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The Measurement of CO2 Embodiments in International Trade: Evidence from the Harmonised Input-Output and Bilateral Trade Database

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THE MEASUREMENT OF CO_2 EMBODIMENTS IN INTERNATIONAL TRADE: EVIDENCE FROM THE HARMONISED INPUT-OUTPUT AND BILATERAL TRADE DATABASE

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ABSTRACT

Efforts to reduce greenhouse gas (GHG) emissions which are linked to the global climate system such as the Kyoto Protocol might fail, if emission-restricted states relocate their carbon-intensive production activities to non-restricted countries where the primary production factors depend on more GHG-intensive sources. Such a relocation process and increased 'carbon trade' appear to be contrary to the GHG reductions envisioned in international agreements. This study addresses the issue of carbon embodiments in trade using internationally-comparable OECD data sources (Input-Output, Bilateral Goods Trade and CO_2 emissions) for 41 countries/regions by 17 industries. Simulation results under base case scenarios for the mid-1990s and the early 2000s suggest that "trade deficits" of CO_2 emissions are observed in 21 OECD countries in the early 2000s and that for 16 countries, the magnitude of the trade deficit increased in the late 1990s. While a third (860 Mt CO_2) of the global increase in production-based emissions took place within the non-OECD economies in the late 1990s, more than half of the consumption-based emission (1550 Mt CO_2) is still attributable to OECD consumption. The sensitivity simulations imply that an increase in global trade intensity has an increasing impact on embodied emissions while technology transfers from carbon-intensive countries to high carbon-intensive countries reduce global emissions and carbon trade gaps.

LA MESURE DES QUANTITÉS DE CO_2 INCORPORÉES DANS LES ÉCHANGES INTERNATIONAUX : DONNÉES PROVENANT DE LA BASE DE DONNÉES HARMONISÉE DES ENTRÉES-SORTIES ET DU COMMERCE BILATÉRAL

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RÉSUMÉ

Les efforts visant à réduire les émissions de gaz à effet de serre (GES) liées au système climatique mondial, notamment dans le cadre du Protocole de Kyoto, risquent d'échouer si les États où s'appliquent des limitations des émissions délocalisent leurs activités de production à forte intensité de carbone vers des pays où ces restrictions ne sont pas imposées et où les facteurs de production primaire sont tributaires de sources qui émettent plus de GES. Ce processus de délocalisation et l'augmentation des 'échanges de carbone' vont à l'encontre des réductions des GES envisagées dans les accords internationaux. Cette étude aborde la question des quantités de carbone incorporées dans les échanges en utilisant des sources de données de l'OCDE comparables au plan international (entrées-sorties, commerce bilatéral et émissions de CO_2) concernant 41 pays/régions et 17 branches d'activité. Dans les résultats des simulations effectuées avec des scénarios de référence couvrant le milieu des années 1990 et le début des années 2000, on observe des "déficits des échanges" d'émissions de CO_2 dans 21 pays de l'OCDE au début des années 2000 et, s'agissant de 16 pays, un accroissement du solde négatif de ces échanges à la fin des années 1990. Si un tiers (860 Mt de CO_2) de l'augmentation mondiale des émissions dues à la production a été produit dans des économies non membres de l'OCDE à la fin des années 1990, plus de la moitié des émissions associées à la consommation (1550 Mt de CO_2) sont encore imputables à la consommation de la zone OCDE. Les simulations des sensibilités laissent supposer qu'un accroissement de l'intensité des échanges mondiaux a un effet à la hausse sur les émissions incorporées, tandis que les transferts de technologie des pays moins émetteurs de carbone vers les pays gros émetteurs réduisent les émissions mondiales et les soldes négatifs des échanges de carbone.

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EXECUTIVE SUMMARY

Efforts such as the Kyoto Protocol to mitigate greenhouse gas (GHG) emissions will be less effective in reducing global emissions of GHG, if they lead countries with emission commitments to relocate their carbon-intensive production activities to countries without such commitments, particularly if production in these latter countries is GHG-intensive. Concern about such "carbon leakage" is high in the run-up to an agreement on the post-2012 climate regime.

Following the previous OECD study by Ahmad and Wyckoff (2003), this study measures the international transfer effects of CO_2 emissions (fuel combustion based) using an updated internationally-comparable economic and energy database. The number of target countries has been increased to 41 countries/regions so that more than 90% of global GDP is now covered. The major findings of our simulation results are as follows (Table 1).

- Accounting for emissions in terms of production and in terms of consumption yield very different results. While one-third of global increase in production-based CO_2 emissions (860 Mt CO_2) took place within the OECD economies (total of 30 members) in the late 1990s, more than half of the global increase in consumption-based emission (1 550 Mt CO_2) is attributable to OECD consumption.

- The acceleration of globalisation, such as international outsourcing and fragmenting of production processes, increased the carbon embodied in international trade in the late 1990s. Among the carbon trade deficit countries in the mid-1990s (28 countries, Table 1), the magnitude of carbon trade deficit (net carbon imports / production-based emissions) has increased in 17 countries (Belgium, Germany, Hungary, Ireland, Italy, Japan, Luxembourg, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States, Argentina, Brazil, Israel, and Singapore).

- Net trade deficits in the embodied CO_2 trade are observed in 21 OECD countries in 2000. The G6 OECD countries (France: -134 Mt CO_2; Germany: -147 Mt CO_2; Italy: -127 Mt CO_2; Japan: -312 Mt CO_2; United Kingdom: -196 Mt CO_2 and United States: -858 Mt CO_2) accounted for 91% of the CO_2 trade deficit. The consumption-based emissions of these G6 countries exceed production-based emissions by 35% for France, 18% for Germany, 30% for Italy, 27% for Japan, 37% for United Kingdom, and 15% for United States respectively in 2000.

- 75% of the non-OECD's CO_2 trade surplus is attributable to five major non-OECD countries: Russia (586 Mt CO_2), China (387 Mt CO_2), Indonesia (64 Mt CO_2), India (56 Mt CO_2), and South Africa (55 Mt CO_2).

- Additional sensitivity simulations suggest that an increase in trade intensity increases emissions embodied in international trade, whereas technology transfers from less carbon-intensive countries to more carbon-intensive countries reduce aggregate global emissions as well as carbon trade gaps.

Our simulation results suggest that future policy discussions on global emissions of GHG need to consider inter-country frameworks rather than just setting goals for individual countries as if economies were unconnected by trade. Thus, multi-sectoral inter-country models have a great potential to provide effective indicators for policy discussions of post-Kyoto.

Table 1. Consumption-based CO_2 emissions (base case)

	Production-based emissions (Mton CO2)		Consumption-based emissions (Mton CO2)		CO2 trade balance (Mton CO2)		emissions per GDP and per capita (2000)	
	1995	2000	1995	2000	1995	2000	(t/USD)	(t/person)
Australia	272	319	258	302	14	17	618	15.9
Austria	60	64	91	92	-31	-28	408	11.4
Belgium	114	118	135	143	-21	-25	509	13.8
Canada	461	531	398	492	64	39	589	16.0
Czech Republic	121	118	98	98	23	20	624	9.5
Denmark	58	50	72	60	-14	-10	395	11.3
Finland	56	55	55	52	2	3	390	10.1
France	358	380	515	514	-158	-134	324	8.7
Germany	874	834	994	981	-119	-147	468	11.9
Greece	73	83	88	99	-15	-16	564	9.1
Hungary	58	56	58	59	-1	-3	449	5.7
Ireland	38	41	42	50	-5	-9	452	13.0
Italy	413	427	511	554	-98	-127	380	9.6
Japan	1098	1159	1377	1471	-279	-312	458	11.6
Korea	362	428	405	442	-43	-14	589	9.4
Luxembourg	8	8	10	11	-1	-3	511	25.7
Netherlands	172	173	184	186	-12	-13	395	11.7
New Zealand	25	32	31	38	-6	-7	452	10.0
Norway	33	34	41	41	-8	-7	270	9.1
Poland	333	293	306	279	27	14	682	7.2
Portugal	49	60	71	88	-23	-28	462	8.6
Slovak Republic	41	38	35	33	6	5	547	6.1
Spain	236	280	275	330	-39	-50	377	8.1
Sweden	54	50	76	79	-22	-30	340	8.9
Switzerland	44	44	73	76	-29	-32	338	10.6
Turkey	172	182	176	180	-5	2	427	2.6
United Kingdom	533	526	623	722	-89	-196	462	12.3
United States	5112	5707	5489	6564	-377	-857	680	23.1
OECD	11229	12088	12487	14037	-1259	-1949		13.6
Argentina	126	126	140	140	-14	-14	317	3.8
Brazil	239	304	252	325	-13	-21	264	1.9
China	2977	2935	2477	2547	500	387	518	2.0
Chinese Taipei	167	223	164	195	3	27	382	8.8
India	699	882	649	826	50	56	388	0.8
Indonesia	202	279	195	215	6	64	364	1.0
Israel	46	46	53	54	-6	-8	474	8.9
Malaysia	76	108	77	78	-1	29	402	3.4
Philippines	59	69	70	79	-10	-10	262	1.0
Russia	1589	1513	1163	928	426	586	915	6.3
Singapore	38	39	45	56	-7	-17	593	13.8
South Africa	251	299	215	243	36	55	638	5.3
non-OECD	6469	6821	5498	5687	971	1134		1.9
ROW	1440	2848	1287	2446	153	402		
World Total	19138	21757	19272	22171	-134	-414		

