321.8
2	Greece	157.0
3	Bulgaria	130.5
Metal ores		
1	Bulgaria	191.9
2	France	147.8
3	India	107.1
Minerals		
1	Sweden	1259.3
2	Latvia	918.8
3	Taiwan	707.3

Due to the large amount of sectors; 59 sectors in each of the 42 countries included in the dataset, we have chosen to focus our analysis to the sectors that have the highest resource use per € of demand for that sectors' output. See Table 2 for the ranking of the industries and the related value of the environmental multiplier for each of the material groups considered. See Appendix 1 for the sector classification codes and labels. For each material group the sector which mines or extracts that resource is associated to the largest environmental multiplier. Fossil fuel carriers are extracted by sector i10 and sector i11. More interesting are the sectors in the table that are not directly related to the mining of the material resources. In Appendix 2 – Table 2 the detailed breakdown of the environmental multipliers per country can be found.

[10] See Appendix 2, Table 1 for the table of resource use in kilogram per € output for all countries

Table 2: Largest environmental multipliers per material for the 'World'

Kilogram of additional domestic extraction per additional € demand

Rank	*Fossil fuel carriers*		*Metals*		*Minerals*	
1	i10	34.6	i13	25.9	i14	147.3
2	i11	7.1	i12	1.8	i26	4.6
3	i23	2.8	i27	1.3	i23	1.9
4	i40	2.0	i23	0.8	i13	1.6
5	i12	1.1	i37	0.4	i10	1.5

There is a large variation in the individual country multipliers as shown in Appendix 2 – Table 2. For metals, the Czech Republic, Italy, Japan, Portugal, Slovenia and Taiwan have very small multipliers compared to the world average. Bulgaria, Cyprus, France, India, Indonesia and South Korea all require more than 100 kg metals per euro of extra final demand for sector i13; metal ores. About four times as much as the world average. For sector i27 all multipliers are due to embodied metals in the inputs bought by the sector. Large values are found for Australia, Bulgaria and Indonesia. Basic manufacturing of metals in these countries requires more metals per euro of final demand.

The multipliers per country-sector can be broken into a domestic environmental multiplier and an international environmental multiplier. The international environmental multiplier as percentage of the total multiplier is a measure of the dependence of a country on foreign suppliers. It shows the share of additional demand for materials that has to be satisfied from suppliers abroad. The higher this percentage the more dependent a country is on foreign suppliers. In Appendix 2 the international multiplier percentage is given for each country for the five sectors that required, on a world scale, the most additional material resources when demand for its products increase.

The tables in Appendix 2 also show the Herfindahl index (HI) calculated based on the international multipliers. A combination of a high international environmental multiplier combined with a high value for the Herfindahl index can indicate a vulnerable supplier relationship for a specific material resource and the sector that requires the material in its production process. Table 3 below shows the results for 30 countries that have relatively high percentages of international multipliers and high values of the Herfindahl index. Sector i23, manufacture of coke, refined petroleum products, and nuclear fuels has high values for these two indicators for all three material resources.

Table 3: Sector i23: Manufacture of coke, refined petroleum products, and nuclear fuels

	Fossil fuel carriers		*Metals*		*Minerals*	
	inter %	HI	inter %	HI	inter %	HI
Austria	99	0.30	100	0.22	68	0.14
Belgium	100	0.35	100	0.20	98	0.18
Bulgaria	97	0.99	28	0.60	64	0.49
Canada	42	0.38	81	0.31	59	0.68
Cyprus	100	0.32	100	0.61	96	0.64
Czech_Republic	83	0.86	100	0.67	73	0.51
Denmark	47	0.69	100	0.12	83	0.20
Finland	100	0.59	100	0.48	87	0.37
France	100	0.31	100	0.14	67	0.13
Germany	94	0.43	100	0.33	66	0.20
Greece	98	0.99	88	0.53	24	0.48
Hungary	99	0.53	97	0.34	42	0.21
Italy	99	0.64	100	0.22	85	0.24
Japan	100	0.30	100	0.17	99	0.41
Latvia	100	0.61	100	0.43	69	0.29
Malta	100	0.20	100	0.13	79	0.13
Netherlands	95	0.31	100	0.20	90	0.17
Poland	19	0.89	98	0.53	100	0.77
Portugal	100	0.24	99	0.13	65	0.12
Romania	68	0.94	75	0.15	69	0.26
Slovak_Republic	100	0.98	100	0.63	95	0.48
Slovenia	93	0.78	100	0.15	33	0.10
South_Africa	2	0.25	100	0.70	97	0.24
South_Korea	100	0.20	100	0.28	85	0.60
Spain	99	0.40	98	0.19	61	0.18
Sweden	100	0.46	55	0.15	12	0.24
Switzerland	100	0.39	100	0.49	99	0.37
Taiwan	100	0.36	100	0.33	45	0.12
Turkey	93	0.88	84	0.18	8	0.13
United_Kingdom	10	0.70	100	0.11	73	0.15