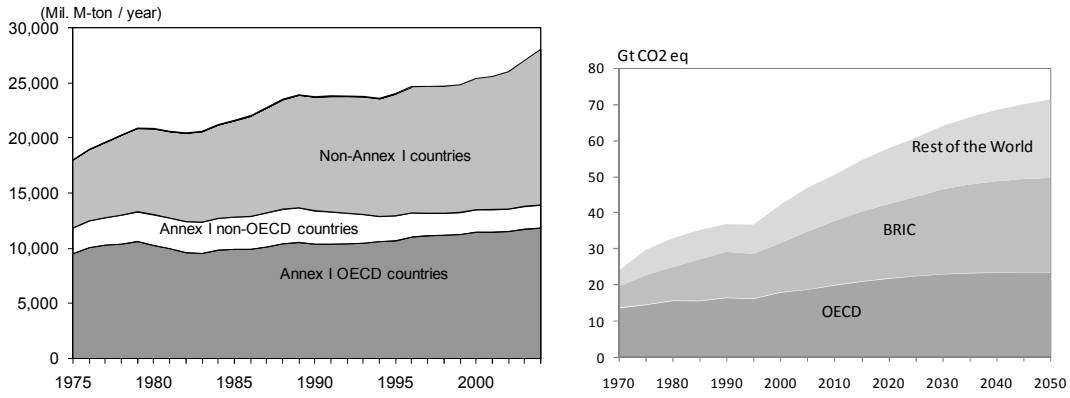
Note: GDP (OECD Main Economic Indicators) in PPP based USD. 1995 data is 1994 for Australia, 1996 for Turkey and Chinese Taipei, 1997 for Argentina, and 1993 for India. 2000 data is 1998 for Australia, 1999 for Greece, 2002 for New Zealand, 1998 for Turkey and India, and 2001 for Chinese Taipei. Iceland and Mexico included in RoW.

1. INTRODUCTION

The reduction of emissions of greenhouse gasses (GHG), notably CO_2, is a goal which has gained worldwide consensus as part of the desired mitigation of global warming processes within the framework of the United Nations Framework Convention on Climate Change (UNFCCC). As of October 2008, the Kyoto Protocol has been ratified by more than 180 countries. The ratified countries have tried to reduce CO_2 emissions by implementing various energy related-policies such as support for the development of renewable energy sources and energy-efficient technologies, implementation of various regulations for energy-intensive activities, and establishment of carbon-trading markets (*e.g.* the EU Emission Trading Scheme), in addition to other activities in arenas including forestry, agriculture, and waste management.

Global emissions, however, have been consistently increasing, most notably in the states designated as non-Annex I countries (Figure 1) by the UNFCCC. The global agreement under UNFCCC's Kyoto Protocol has been argued on the anticipated limitation of global reduction in emissions and the possibilities of carbon leakages through international trade. Global CO_2 emissions are likely to continue to increase if the more strongly carbon-restricted Annex I countries relocate their carbon-intensive production activities to less-strictly constrained countries which have lower environmental standards. This relocation process is likely to lead to an increase in overall global GHG emissions.

Figure 1. Greenhouse gas emissions (territorial-base)



Sources: IEA CO2 emissions from Fuel Combustion and OECD Environmental Outlook 2008.
OECD Countries: Current 30 members, BRIC: Brazil, Russia, India, and China.

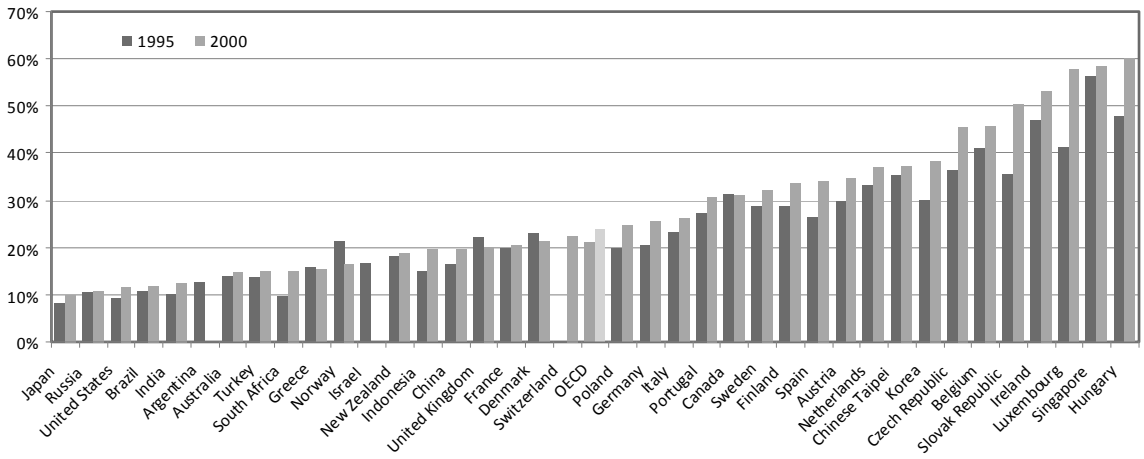
Most of the CO_2 emissions from fuel combustion are directly correlated to the level of carbon-intensive activities, such as electricity generation, production of chemicals and basic metal products, and consumption of transport fuels. In terms of these direct production-based emissions, 37.1% of global CO_2 emissions in 2006 originate from electricity and heat production, 23.0% from transport, and 19.6% from manufacturing industries/construction (CO_2 Emissions from Fuel Combustion Edition 2008, IEA).

The consumption-based emissions, on the other hand, are accounted for by demand of goods and services by households and firms. The net carbon trade balances could even become negative in countries with monetary trade surpluses, if those countries import highly-carbon-intensive goods and export products that are less carbon-intensive. Such possibilities may be explored through quantifying the complex

interdependencies among industries, domestic and foreign final demands. Practical estimations of such effects may be found through analysing Input-Output (I-O) databases. Many studies have in fact applied I-O analysis to measure the emissions embodied in international trade. Most of such efforts are applications which employ a single-country framework, such as Machado *et al.* (2001) for Brazil, Munksgaard and Pedersen (2001) for Denmark, Sanchez-Choliz and Duarte (2004) and Santacana *et al.* (2008) for Spain, Mongelli *et al.* (2006) for Italy, and Schoer *et al*. (2007) for Germany. The gap between production-based and consumption-based emissions has become even larger in the years since 2000 (Santacana *et al*., 2008).

As cross-border supply chains have become more prevalent in the global economy, feedback effects and fragmented production processes must be taken into account by using a multinational framework to measure the emissions embodied in trade. Evidence for this position can be found by examining the import contents embodied within exported goods and services – an indicator for the transnational fragmentation introduced by a globalising economy – which increased in most countries during the late 1990s (Figure 2).

Figure 2. Import contents of exports by country (Input-Output based)



Note: Import contents of countries' exports `is calculated as $u * Am * (I-Ad)^{-1} * X/X_k$ where Am and Ad are the input-output coefficient for imported and domestic goods respectively; u denotes a vector each of whose components is unity, X is a vector of exports and X_k is total country exports. For example, an import content of exports of 20% indicates that 20% of the exports in a country are directly and indirectly based on intermediate inputs that have been imported.
Source: OECD Input-Output Database (De Backer and Yamano, 2007).

Multinational I-O analysis, however, requires highly-harmonised economic datasets (*e.g.* Peters, 2007), including appropriate national I-O tables, adequate data on bilateral trade in goods and services, and some other components of national accounts. Adequate databases are not often published by national statistical offices. The preceding examples have devoted significant efforts to the gathering and developing of comparable multinational data sources, including Nakano *et al.* (2008) for the nine East Asian countries, Shui and Harris (2005) for United States-China, Ackerman *et al*. (2007) for Japan-US, and Hayami and Nakamura (2007) for Canada-Japan.

For OECD economies, Wyckoff and Roop (1994) measured the emissions embodied in the inputs of manufacturing goods using the I-O tables of six OECD countries (Canada, France, Germany, Japan, United Kingdom and United States) and indicated that an equivalent of 13% of the total carbon emissions are embodied within imported goods in the mid-1980s.

Ahmad and Wyckoff (2003) then expanded the country coverage using highly harmonised data on bilateral trade in goods alongside the I-O tables of 24 countries for years around 1995 in order to measure the CO_2 embodiments in international trade. Their results suggest that the emissions required for domestic

consumption are higher than the emissions given off by domestic production within the OECD as a whole. Particularly, the emissions associated with domestic consumption are significantly larger than those associated with domestic production in those larger OECD countries where less-carbon-intensive facilities have been introduced into electricity-generation sectors.

Building on previous analyses based on OECD data sources, we have carried out carbon-embodiment analyses which rely on the following contributions:

1. Greater accuracy in calculation through the inclusion of a more harmonised input-output database which also has wider coverage on target countries.

2. Sensitivity analyses of counterfactual simulations, including exploration of the impacts of improved energy efficiency as well as of changes in import dependencies.