From Table 3 it can be seen that most European countries have a high international multiplier percentage, which is consistent with the European open market. However, the Herfindahl index for the East-European countries is in general higher than the Herfindahl index for the West-European countries. The concentration of supplier relations is especially high for fossil fuel carriers, even though 35 of the countries included in the dataset extract fossil fuel carriers domestically. This would suggest that especially for Bulgaria, Czech Republic, Greece, Slovak Republic and Slovenia, it might be wise to diversify their supplier relations more.

In Table 4 the coefficients of determination are presented. These values show for the five 'heavy use' sectors for each of the three material groups how much of the variation in the one variable can be explained by the variation of the other. In other words, a high coefficient of determination shows whether the total material multipliers (tm), the extent of international dependency (id) and the Herfindahl index (hi) of the international multipliers correlate over the countries.

Table 4: Coefficients of determination as percentage (R^2 – % of variation explained)

Fossil fuel carriers				*Metals*			*Minerals*		
		id	hi		id	hi		id	hi
i10	tm	(-) 3.6	9.9	i13	(-) 5.1	0.3	i14	(-) 5.1	(-) 0.0
	id		9.1			1.4			6.4
i11	tm	(-) 2.2	11.7	i12	(-) 1.26	3.8	i26	(-) 10.7	1.4
	id		11.2			24.5			14.4
i23	tm	1.0	25.4	i27	(-) 34.1	4.0	i23	(-) 4.57	17.8
	id		10.4			(-) 1.8			13.3
i40	tm	(-) 25.2	23.8	i23	0.25	4.2	i13	(-) 2.57	0.0
	id		1.4			7.7			13.0
i12	tm	0.0	30.3	i37	(-) 5.76	4.2	i10	(-) 3.9	7.2
	id		23.0			21.5			16.9

For two sectors there is a significant correlation between the total resource multiplier and international dependency. That some of the sectors are more exposed to international concentrated relations can be seen from the coefficients of determination for the international environmental dependency measure and the Herfindahl index of the international multipliers. For both fossil fuel carriers seem and metal resources supplier dependency can become an issue for sectors i12 – Mining of uranium and thorium ores.

5. Conclusion and outlook

These first results indicate that international dependency on material resource suppliers differs much from sector to sector. Especially for sectors that are of strategic importance to the functioning of the economy at large, it is important to investigate the extent of dependency and the concentration of dependency. A start of the analysis of dependency has been made in this paper, but the matter is definitely in need of further investigation.

The EXIOPOL database will offer a wealth of information. Unfortunately not all of this information is available yet. The large differences in the environmental multipliers could be the result of the aggregation of the sectors, causing different products to be lumped together. For example, in the final EXIOPOL database sector i13; metal ores will be split into six different metal ore sectors. The aggregation bias of the results will be checked as soon as the more detailed data becomes available.

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Appendix 1: sector classification