The structure of this paper is as follows. The next section describes the proposed model for measuring CO_2 embodiments in international trade. The data sources and findings from the harmonised database are described in section 3. The simulation cases are described in section 4 with detailed comparison of the simulation results. In the last section, we conclude by suggesting how our calculations on production and consumption-based emissions can be useful for further policy discussions. The details of database harmonisation and simulation results are also provided in the annexes.

2. MODEL

2.1 Overview

In order to accurately estimate the total effects of international CO_2 trade, the single-country model framework has to be extended to a more complicated multinational framework. Employing simulation methodology similar to that of Ahmad and Wyckoff (2003), the production and consumption-based emissions of CO_2 are explicitly separated in each country within our model.

Imported CO_2 is defined in this paper as the emissions embodied in the imports used for intermediate and final consumption. The emission factor of each country is simultaneously determined under the conditions of interdependent relations between import trade partners. The exported CO_2 is also solved through rigorous iterative procedures because a part of CO_2 imported to a country is obviously exported back. Thus the eventual trade balances of imported and exported CO_2 emissions are determined by the complex conditions of existing natural resources, energy efficiencies of production facilities, import penetration ratios and the combinations of trade partners.

The domestic consumption of embodied CO_2 emissions is defined as the emissions embodied within household and government final consumption, investment, and the changes in inventory. This includes direct and indirect effects from goods, accounting for the differing degrees to which the constituents of utilised goods are produced domestically and/or internationally.

On the other hand, the production-based CO_2 emission is defined simply as the CO_2 emitted within each country. Measuring the production-based CO_2 is easier than capturing the total emissions of consumption basis because the calculation of consumption-based emissions requires the detailed

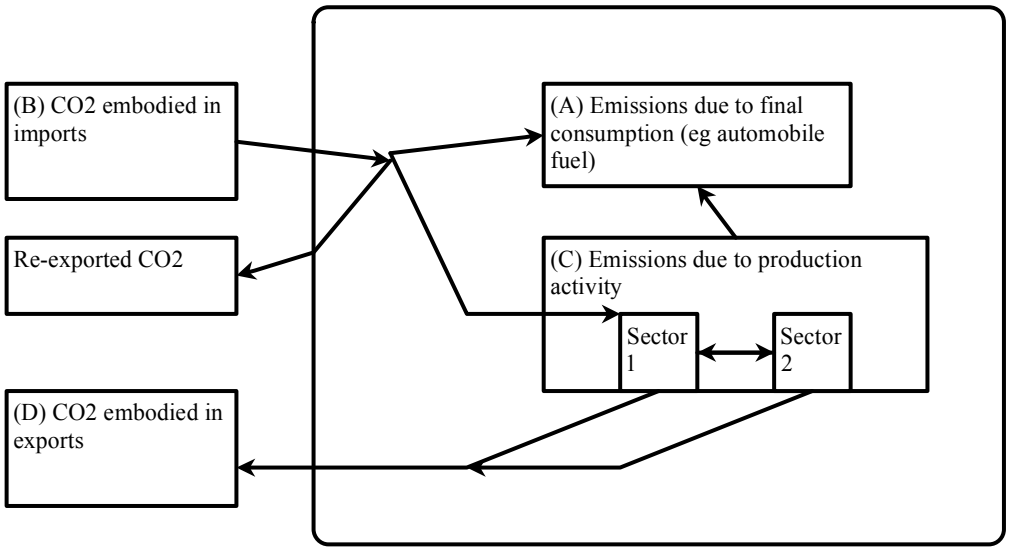
specification of inter-industry and international trade structures (See Figure 3 for an example of CO_2 embodied in trade).

The consumption-based and production-based emissions measures, taking into account CO_2 embodied in international trade, can be subdivided into the following components:

a) Consumption-based emissions = Emissions regarding the domestic final demand (A)
+ Emissions embodied in imports (B)
+ Emissions of production activities (C)
- Exports (D).

b) Production-based emissions = Emissions regarding domestic final demand (A)
+ Emissions embodied in exports (C)

Figure 3. Emissions embodied in international trade for a single country



2.2 Mathematical specification

The following equations detail the mathematical formulations for calculating the CO_2 emissions of domestic consumption, of production, and of those embodied in international trade.

The CO_2 associated with domestic consumption includes the emissions induced domestically by domestic final demand as well as the emissions in trade partners that are indirectly embodied in imports (whether intermediate or final). The emissions induced by domestic consumption of country α are defined as the product of direct emission factors and the output induced by domestic final demand as follows:

(1) $\mathbf{e}_{\alpha}(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\mathbf{f}_{\alpha}$

where $\mathbf{e}_{\alpha}$ is a *1 x N* industries vector of emission factors (CO_2 emissions per unit of domestic output in USD), $(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}$ is the ordinary $N \times N$ Leontief inverse matrix, and $\mathbf{f}_{\alpha}$ is the $N \times 1$ vector of domestic final consumption of domestically produced goods. The domestic final consumption refers to the sum of

household final consumption, general government final consumption, changes in inventories, gross fixed-capital formation and valuables by industry.

On the other hand, the emissions embodied in imported goods are determined by the emission factors of trade partners. The emission factors of goods imported from country β is written as

$$(2)\ \mathbf{e}_{\beta}^{*}\left[\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\mathbf{f}_{\alpha}+\mathbf{nm}_{\alpha,\beta}\right]$$

where $\mathbf{e}_{\beta}^{*}$ is a *1 x N* industries vector of the trade-embodied CO_2 emission factors of exports from country β, $\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}$ is the input-output coefficient of goods imported to country α from country β, and **nm** is a $N \times 1$ vector of non-comparable imports (*i.e.* imports directly for domestic final consumption) from country β. $\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}$ and **nm** are simply separated from the intermediate and final demand matrices of total imported goods using the corresponding import share from the bilateral trade database, because the intercountry input-output structures of intermediate and final demand are not available in the ordinary non-competitive input-output table framework.

Summing the emissions embodied in the imports from all trade partners and emissions induced by domestic industry, the total emissions associated with country α, measured on a consumption basis, $\mathbf{z}_{\alpha}^{\mathbf{DC}}$, is written as

$$(3)\ \mathbf{z}_{\alpha}^{\mathbf{DC}}=\mathbf{e}_{\alpha}(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\mathbf{f}_{\alpha}+\sum_{\beta}^{\mathbf{W}}\mathbf{e}_{\beta}^{*}\left[\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\mathbf{f}_{\alpha}+\mathbf{nm}_{\alpha,\beta}\right]+e^{fd}\mathbf{f}_{\alpha}$$

where W is number of trade partners, and $e^{fd}\mathbf{f}_{\alpha}$ is the emissions regarding fuel combustions regarding final consumption which are non-tradable emissions.

Since the trade-embodied emission factors are simultaneously determined with the imports, the emission factor by sector in each country is calculated as a result of numerical iterations. The converged CO_2 emission factor and emissions embodied in exports are simultaneously determined by

$$(4)\ \mathbf{e}_{\alpha}^{*}=\mathbf{z}_{\alpha}^{EX}\left(\hat{\mathbf{f}}_{\alpha}^{ex}+\sum_{\beta}^{\mathbf{W}}\hat{\mathbf{f}}_{\alpha,\beta}^{rx}\right)^{-1}$$

and

$$(5)\ \mathbf{z}_{\alpha}^{EX}=\mathbf{e}_{\alpha}(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\hat{\mathbf{f}}_{\alpha}^{ex}+\sum_{\beta}^{\mathbf{W}}\mathbf{e}_{\beta}^{*}\left[(\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\hat{\mathbf{f}}_{\alpha}^{ex}+\hat{\mathbf{f}}_{\alpha,\beta}^{rx}\right],$$

where $\hat{\mathbf{f}}_{\alpha}^{ex}$ and $\hat{\mathbf{f}}_{\alpha,\beta}^{rx}$ are the diagonal matrices of exports and re-exports from trade partner country β to α, $(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\hat{\mathbf{f}}_{\alpha}^{ex}$ is the domestically emitted CO_2 and $\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}(\mathbf{I}-\mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\hat{\mathbf{f}}_{\alpha}^{ex}$ is the CO_2 imports induced by exports.

Unlike the domestic consumption of CO_2 of (3), the domestic production of CO_2 is only determined by the emission factors of own country as

$$(6)\ \mathbf{z}_{\alpha}^{\mathbf{DP}} = \mathbf{e}_{\alpha}(\mathbf{I} - \mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}(\mathbf{f}_{\alpha} + \mathbf{f}_{\alpha}^{ex}) + e^{fd}\mathbf{f}_{\alpha}$$

The CO_2 embodied in imports z_{α}^{IM} is the emissions regarding the comparative imports, non-comparative imports and re-export and written as

$$(7)\ \mathbf{z}_{\alpha}^{\mathbf{IM}} = \sum_{\beta}^{\mathrm{W}} \mathrm{e}_{\beta}^{*}\left[(\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}(\mathbf{I} - \mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}(\mathbf{f}_{\alpha} + \mathbf{f}_{\alpha}^{ex}) + \mathbf{nm}_{\alpha,\beta} + \mathbf{f}_{\alpha,\beta}^{rx}\right]$$

From (3), (5), (6) and (7), the difference of emissions embodied in exports and imports is equivalent to the difference of consumption-based emissions (excluding the direct emissions of final consumption) and production-based emissions.