i01	Agriculture, hunting and related service activities
i02	Forestry, logging and related service activities
i05	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing
i10	Mining of coal and lignite; extraction of peat
i11	Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying
i12	Mining of uranium and thorium ores
i13	Mining of metal ores
i14	Other mining and quarrying
i15	Manufacture of food products and beverages
i16	Manufacture of tobacco products
i17	Manufacture of textiles
i18	Manufacture of wearing apparel; dressing and dyeing of fur
i19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
i20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting material
i21	Manufacture of pulp, paper and paper products
i22	Publishing, printing and reproduction of recorded media
i23	Manufacture of coke, refined petroleum products and nuclear fuels
i24	Manufacture of chemicals and chemical products
i25	Manufacture of rubber and plastic products
i26	Manufacture of other non-metallic mineral products
i27	Manufacture of basic metals
i28	Manufacture of fabricated metal products, except machinery and equipment
i29	Manufacture of machinery and equipment n.e.c.
i30	Manufacture of office machinery and computers
i31	Manufacture of electrical machinery and apparatus n.e.c.
i32	Manufacture of radio, television and communication equipment and apparatus
i33	Manufacture of medical, precision and optical instruments, watches and clocks
i34	Manufacture of motor vehicles, trailers and semi-trailers
i35	Manufacture of other transport equipment
i36	Manufacture of furniture; manufacturing n.e.c.
i37	Recycling
i40	Electricity, gas, steam and hot water supply
i41	Collection, purification and distribution of water
i45	Construction
i50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale services of automotive fuel
i51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
i52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
i55	Hotels and restaurants
i60	Land transport; transport via pipelines
i61	Water transport
i62	Air transport
i63	Supporting and auxiliary transport activities; activities of travel agencies
i64	Post and telecommunications
i65	Financial intermediation, except insurance and pension funding
i66	Insurance and pension funding, except compulsory social security
i67	Activities auxiliary to financial intermediation
i70	Real estate activities
i71	Renting of machinery and equipment without operator and of personal and household goods
i72	Computer and related activities
i73	Research and development
i74	Other business activities
i75	Public administration and defence; compulsory social security
i80	Education
i85	Health and social work
i90	Sewage and refuse disposal, sanitation and similar activities
i91	Activities of membership organisation n.e.c.
i92	Recreational, cultural and sporting activities
i93	Other service activities
i95	Private households with employed persons

Appendix 2: additional result tables

Table 1: Domestic extraction used – kilogram per € output by country, ordered

	fossil fuel carriers			metals			minerals	
1	Hungary	321.8	1	Bulgaria	191.9	1	Sweden	1259.3
2	Greece	157.0	2	France	147.8	2	Latvia	918.8
3	Bulgaria	130.5	3	India	107.1	3	Taiwan	707.3
4	Russian_Federation	128.1	4	South_Korea	102.8	4	Slovenia	599.1
5	Indonesia	93.2	5	Indonesia	89.2	5	Cyprus	407.9
6	Romania	80.6	6	United_States	73.8	6	Lithuania	348.3
7	South_Africa	74.0	7	Brazil	68.7	7	Russian_Federation	347.6
8	Canada	67.9	8	Australia	51.9	8	India	345.7
9	India	63.4	9	Hungary	50.9	9	Romania	335.9
10	Czech_Republic	53.2	10	Spain	40.5	10	Hungary	318.0
11	Turkey	46.7	11	Cyprus	34.7	11	Japan	305.2
12	Slovak_Republic	46.3	12	Romania	33.0	12	United_States	271.4
13	United_States	46.0	13	Sweden	32.5	13	Czech_Republic	236.0
14	Germany	45.5	14	Poland	29.8	14	Bulgaria	230.8
15	Australia	40.5	15	China	28.3	15	Slovak_Republic	222.5
16	Poland	34.4	16	Greece	27.0	16	Denmark	203.9
17	China	32.4	17	Turkey	26.4	17	Malta	176.8
18	Slovenia	31.9	18	Slovak_Republic	22.4	18	Finland	169.9
19	Mexico	31.4	19	Canada	18.6	19	Greece	162.8
20	Austria	28.7	20	Norway	14.9	20	Brazil	155.3
21	France	23.8	21	South_Africa	12.5	21	Spain	141.6
22	Spain	21.9	22	Finland	9.8	22	Germany	136.5
23	Brazil	20.1	23	Ireland	8.9	23	Canada	132.1
24	United_Kingdom	17.5	24	Russian_Federation	6.0	24	South_Africa	129.1
25	South_Korea	16.8	25	Mexico	4.5	25	South_Korea	117.5
26	Norway	13.1	26	Portugal	2.5	26	Turkey	104.8
27	Taiwan	10.0	27	Italy	2.0	27	Portugal	103.8
28	Lithuania	6.7	28	Japan	0.6	28	Belgium	97.0
29	Latvia	5.2	29	Latvia	0	29	France	95.1
30	Denmark	4.9	30	Taiwan	0	30	Switzerland	91.7
31	Italy	4.5	31	Slovenia	0	31	China	83.3
32	Netherlands	4.1	32	Lithuania	0	32	Austria	78.2
33	Sweden	3.9	33	Czech_Republic	0	33	Indonesia	72.5
34	Finland	3.8	34	Denmark	0	34	Netherlands	70.8
35	Japan	3.7	35	Malta	0	35	Luxembourg	69.3
36	Cyprus	0	36	Germany	0	36	Norway	67.8
37	Ireland	0	37	Belgium	0	37	Italy	67.5
38	Portugal	0	38	Switzerland	0	38	Ireland	58.7
39	Malta	0	39	Austria	0	39	Mexico	45.2
40	Belgium	0	40	Netherlands	0	40	Australia	42.6
41	Switzerland	0	41	Luxembourg	0	41	United_Kingdom	41.4
42	Luxembourg	0	42	United_Kingdom	0	42	Poland	0

Note: 0 means no value.

Table 2: Environmental multipliers by country –kilogram per € demand

	fossil fuel carriers			metals			minerals		
	i10	i11	i23	i13	i12	i27	i14	i26	i23
Australia	35.2	5.9	2.2	52.7	0.4	9.1	44.6	1.3	5.1
Austria	23.1	5.8	1.3	0	0	0.2	79.7	2.8	0.1
Belgium	0	0	0.8	0	0	0.3	97.7	1.1	0.3
Brazil	0.9	19.5	1.8	73.9	7.9	2.1	161.7	6.6	0.6
Bulgaria	132.2	6.5	10.3	199.5	0.1	16.8	234.0	7.6	0.3
Canada	63.9	4.3	2.1	19.3	1.5	2.3	132.2	1.2	4.0
China	28.4	6.2	3.3	29.9	1.3	2.1	86.3	3.6	0.3
Cyprus	0	0	16.3	146.5	0	0.3	409.7	32.3	0.2
Czech_Republic	50.2	5.5	9.9	0.5	0.1	0.8	241.8	5.4	0.2
Denmark	0	5.0	3.6	0	0	0.1	211.8	4.2	0.1
Finland	3.8	0	5.8	9.9	0	2.1	177.2	4.8	0.1
France	21.5	7.3	1.7	151.8	0.0	0.6	98.3	5.0	0.1
Germany	41.1	6.9	3.8	0	0	1.1	142.4	4.5	0.1
Greece	152.8	5.1	2.5	27.0	0	1.2	165.5	16.0	0.2
Hungary	268.1	63.6	6.1	51.0	0	1.8	332.2	7.1	0.3
India	49.2	15.0	3.5	107.2	0.0	2.7	345.7	4.6	0.0
Indonesia	80.1	14.3	2.2	102.5	0.0	9.3	72.8	1.4	0.0
Ireland	0	0	0	9.3	0	0.1	64.3	3.1	0
Italy	0.6	4.0	2.1	2.0	0	0.6	70.6	2.9	0.2
Japan	2.0	1.8	2.8	0.7	0.1	1.5	305.3	0.4	0.9
Latvia	7.6	0	2.4	0	0	0.3	919.2	8.9	0.2
Lithuania	4.9	6.2	0	0	0	0.1	348.9	15.7	0
Luxembourg	0	0	0	0	0	0.1	76.9	2.4	0
Malta	0	0.0	0.0	0	0	0.0	194.2	7.5	0.0
Mexico	4.7	27.1	0.3	4.6	0.6	0.6	45.5	3.4	13.6
Netherlands	0	4.2	2.0	0	0	0.6	75.6	1.9	0.0
Norway	8.6	4.6	2.3	14.9	0	0.6	70.1	5.2	0.5
Poland	35.6	0	2.5	30.7	0	1.8	0	0.2	0.4
Portugal	0	0	1.6	2.5	0.0	0.3	108.2	10.2	0.1
Romania	68.1	17.4	8.8	36.7	0	4.4	350.1	9.2	0.2
Russian_Federation	110.6	28.7	11.1	8.8	0.8	1.7	347.6	2.3	0.2
Slovak_Republic	45.7	4.9	12.2	22.4	0	1.2	228.5	2.8	0.2
Slovenia	32.1	0	1.2	0.1	0.1	0.2	609.6	4.0	0.4
South_Africa	71.5	3.2	7.9	12.5	0.0	0.1	129.1	1.7	0.2
South_Korea	17.0	0	1.1	102.8	0.0	1.1	129.1	6.6	0.2
Spain	20.3	2.0	1.6	40.5	0	0.9	142.1	4.1	0.0
Sweden	4.0	0	2.6	33.4	0	0.9	1260.0	0.9	0.4
Switzerland	1.0	0.2	0.2	3.2	0.1	0.1	92.1	1.1	2.4
Taiwan	2.1	8.8	0.8	0.3	0	0.3	707.4	5.8	1.3
Turkey	42.0	5.3	0.6	26.6	0	1.4	109.9	13.0	0.4
United_Kingdom	13.7	4.7	2.9	0	0	0.5	44.8	1.8	0.0
United_States	44.0	4.9	2.9	77.0	4.1	1.3	283.0	9.1	0.6
World	34.6	7.1	2.8	25.9	1.8	1.3	147.3	4.6	1.9