The net CO_2 emissions embodied in international trade is given as

$$\mathbf{z}_{\alpha}^{\mathbf{EX}} - \mathbf{z}_{\alpha}^{\mathbf{IM}} = \mathbf{z}_{\alpha}^{\mathbf{DP}} - \mathbf{z}_{\alpha}^{\mathbf{DC}} = \mathbf{e}_{\alpha}(\mathbf{I} - \mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\mathbf{f}_{\alpha}^{ex} - \sum_{\beta}^{\mathbf{W}} \mathbf{e}_{\beta}^{*}\left[(\mathbf{A}_{\alpha,\beta}^{\mathbf{M}}(\mathbf{I} - \mathbf{A}_{\alpha}^{\mathbf{D}})^{-1}\mathbf{f}_{\alpha} + \mathbf{nm}_{\alpha,\beta}\right].$$

3. DATA

3.1 Availability overview

Obviously, the accuracy of the calculation results depends heavily on the number, comparability, and limitations of available country databases for production and trade structures. One of the major challenges of a multinational carbon-embodiment analysis is the provision of an internationally-harmonised economic database. The sector classifications and database format of original published-data sources unfortunately vary across countries (Table 2).

Using the international harmonised database estimated by the OECD, this study has succeeded in increasing the country coverage to 41 countries/regions. The sector classifications of OECD Input-Output, STAN Bilateral trade database (BTD) and the IEA CO_2 Emissions from Fuel Combustion are basically formatted and harmonised in the sector classification of ISIC Rev.3. Although more detailed sectors are available for OECD I-O and BTD, the 17 aggregated sectors (Table 3) are used in this study mainly due to the limitations of detailed industry of emissions database.[1] The rest of this section provides descriptions of each data source and its limitations, adjustment procedures and of some indicators calculated using the collected database.

1. See Table A1 for the sector concordance table across data sources. The detailed sector analysis certainly needs to be undertaken in future extensions to the present work. Some single-country studies produced analysis at relatively detailed sectoral resolutions.

Table 2. Existing data sources for intercountry CO_2 transfer analysis

	CO_2 Emissions	Input-Output	Bilateral Trade	
			Goods	Services
Sources	IEA	National Statistics Offices	OECD,UN, Eurostat	OECD,UN, Eurostat
Sector details	Not as detailed as I-O and BTD	Good (except for a few countries)	Very detailed.	No detailed information available for most
Sector classification	ISIC	Various classifications (Industry and Products)	HS, SITC (not harmonised with industry and product class.)	BoP, EBOPS (not harmonised with industry and product class.)
Year	Good	Recent years not available	Good	Only available for years after 2000
Country coverage	Good	Good	Good	Poor
International comparability	Good	Various formats	Various mirror statistics problems (re-export, fob/cif, origin/destination differences)	

Sources: IEA CO2 emissions from fuel combustions, OECD ITCS, UN Comtrade, OECD Input-Output (2006), ed Rev.1, OECD Trade in Services, Eurostat External Trade.

Table 3. Sector classification

	Industry	ISIC Rev 3		Industry	ISIC Rev 3
1	Agriculture, hunting, forestry and fishing	1+2+5	11	Fabricated metal products, machinery & equipment	28-32
2	Mining, quarrying and petroleum refining	10-14,23	12	Transport equipment	34+35
3	Food products, beverages and tobacco	15+16	13	Rubber, plastics products and other manufacturing	25,33,36,37
4	Textiles, textile products, leather & footwear	17+18+19	14	Utility	40+41
5	Wood, wood products and cork	20	15	Construction	45
6	Paper, paper products, printing & publishing	21+22	16	Transport and storage	60-63
7	Chemicals and chemical products	24	17	All other services	50-55,64-99
8	Other non-metallic mineral products	26			
9	Iron and Steel	271+2731			
10	Non-ferrous metals	272+2732			

Input-Output tables

The key variables of this analysis, such as input-output coefficient matrices of domestic and imported products, domestic final demand on domestically-produced goods, domestic final demand on total imported goods, and exports, are given by national input-output tables.

The latest edition of the OECD Input-Output database (2006 edition Rev.1) covers the domestic and import transaction tables of 38 countries for the mid-1990s and the early-2000s (Table 4). The global GDP coverage is about 90% (in USD) and the population coverage is 67% for 2000 (Yamano and Ahmad, 2006).

Among our target 41 countries/regions, tables for five countries/regions (Hong Kong, Iceland, Mexico, OPEC, and the rest of the world) were not available for either 1995 or 2000. Alternate tables for these countries/regions were thus chosen in order to approximate their production structures. The selection criteria for choosing alternate tables were similarities in production and trade structures, such as share of manufacturing sectors, import share of manufacturing goods, and import trade partners. The alternate input-output coefficients are selected from Singapore for Hong Kong, from Norway for Iceland, from the

United States for Mexico, from Indonesia for OPEC and from Indonesia for the rest of the world. The final components were accordingly modified by the ratio of GDP between countries and by the alternate country's final demand structures.

Even for the 17 aggregated sectors, there are various restrictions on a number of sectors. The non-ferrous metals cannot be separated from the rest of basic metals (ISIC Rev.3, 27) for most European countries,[2] Canada, China, New Zealand, and the United States. For Russia, the following sectors are also merged in our analysis: 1) Wood, wood products and cork (ISIC Rev.3, 20) and Paper, paper products, printing (ISIC Rev.3, 21-22); 2) Fabricated metal products, machinery and equipment (ISIC Rev.3, 28-32), and Transport equipment (ISIC Rev.3, 34-35).

Further adjustment procedures were required to calculate the proper input-output coefficients for the tables, in which the transactions of scrap and by-products were recorded as negative values. For example, the Japanese table for 1995 is compiled by the Stone procedure and the table for 2000 is compiled through the Reuse-Recycling procedure. Using separately-published scrap and by-product satellite tables, the original I-O tables have been converted to transfer-type tables in which negative values are removed from the intermediate transactions.

Table 4. Available Input-Output tables

Country (ISO code)	mid 1990s	early 2000s	Country (ISO code)	mid 1990s	early 2000s	Country (ISO code)	mid 1990s	early 2000s
Argentina (ARG)	1997	1997	Hungary (HUN)	1998	2000	Poland (POL)	1995	2000
Australia (AUS)	1994/5a	1998/9	India (IND)	1993/4	1998/9	Portugal (PRT)	1995	1999
Austria (AUT)	1995	2000	Indonesia (IDN)	1995	2000	Russia (RUS)	1995	2000
Belgium (BEL)	1995	2000	Ireland (IRL)	1998	2000	Singapore (SGP)	1995	2000
Brazil (BRA)	1995	2000	Israel (ISR)	1995	1995	Slovak Republic (SVK)	1995	2000
Canada (CAN)	1995	2000	Italy (ITA)	1995	2000	South Africa (ZAF)	1993	2000
China (CHN)	1995	2000	Japan (JPN)	1995	2000	Spain (ESP)	1995	2000
Chinese Taipei (TWN)	1996	2001	Korea (KOR)	1995	2000	Sweden (SWE)	1995	2000
Czech Rep. (CZE)	1995	2000	Luxembourg (LUX)	1995	2000	Switzerland (CHE)	2001	2001
Denmark (DNK)	1995	2000	Malaysia (MYS)	1995b	2000b	Turkey (TUR)	1996	1998
Finland (FIN)	1995	2000	Netherlands (NLD)	1995	2000	United Kingdom (GBR)	1995	2000
France (FRA)	1995	2000	New Zealand (NZL)	1995/6	2002/3	United States (USA)	1995	2000
Germany (DEU)	1995	2000	Norway (NOR)	1995	2000			
Greece (GRC)	1995	1999	Philippines (PHL)	1995b	2000b			

Sources: OECD Input-Output database 2006 ed. Rev.1; except for
a: OECD I-O 2002ed., b: Institute of Developing Economies, JETRO.
1994/5 is the fiscal year of 1994-95.

Currency conversion rates

In order to harmonise the currency unit of national input-output tables with US dollar-based trade statistics, the national tables are depreciated by currency exchange rates. The annual market currency exchange rates are from OECD Annual National Accounts for OECD members, Brazil, China, India, Indonesia, Russia, and South Africa; National Income Data, National Statistics, Republic of China for Chinese Taipei; and International Financial Statistics, IMF for other countries.

In many countries, the nominal growth rates based on the national currency decreased in the US dollar-based figures, as the exchange rate to USD relatively appreciated for 31 countries in 1995 and 2000 (Table 5). Significant changes in the currency exchange rates in the late 1990s are observed in Turkey

2. Austria, Belgium, Czech Republic, Denmark, Greece, Finland, France, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Switzerland, Sweden, and United Kingdom.

(78.9%/year), Russia (43.8%/year), Indonesia (30.2%/year), Brazil (12.7%/year), Poland (12.4%/year), Philippines (11.4%/year), and South Africa (11.4%/year).