Note: 0 means no value.

Table 3: International environmental multiplier as % of total environmental multiplier – Herfindahl index of international multipliers – Fossil fuel carriers

Fossil fuel carriers	% international multiplier					Herfindahl index of international multipliers				
	i10	i11	i23	i40	i12	i10	i11	i23	i40	i12
Australia	0	0	18	1	4	0.27	0.24	**0.75**	0.18	0.19
Austria	0	1	**99**	**91**	-	0.25	0.22	0.30	0.25	-
Belgium	-	-	**100**	**100**	-	-	-	0.35	0.48	-
Brazil	9	0	24	52	34	0.20	0.22	0.22	0.22	0.16
Bulgaria	1	24	**97**	14	**60**	**0.87**	**0.77**	**0.99**	**0.92**	**0.69**
Canada	0	0	42	4	7	0.39	0.37	0.38	0.34	0.47
China	0	0	5	1	3	0.20	0.22	0.32	0.29	0.17
Cyprus	-	-	**100**	**100**	-	-	-	**1.00**	**1.00**	-
Czech_Republic	1	18	**83**	31	37	**0.71**	**0.83**	**0.86**	**0.72**	**0.74**
Denmark	-	0	47	68	-	-	0.25	**0.69**	**0.50**	-
Finland	1	-	**100**	**98**	-	0.49	-	**0.59**	0.42	-
France	22	2	**100**	**98**	**100**	0.20	0.34	0.31	0.16	0.14
Germany	0	1	**94**	13	-	0.16	0.34	0.43	0.18	-
Greece	0	0	**98**	2	-	**0.82**	**0.71**	**0.99**	**0.93**	-
Hungary	1	1	**99**	**82**	-	0.32	**0.65**	**0.53**	**0.91**	-
India	0	0	1	1	2	0.19	0.15	0.27	0.40	0.23
Indonesia	0	0	2	1	30	0.19	0.29	**0.71**	0.21	0.16
Ireland	-	-	-	**100**	-	-	-	-	0.12	-
Italy	12	0	**99**	**99**	-	0.35	0.32	**0.64**	0.39	-
Japan	2	7	**100**	**100**	**100**	0.22	0.27	0.30	0.19	0.26
Latvia	30	-	**100**	**99**	-	**0.98**	-	**0.61**	**0.96**	-
Lithuania	39	41	-	**99**	-	**0.93**	**0.94**	-	**0.94**	-
Luxembourg	-	-	-	**100**	-	-	-	-	**0.54**	-
Malta	-	**100**	**100**	**100**	-	-	0.33	0.20	**0.58**	-
Mexico	1	0	6	27	11	0.27	**0.64**	0.38	0.48	**0.51**
Netherlands	-	2	**95**	26	-	-	0.29	0.31	0.26	-
Norway	0	0	10	39	-	0.20	0.16	0.35	0.20	-
Poland	0	-	19	3	-	**0.53**	-	**0.89**	**0.57**	-
Portugal	-	-	**100**	**100**	**100**	-	-	0.24	0.38	0.19
Romania	1	3	68	39	-	**0.66**	**0.82**	**0.94**	**0.75**	-
Russian_Federation	0	0	0	0	0	0.16	0.12	0.14	0.17	0.20
Slovak_Republic	1	72	**100**	**99**	-	**0.62**	**0.97**	**0.98**	0.43	-
Slovenia	0	-	**93**	10	44	0.39	-	**0.78**	0.35	0.41
South_Africa	0	0	2	1	5	0.11	0.28	0.25	0.28	0.14
South_Korea	1	-	**100**	**99**	**99**	0.23	-	0.20	0.25	0.22
Spain	1	8	**99**	**70**	-	0.20	0.22	0.40	0.26	-
Sweden	1	-	**100**	**97**	-	0.16	-	0.46	0.16	-
Switzerland	**100**	**100**	**100**	**100**	**100**	0.45	0.25	0.39	0.47	0.41
Taiwan	15	7	**100**	**100**	-	0.24	0.24	0.36	0.26	-
Turkey	0	1	**93**	**50**	-	0.34	0.31	**0.88**	0.45	-
United_Kingdom	2	3	10	29	-	0.17	**0.71**	**0.70**	0.47	-
United_States	0	1	42	3	12	0.36	0.18	0.30	0.24	0.48