Table 5. Currency conversion rates (=1 US dollar)

Country	ISO 4217	mid-90s	early-00s	Country	ISO 4217	mid-90s	early-00s
Argentina	ARS	0.9995		Japan	JPY	94.06	107.77
Australia	AUD	1.37	1.59	Korea	KRW	771.27	1130.96
Austria	EUR	0.73	1.09	Luxembourg	EUR	0.73	1.09
Belgium	EUR	0.73	1.09	Malaysia	MYR	2.50	3.80
Brazil	ERL	1.01	1.83	Netherlands	EUR	0.73	1.09
Canada	CAD	1.37	1.49	New Zealand	NZD	1.52	2.16
China	CNY	8.35	8.28	Norway	KOK	6.34	8.80
Chinese Taipei	TWD	27.46	33.89	Philippines	PHL	25.71	44.19
Czech Republic	CZK	26.54	38.60	Poland	PLN	2.42	4.35
Denmark	DKK	5.60	8.08	Portugal	EUR	0.75	1.09
Finland	EUR	0.73	1.09	Russia	RUB	4.63	28.13
France	EUR	0.76	1.09	Singapore	SGD	1.42	1.72
Germany	EUR	0.73	1.09	Slovak Republic	SKK	29.71	46.04
Greece	EUR	0.68	0.90	South Africa	ZAR	3.27	6.94
Hungary	HUF	214.40	282.18	Spain	EUR	0.75	1.09
India	INR	30.49	41.26	Sweden	SEK	7.13	9.16
Indonesia	IDR	2249	8422	Switzerland	CHF		1.69
Ireland	EUR	0.89	1.09	Turkey	TRL*	81405	260724
Israel	ILS	3.01		United Kingdom	GBP	0.63	0.66
Italy	EUR	0.84	1.09	United States	USD	1.00	1.00

Sources: OECD Annual National Accounts for OECD members plus Brazil, China, India, Indonesia, Russia, and South Africa; National Income Data, National Statistics, Republic of China for Chinese Taipei; and International Financial Statistics, IMF for other countries. The official rate published by EU commissions is used for EURO zone countries.

Trade data

Using the import partner shares of the bilateral trade data in goods, the import transaction table in the I-O tables can be separated into the corresponding trade partners. The sector classification of OECD STAN Bilateral Trade Data (BTD) is based on ISIC Rev.3, similar to the OECD Input-Output database.[3] The trade transactions not covered by BTD are supplemented by the detailed HS-based data source of OECD ITCS and UN Comtrade for Argentina, Malaysia, Philippines, Singapore, OPEC[4] and the rest of the world. For I-O-unavailable countries, the export columns of alternate countries' export series are also adjusted by the bilateral trade data sources (*i.e.* BTD, OECD ITCS, and UN Comtrade).

Ideally, to link national I-O tables in order to carry out inter-country analysis requires a consistent set of harmonised international trade, accounting for mirror statistics issues in exports and imports, including adjusted re-exports and uniform definitions of origin and destination countries. Although these statistical issues have been discussed for many years, none of the existing data sources, however, provide "the harmonised" dataset yet. The compilations of the harmonised trade statistics is an issue remaining to be solved for future research to progress (Guo *et al*., 2009).

3. See Guo *et al*. (2009), for the limitations of currently available data sources of bilateral trade data in goods and services.

4. Algeria, Islamic Republic of Iran, Kuwait, Nigeria, Qatar, Saudi Arabia and Venezuela for 2000. Algeria, Saudi Arabia and Venezuela for 1995.

CO_2 emissions by industry sector

The sector classification of the IEA's CO_2 Emissions from Fuel Combustion data is also based on ISIC Rev. 3. The emissions of transport activity are prorated to each sector by the share of petroleum inputs of I-O tables. The emissions from unallocated auto-producers of electricity are also allocated to the following 4 sectors on the basis of petroleum inputs calculated in the I-O tables: Mining, quarrying and petroleum refining (sector 2), Chemicals and chemical products (sector 7), Iron and steel (sector 9), and Non-ferrous metals (sector 10).

3.2 CO_2 emission factors by sector

A CO_2 emission factor, the average unit of CO_2 emitted per unit of sectoral output, is simply calculated by dividing CO_2 emissions[5] by output for each sector. The CO_2 emission factor of the utility sector is a primary source of CO_2 emissions in most countries.[6] Yet, the direct emissions factors of the utility sector vary greatly across countries due to the different power generation systems used (Figure 4).

For example, the direct emission factors of the utility sector are relatively low in Brazil, France, Iceland, Norway and Switzerland where the majority of electricity is supplied by non-thermal power generations (*i.e.* hydro and nuclear). On the other hand, the emission factors are significantly high in some eastern European countries and major non-OECD countries such as China, India, and Russia where coal-fired fuels are the primary source of power generation.

The country deviations of emission factors for other sectors are much smaller than the utility sector (Table A. 2 and Table A.3) and the relative order by sectors is basically stable between 1995 and 2000. The following are generally highly carbon-intensive sectors in the target countries: (2) Mining, quarrying and petroleum refining, (7) Chemicals and chemical products, (8) Other non-metallic mineral products, (9) Iron and Steel, and (14) Utility.

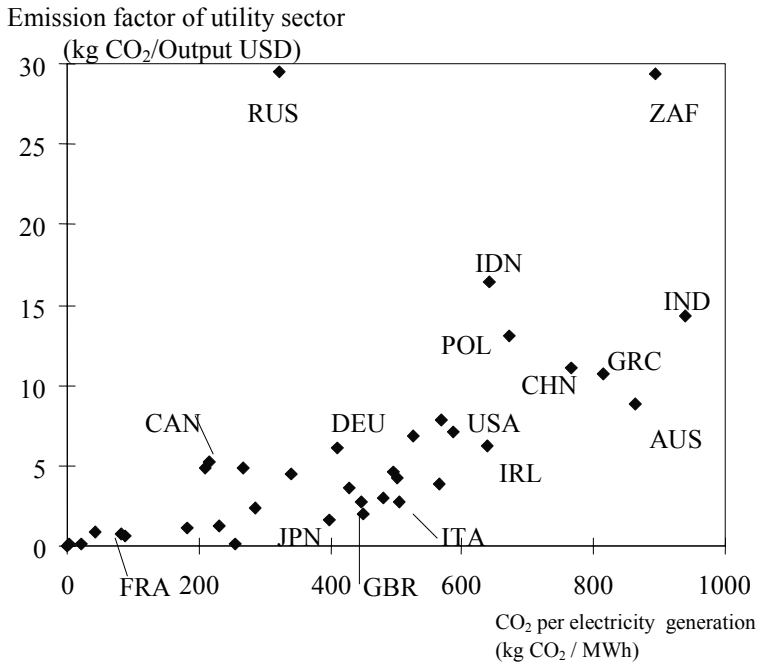
Note that changes in the emission factors are also affected by the denominator, *i.e.* the US dollar-based sectoral output. For example, the emission factor of the electricity sector of Japan has increased from 1.403 kg CO_2 /USD to 1.637 kg CO_2/USD from 1995-2000, as has the currency exchange rate over the same period (94.1 Yen/USD in 1995 to 107.8 Yen/USD in 2000). So the "unimproved" Japanese emission factors are mainly due to the changes in the currency exchange rate. However, among the 30 countries where the USD-based emission factors increased, the indices in national currency increased in only 11 of the countries (*e.g.* Russia and India).

For the I-O unavailable countries, the emission factors of alternate countries are used, such as Singapore for Hong-Kong, Denmark for Iceland, Brazil for Mexico, Indonesia for OPEC and Indonesia for the rest of the world. However, for the utility sector, the emission factors of neighbour countries are adjusted by the mix of generation techniques (kg CO_2/MWh).

5. IEA's CO_2 Emissions from Fuel Combustion is based on the IPCC Tier 1 Sectoral Approach. The database only includes the emissions from fuel combustion. The other sources of global warming factors are not covered *e.g.* the industrial processes of chemical reactions and waste combustion.

6. The emission from public electricity and heat production is about 35% of sectoral approach total in 2002 for OECD average and it has been constantly increasing in the last 30 years.

Figure 4. Emission factor of utility sector vs. unit emissions per power generation (2000)



Sources: IEA, OECD.

3.3 Production and trade structure

The target countries obviously increased their foreign dependencies in the late 1990s (Table 6 and Table 7). The ratios of imports to GDP have increased in 29 countries, while the ratios of export to GDP have increased in all target countries except for France and Norway.

The sectorally-aggregated output and trade figures show significant increases in highly carbon-intensive sectors such as (2) Mining, quarrying and petroleum refining, (7) Chemicals and chemical products, (8) Other non-metallic mineral products, (9) Iron and Steel, and (14) Utility, increases which were greater in non-OECD countries where the direct emission factors are larger than in the OECD countries. The increases in trade volumes of carbon-intensive products imply that the apparent increases in international carbon embodiments took place.

Note that the changes in these tables are also affected by movements in currency exchange rates measured against the key currency (US dollar). The nominal GDP in 15 countries thus decreased in the late 1990s, but this is not generally due to economic recessions.