Note: - means no value, 0 indicates a value smaller than 0.5

Table 4: International environmental multiplier as % of total environmental multiplier – Herfindahl index of international multipliers – Metals

Metals	% international multiplier					Herfindahl index of international multipliers				
	i13	i12	i27	i23	i37	i13	i12	i27	i23	i37
Australia	0	10	8	18	-	0.24	0.34	0.47	0.26	-
Austria	-	-	100	100	100	-	-	0.16	0.22	0.14
Belgium	-	-	100	100	100	-	-	0.13	0.20	0.15
Brazil	0	0	1	22	2	0.15	0.15	0.15	0.37	0.15
Bulgaria	0	3	1	28	5	0.19	0.18	0.35	0.60	0.17
Canada	3	18	78	81	74	0.50	0.33	0.62	0.31	0.30
China	1	9	17	21	-	0.29	0.24	0.25	0.23	-
Cyprus	-	-	100	100	100	-	-	0.21	0.61	0.18
Czech_Republic	100	100	100	100	100	0.37	0.38	0.74	0.67	0.29
Denmark	-	-	100	100	100	-	-	0.15	0.12	0.15
Finland	1	-	100	100	99	0.15	-	0.18	0.48	0.17
France	3	100	100	100	100	0.31	0.12	0.32	0.14	0.22
Germany	-	-	100	100	100	-	-	0.23	0.33	0.15
Greece	0	-	44	88	69	0.15	-	0.47	0.53	0.24
Hungary	0	-	92	97	52	0.34	-	0.48	0.34	0.26
India	0	22	8	25	-	0.22	0.20	0.27	0.21	-
Indonesia	0	6	5	4	1	0.31	0.26	0.42	0.24	0.29
Ireland	3	-	38	-	78	0.80	-	0.52	-	0.17
Italy	0	-	100	100	100	0.18	-	0.48	0.22	0.13
Japan	13	100	100	100	99	0.16	0.23	0.18	0.17	0.15
Latvia	-	-	100	100	100	-	-	0.35	0.43	0.30
Lithuania	-	-	100	-	100	-	-	0.29	-	0.35
Luxembourg	-	-	100	-	100	-	-	0.20	-	0.17
Malta	-	-	100	100	100	-	-	0.11	0.13	0.10
Mexico	1	33	47	1	-	0.40	0.71	0.53	0.37	-
Netherlands	-	-	100	100	100	-	-	0.22	0.20	0.13
Norway	0	-	96	97	100	0.16	-	0.27	0.18	0.14
Poland	2	-	58	98	31	0.37	-	0.50	0.53	0.39
Portugal	0	99	90	99	99	0.14	0.12	0.26	0.13	0.18
Romania	5	-	56	75	-	0.24	-	0.52	0.15	-
Russian_Federation	4	9	6	9	41	0.48	0.32	0.32	0.23	0.39
Slovak_Republic	0	-	99	100	98	0.45	-	0.68	0.63	0.49
Slovenia	100	100	100	100	100	0.13	0.13	0.18	0.15	0.16
South_Africa	0	98	94	100	-	0.46	0.49	0.49	0.70	-
South_Korea	0	100	99	100	-	0.14	0.14	0.18	0.28	-
Spain	0	-	96	98	96	0.20	-	0.31	0.19	0.22
Sweden	0	-	11	55	43	0.22	-	0.14	0.15	0.15
Switzerland	100	100	100	100	100	0.34	0.32	0.21	0.49	0.18
Taiwan	100	-	100	100	-	0.21	-	0.16	0.33	-
Turkey	0	-	69	84	74	0.21	-	0.22	0.18	0.20
United_Kingdom	-	-	100	100	100	-	-	0.22	0.11	0.15
United_States	0	1	16	56	-	0.18	0.21	0.29	0.17	-

Note: - means no value, 0 indicates a value smaller than 0.5

Table 5: International environmental multiplier as % of total environmental multiplier – Herfindahl index of international multipliers – Minerals

Minerals	% international multiplier					Herfindahl index of international multipliers				
	i14	i26	i23	i13	i10	i14	i26	i23	i13	i10
Australia	0	14	**58**	3	3	0.16	0.13	0.23	0.16	0.18
Austria	0	33	**68**	-	38	0.20	0.16	0.14	-	0.15
Belgium	1	**67**	**98**	-	-	0.16	0.14	0.18	-	-
Brazil	0	9	25	7	16	0.26	0.29	0.35	0.27	0.21
Bulgaria	0	5	**64**	22	27	0.12	0.11	0.49	0.13	0.14
Canada	0	**90**	**59**	23	33	**0.56**	**0.63**	**0.68**	**0.58**	**0.65**
China	0	3	7	14	9	0.15	0.14	0.12	0.14	0.11
Cyprus	0	1	**96**	-	-	0.18	0.21	**0.64**	-	-
Czech_Republic	0	10	**73**	14	24	0.34	0.24	**0.51**	0.19	0.17
Denmark	0	12	**83**	-	-	0.14	0.17	0.20	-	-
Finland	0	7	**87**	**60**	7	0.12	0.09	0.37	0.11	0.10
France	0	4	**67**	24	**92**	0.12	0.13	0.13	0.18	0.39
Germany	0	7	**66**	-	22	0.08	0.07	0.20	-	0.06
Greece	0	4	24	17	8	0.15	0.26	0.48	0.08	0.08
Hungary	0	18	42	20	9	0.13	0.15	0.21	0.11	0.10
India	0	33	**51**	46	43	0.22	0.32	0.17	0.19	0.30
Indonesia	0	19	47	**84**	26	0.12	0.28	0.26	0.29	0.15
Ireland	1	21	-	**72**	-	0.20	0.16	-	0.20	-
Italy	0	8	**85**	19	**63**	0.08	0.09	0.24	0.09	0.09
Japan	0	**77**	**99**	**92**	**74**	0.16	0.10	0.41	0.14	0.11
Latvia	0	26	**69**	-	19	**0.56**	0.41	0.29	-	0.21
Lithuania	0	**99**	-	-	**67**	0.49	**0.71**	-	-	0.48
Luxembourg	5	46	-	-	-	0.39	0.39	-	-	-
Malta	1	21	**79**	-	-	0.23	0.19	0.13	-	-
Mexico	0	7	1	23	40	**0.69**	**0.69**	**0.72**	**0.70**	**0.73**
Netherlands	1	49	**90**	-	-	0.27	0.26	0.17	-	-
Norway	1	39	**82**	**62**	48	0.41	0.38	0.22	0.13	0.13
Poland	-	**100**	**100**	**100**	**100**	-	0.13	**0.77**	0.36	0.27
Portugal	0	5	**65**	32	-	**0.61**	0.39	0.12	0.19	-
Romania	0	12	**69**	**61**	**52**	0.26	0.26	0.26	0.16	0.18
Russian_Federation	0	4	5	13	6	0.08	0.09	0.07	0.13	0.08
Slovak_Republic	0	**60**	**95**	**53**	46	0.45	0.35	0.48	0.19	0.19
Slovenia	0	26	33	6	5	0.18	0.11	0.10	0.10	0.13
South_Africa	0	**99**	**97**	**99**	**99**	0.12	0.23	0.24	0.12	0.11
South_Korea	0	4	**85**	18	34	0.18	0.16	**0.60**	0.32	0.31
Spain	0	1	**61**	18	21	0.08	0.07	0.18	0.08	0.10
Sweden	0	**52**	12	**51**	21	0.09	0.12	0.24	0.24	0.08
Switzerland	0	**52**	**99**	**86**	**61**	0.24	0.19	0.37	0.23	0.19
Taiwan	0	22	45	33	25	0.15	0.13	0.12	0.42	0.12
Turkey	0	2	8	4	8	0.12	0.10	0.13	0.08	0.11
United_Kingdom	6	**70**	**73**	-	**79**	0.41	0.37	0.15	-	0.19
United_States	0	2	19	1	1	0.17	0.06	0.19	0.22	0.37