Table 6. Exports by sectors (Billion USD, current exchange rate based)

	OECD				non OECD			
Exports (Billion USD)	1995	% of Output	2000	% of Output	1995	% of Output	2000	% of Output
1 Agriculture, hunting, forestry and fishing	108	10%	92	10%	28	3%	31	3%
2 Mining, quarrying and petroleum refining	196	21%	268	23%	133	27%	186	28%
3 Food products, beverages and tobacco	244	12%	219	12%	94	11%	76	10%
4 Textiles, textile products, leather & footwear	213	29%	221	37%	195	41%	229	46%
5 Wood, wood products and cork	48	13%	48	17%	39	39%	35	41%
6 Paper, paper products, printing & publishing	149	12%	159	14%	24	14%	35	20%
7 Chemicals and chemical products	461	36%	507	38%	71	17%	90	18%
8 Other non-metallic mineral products	57	13%	57	14%	14	7%	18	12%
9 Iron and Steel	189	26%	167	28%	46	17%	31	13%
10 Non-ferrous metals	36	22%	45	31%	26	37%	33	29%
11 Fabricated metal products, machinery & equipm	1206	34%	1526	41%	385	43%	601	56%
12 Transport equipment	635	38%	840	44%	55	20%	56	20%
13 Rubber, plastics products and other manufacturi	304	24%	373	28%	105	29%	142	40%
14 Utility	12	1%	13	1%	1	0%	1	0%
15 Construction	0	0%	0	0%	0	0%	0	0%
16 Transport and storage	0	0%	0	0%	0	0%	0	0%
17 All other services	663	3%	850	3%	157	4%	212	6%
TOTAL	4521	10%	5385	11%	1373	12%	1777	16%

Notes: Exchange rate based. 1995 data is 1994 for Australia, 1996 for Turkey, 1997 for Argentina, 1996 for Chinese Taipei, and 1993 for India; no data for Iceland, Mexico and Switzerland for OECD. 2000 data is 1998 for Australia, 1999 for Greece, 2002 for New Zealand, 1998 for Turkey, 2001 for Chinese Taipei, and 1998 for India; no data for Iceland and Mexico for OECD.

Table 7. GDP, export, import by country (current exchange rate based Billion USD)

	GDP		Export				Import			
	1995	2000	1995	% of GDP	2000	% of GDP	1995	% of GDP	2000	% of GDP
OECD										
Australia	334	350	64	19%	68	19%	71	21%	77	22%
Austria	181	165	80	44%	82	50%	82	45%	81	49%
Belgium	316	295	147	47%	146	50%	135	43%	139	47%
Canada	552	670	198	36%	312	47%	204	37%	273	41%
Czech Republic	87	87	28	32%	36	41%	30	35%	38	43%
Denmark	141	131	62	44%	66	50%	54	39%	56	43%
Finland	124	126	47	38%	50	40%	36	29%	39	31%
France	1263	1176	351	28%	284	24%	329	26%	268	23%
Germany	2028	1681	521	26%	548	33%	473	23%	541	32%
Greece	78	77	21	26%	25	33%	29	37%	34	45%
Hungary	53	63	24	46%	34	54%	25	47%	36	57%
Ireland	91	110	70	77%	89	81%	60	67%	76	70%
Italy	1089	1152	289	27%	295	26%	246	23%	285	25%
Japan	4493	4414	498	11%	523	12%	465	10%	467	11%
Korea	604	700	148	24%	210	30%	166	27%	212	30%
Luxembourg	19	30	18	93%	26	84%	14	70%	21	70%
Netherlands	404	370	190	47%	175	47%	164	41%	156	42%
New Zealand	68	69	18	26%	20	28%	17	25%	19	27%
Norway	122	128	56	45%	76	60%	46	38%	47	37%
Poland	149	180	32	21%	46	26%	29	19%	55	31%
Portugal	112	115	32	29%	34	29%	39	35%	46	40%
Slovak Republic	28	31	12	43%	15	48%	11	40%	15	49%
Spain	527	524	132	25%	169	32%	133	25%	145	28%
Sweden	232	240	97	42%	109	46%	78	34%	95	40%
Switzerland	-	232	-	-	81	35%	-	-	74	32%
Turkey	144	151	45	31%	56	37%	51	35%	58	38%
United Kingdom	1112	1441	315	28%	404	28%	315	28%	434	30%
United States	6265	8370	783	12%	1028	12%	880	14%	1408	17%
Non-OECD										
Argentina	196	-	31	16%	-	-	41	21%	-	-
Brazil	590	556	54	9%	64	12%	67	11%	73	13%
China	1146	1996	153	13%	279	14%	137	12%	259	13%
Chinese Taipei	317	315	131	41%	140	45%	120	38%	122	39%
India	230	339	29	12%	48	14%	32	14%	60	18%
Indonesia	204	158	54	27%	68	43%	56	28%	50	31%
Israel	80	-	27	34%	-	-	34	42%	-	-
Malaysia	87	92	81	94%	108	118%	49	57%	72	79%
Philippines	73	74	26	35%	42	57%	21	28%	30	41%
Russia	295	216	92	31%	115	53%	81	27%	64	29%
Singapore	128	150	105	82%	119	80%	91	71%	107	71%
South Africa	120	114	28	23%	30	26%	23	19%	26	23%

Note: 1995 data is 1994 for Australia, 1996 for Turkey, 1997 for Argentina, 1996 for Chinese Taipei, and 1993 for India; no data for Iceland, Mexico and Switzerland for OECD. 2000 data is 1998 for Australia, 1999 for Greece, 2002 for New Zealand, 1998 for Turkey, 2001 for Chinese Taipei, and 1998 for India; no data for Iceland and Mexico for OECD.

Sources: OECD Input-Output Database and IDE International Input-Output.

4. MEASUREMENT RESULTS OF CO_2 EMISSIONS EMBODIMENT IN INTERNATIONAL TRADE

4.1 Cases

This section provides the calculation results of carbon embodiment using the data sources described in previous section. In addition to a base case scenario which is based on the actual trade patterns and energy efficiencies, two sensitivity analyses are also calculated: (1) changes in trade patterns, and (2) changes in carbon emission factors. Due to the complex interdependent production processes among countries, the impacts on marginal changes in energy efficiency and trade patterns are difficult to predict without numerical simulation.

Note that the final expenditures and investments *i.e*. final demand components are fixed at the same levels of actual numbers in order to compare the marginal effects of changes in trade patterns and carbon intensities. In other words, any investments and expenditures required to expand the capacity of trade infrastructures or to install less-carbon-intensive production facilities are not taken into account in these numerical examples.

4.2 Major findings: Base case

The worldwide CO_2 emissions generated to satisfy domestic demand in the OECD countries (hereafter consumption-based CO_2 emissions) amounted to 14 037 Mt CO_2 of CO_2 emissions, which was 16.1% (1 949 Mt CO_2) higher than the 12 088 Mt of CO_2 emissions generated by production within the OECD in 2000 (Table 8). The increases in the consumption-based emissions in the late 1990s are significant in the following seven countries: United States (1 075 Mt CO_2), India (177 Mt CO_2), United Kingdom (99 Mt CO_2), Canada (95 Mt CO_2), Japan (94 Mt CO_2), Brazil (73 Mt CO_2), and China (71 Mt CO_2).

The net importer and net exporters are clearly separated by OECD and non-OECD members. The six largest OECD countries accounted for 91% of the total carbon trade deficit of OECD (-1 949 Mt CO_2) in 2000: United States (-858 Mt CO_2), Japan (-312 Mt CO_2), United Kingdom (-196 Mt CO_2), Germany (-147 Mt CO_2), France (-134 Mt CO_2) and Italy (-127 Mt CO_2). On the other hand, large carbon trade surpluses are observed in five major non-OECD countries: Russia (586 Mt CO_2), China (387 Mt CO_2), Indonesia (64 Mt CO_2), India (56 Mt CO_2) and South Africa (55 Mt CO_2). The consumption-based emissions also exceed the production-based emissions in other 16 OECD countries.

The country orders of embodied emissions can also be evaluated by GDP-normalised (OECD Main Economic Indicators for PPP based GDP) and per capita figures (Figure 5 and Figure 6). The larger net imports in terms of GDP normalised emissions are found in Singapore, Portugal, Switzerland, Luxembourg, and Sweden in 2000. On the other hand, Russia, South Africa and Czech Republic are larger net-exporter countries.

For most OECD countries, as the rate of increase for GDP is greater than the rate of increase for CO_2 emissions, the emissions per unit of production have therefore decreased in most countries (only six countries increased in 1995-2000). On the other hand, per capita emissions still increased in most OECD

countries (19 countries) in the late 1990s (Figure 6). The OECD average increased by 8.9% in the late 1990s. The relatively high increases are measured for Canada (18.2%), New Zealand (19.5%), Portugal (20.6%), and Spain (17.7%). The per capita emissions of non-OECD countries however have slightly decreased (-2.8%). This is mainly due to the improvement in carbon intensity in two-highly populated countries (Russia and China) although the significant increases are observed in Brazil (19.8%) and India (16.7%).

Table 8. Production and consumption-based emissions (base case, Mt CO_2)

	Production based emissions		Consumption based emissions		(Consumption - Production)			Production based emissions		Consumption based emissions		(Consumption - Production)	
	1995	2000	1995	2000	1995	2000		1995	2000	1995	2000	1995	2000
OECD	11229	12088	12487	14037	-1259	-1949	Portugal	49	60	71	88	-23	-28
Australia	272	319	258	302	14	16	Slovak Republic	41	38	35	33	6	5
Austria	60	64	91	92	-31	-28	Spain	236	280	275	330	-39	-50
Belgium	114	118	135	143	-21	-24	Sweden	54	50	76	79	-22	-30
Canada	461	531	398	492	64	39	Switzerland	44	44	73	76	-29	-32
Czech Republi	121	118	98	98	23	20	Turkey	172	182	176	180	-5	2
Denmark	58	50	72	60	-14	-10	United Kingdom	533	526	623	722	-89	-196
Finland	56	55	55	52	2	3	United States	5112	5707	5489	6564	-377	-858
France	358	380	515	514	-158	-134	*Non OECD*	6469	6821	5498	5687	971	1134
Germany	874	834	994	981	-119	-147	Argentina	126	126	140	140	-14	-14
Greece	73	83	88	99	-15	-16	Brazil	239	304	252	325	-13	-21
Hungary	58	56	58	59	-1	-3	China	2977	2935	2477	2547	500	387
Ireland	38	41	42	50	-5	-9	Chinese Taipei	167	223	164	195	3	27
Italy	413	427	511	554	-98	-127	India	699	882	649	826	50	56
Japan	1098	1159	1377	1471	-279	-312	Indonesia	202	279	195	215	6	64
Korea	362	428	405	442	-43	-14	Israel	46	46	53	54	-6	-8
Luxembourg	8	8	10	11	-1	-3	Malaysia	76	108	77	78	-1	29
Netherlands	172	173	184	186	-12	-13	Philippines	59	69	70	79	-10	-10
New Zealand	25	32	31	38	-6	-7	Russia	1589	1513	1163	928	426	586
Norway	33	34	41	41	-8	-7	Singapore	38	39	45	56	-7	-17
Poland	333	293	306	279	27	14	South Africa	251	299	215	243	36	55

An index for discrepancies of per capita consumption-based emissions across countries (standard deviation) increased while the disparities remained the same in production-based emissions.[7] In the late 1990s, the population growth, production and electricity generation techniques in each country also remained relatively more stable than changes in consumption-based emissions. This implies that the changes in gaps between consumption-based emissions and production-based emissions are mainly due to the changes in the trade patterns rather than the changes in other factors.

7. Standard deviation of per capita consumption-based emissions has increased from 4.9 in 1995 to 5.4 in 2000 while this index for production-based emissions remained around 4.5.

Figure 5. Production and consumption-based emissions per GDP (base case, 2000, CO_2 tons / USD)

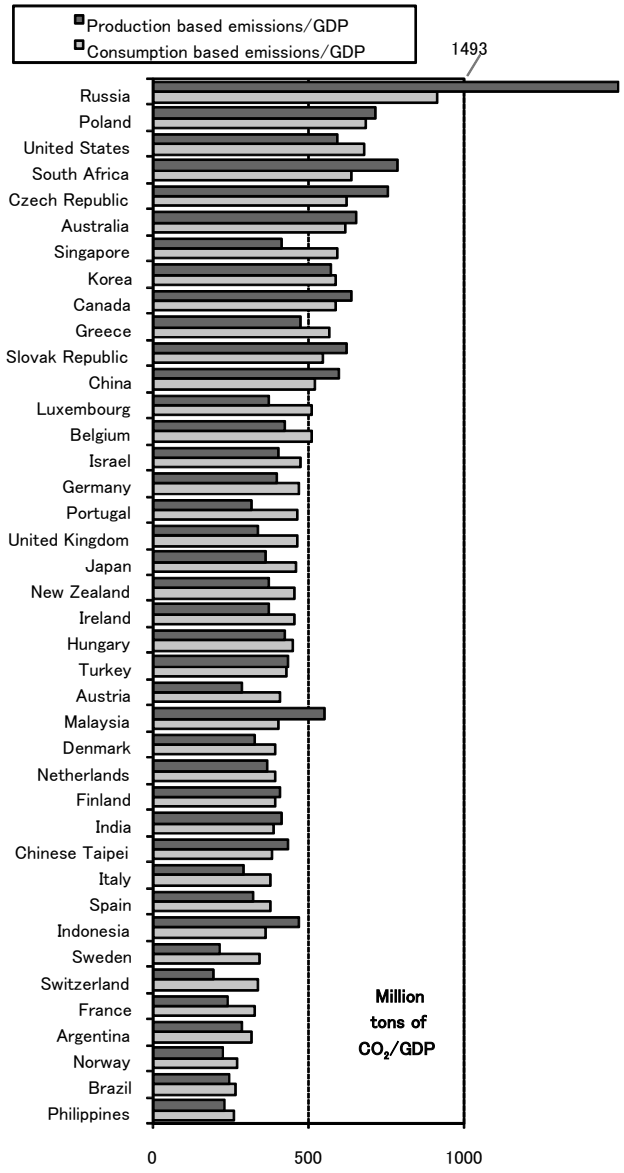
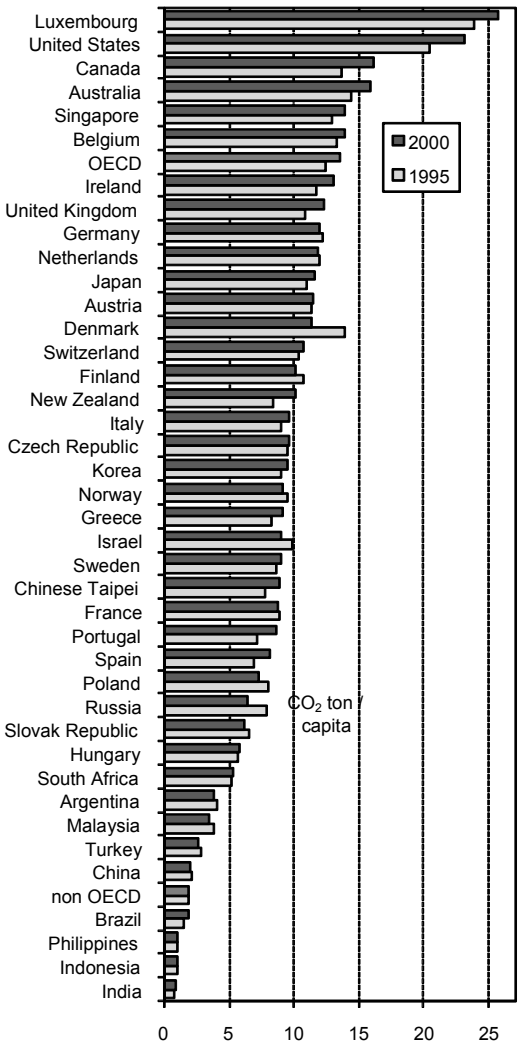


Figure 6. Per capita consumption-based emissions of 1995 and 2000 (base case)



Notes: The OECD figure here does not include Iceland and Mexico. Non-OECD does not include Rest of the world.

The input-output approach is also eligible to show the detailed sector information of CO_2 emission contents for each sector (Table A. 4 and Table A. 5). Since electricity is the most carbon-intensive of the intermediate goods, the CO_2 contents of each country's products are highly correlated to the direct emission factors of the utility sector. Figure 7 and Figure 8 detail the CO_2 emissions contained in the food products, beverages and tobacco sector and fabricated metal products and machinery sector respectively.

Figure 7. Embodied emissions per production: Food products, beverages and tobacco (base case, CO_2/USD)

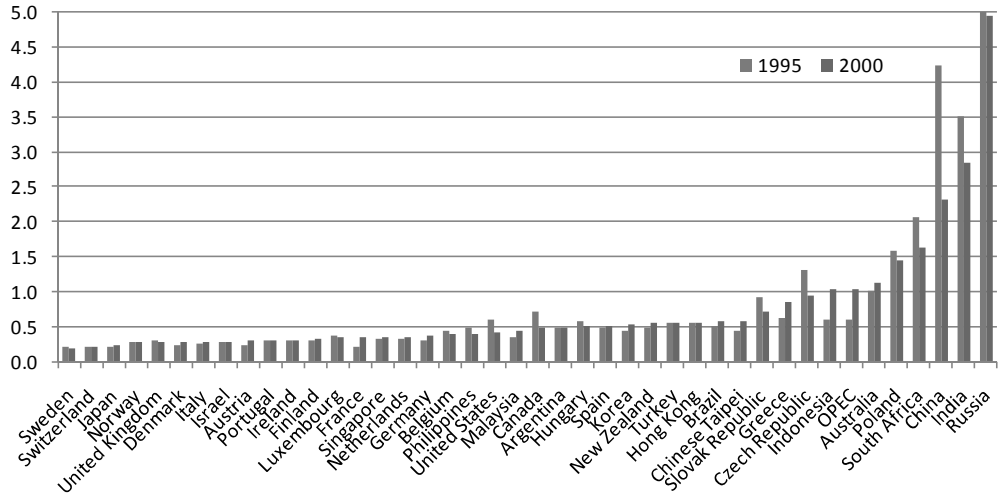
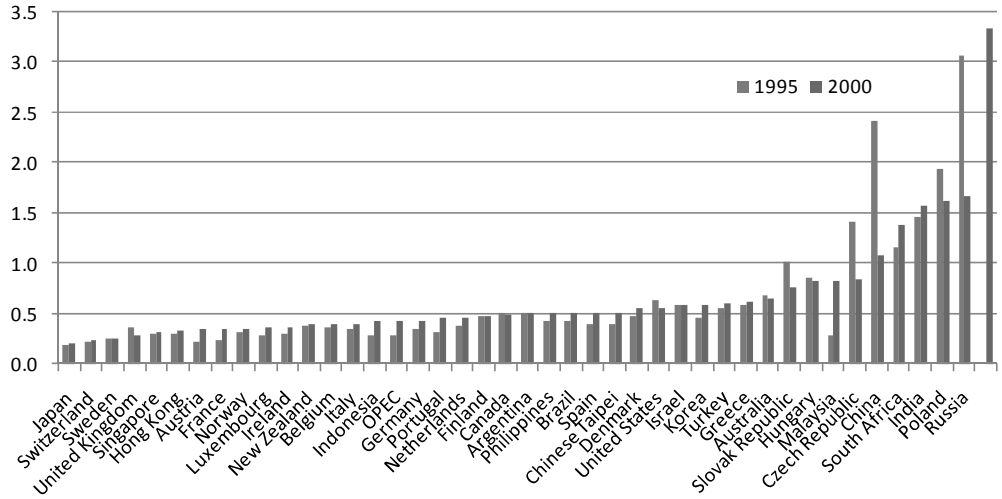


Figure 8. Embodied emissions per production: Fabricated metal products and machinery (base case, CO_2/USD)



4.3 Major findings: Sensitivity analysis

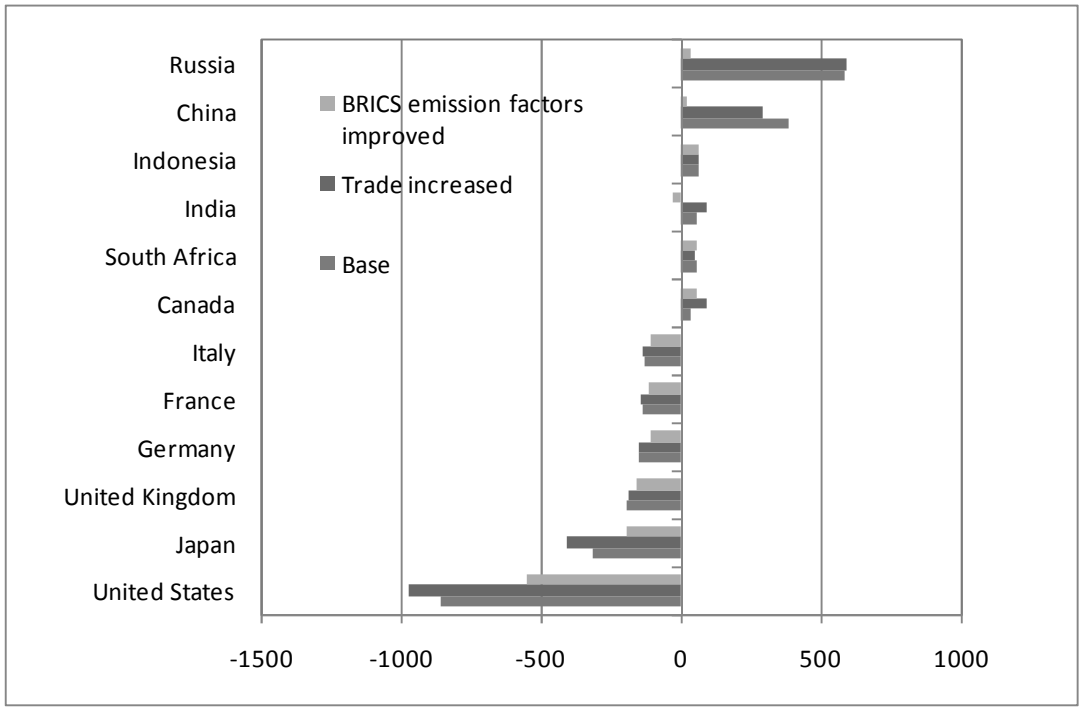
The first-simulation case measures the impacts of further global procurement processes. Under this sensitivity analysis, the import coefficient of each country is increased by 5%, the exports of partner countries are simultaneously inflated by 5%. The gap between consumption-based and production-based emissions becomes wider in the large CO_2 deficit countries (*e.g.* United States and Japan) and the large CO_2 surplus countries (*e.g.* Russia, India and Canada).

The Chinese carbon trade surplus of the base case, however, is reduced by the changes in trade intensities. The impact is different from other major non-OECD countries such as Russia, India, Indonesia and South Africa. The increase in purchases of high-carbon content Chinese products by her partner countries certainly increases the emissions embodied in exports. In the past decade, however, China

became a net-importing country of petroleum. This implies that the current Chinese economy requires an increase in the CO_2 emissions embodied in petroleum imports in order to satisfy increased domestic and foreign demands of their products. Thus, the Chinese net exported emission of base case scenario has decreased from 387 Mt CO_2 to 294 Mt CO_2 in this numerical example. Our simulation results imply that the impacts of changes in trade structure are difficult to predict *a priori* and large impacts are estimated for some countries (*e.g.* China, India, Canada, Japan and United States in Figure 9).

The second sensitivity analysis estimates the impacts of diffusion of OECD's technology and structure to the BRIC countries (Brazil, Russia, India and China). Since the BRIC countries are major emitters and have higher direct emission factors than most of the OECD countries, the global emission level for 2000 is reduced from the 22 171 Mt CO_2 of the base case to 19 151 Mt CO_2. The consumption-based emissions in OECD countries also decreased as a result of reduced emissions embodied in imports. The trade balances disparities between OECD countries and non-OECD countries are significantly reduced (Figure 9).

Figure 9. Differences in consumption and production-based emissions for major OECD and non-OECD countries (consumption – production, Mt CO_2, 2000)



Notes: The detailed results are available at Table A. 8 - Table A. 11.

5. SUMMARY

Despite the various limitations on data sources, a number of potentially significant results are obtained from our calculations and simulations using our interlinked input-output based model. The results derived for emissions embodied by sector and by country are highly valuable for post-Kyoto policy discussions on GHG mitigation. The main results concerning the carbon emissions embodied in international trade include the following:

- The consumption-based CO_2 emission of the OECD overall was 16.1% higher in 2000 than the conventional measurement of production-based emissions suggests. Those differences exceed 30% in seven OECD countries (Austria, France, Luxembourg, Portugal, Sweden, Switzerland, and United Kingdom). As expected, the magnitude of differences increased in the late 1990s due to the increased trade in goods and services.

- Growth of trade-adjusted consumption-based CO_2 emissions has not decelerated as much as has the growth of domestic CO_2 emissions in OECD countries, partly reflecting global relocation of emissions-intensive activity towards non-OECD [or non-Annex I] countries. While less than half of the global increase in CO_2 emissions in the late 1990s took place within the OECD economies, two-thirds of the global increase is still attributable to OECD consumption.

- Our sensitivity analysis results imply that the recent globalisation of industrial activity has had a significant impact on the discrepancies between production and consumption-based emission measures.

- Thus, future international discussions on carbon mitigation programme may need to consider not only individual countries' territorial emissions (as in the Kyoto Protocol approach) but also consider how CO_2 emissions are embodied within the trade among a broader set of target countries, according to a consumption-based measurement approach such as the one explored here.

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ANNEXES

Table A. 1. Industry classification of data sources

OECD IO 2002ed.		OECD IO 2006 ed.		OECD BTD		IEA CO2	
ISIC Rev.3	Description 2002 ed.	ISIC Rev.3	Description 2006 ed.	ISIC Rev.3	Description: BTD	ISIC Rev.3	Description: Carbon Embodiment Estimate
01-05	1 Agriculture, hunting, forestry and fishing	01-05	1 Agriculture, hunting, forestry and fishing	01-05	2 Agriculture, hunting, forestry and fishing	01-05	Agriculture
10-14	2 Mining and quarrying	10-12	2 Mining and quarrying (energy)	10-14	3 Mining and quarrying	10-12	7 Own Use
		13-14	3 Mining and quarrying (non-energy)			13-14	20 Mining and Quarrying
15-16	3 Food products, beverages and tobacco	15-16	4 Food products, beverages and tobacco	15-16	5 Food products, beverages and tobacco	15-16	21 Food and Tobacco
17-19	4 Textiles, textile products, leather and footwear	17-19	5 Textiles, textile products, leather and footwear	17-19	6 Textiles, textile products, leather and footwear	17-19	25 Textile and Leather
20	5 Wood and products of wood and cork	20	6 Wood and products of wood and cork	20	7 Wood and products of wood and cork	20	23 Wood and Wood Products
21-22	6 Pulp, paper, paper products, printing and publishing	21-22	7 Pulp, paper, paper products, printing and publishing	21-22	8 Pulp,paper,paper products, printing and	21-22	22 Paper, Pulp and Printing
23	7 Coke, refined petroleum products and nuclear fuel	23	8 Coke, refined petroleum products and nuclear fuel	23	10 Coke, refined petroleum products and nuclear	23	7 Own Use
24exclude2423	8 Chemicals excluding pharmaceuticals	24exclude2423	9 Chemicals excluding pharmaceuticals	24exclude2423	12 Chemicals excluding pharmaceuticals	24	15 Chemical and Petrochemical
2423	9 Pharmaceuticals	2423	10 Pharmaceuticals	2423	13 Pharmaceuticals		
25	10 Rubber & plastics products	25	11 Rubber & plastics products	25	14 Rubber & plastics products	25	26 Non-Specified Industry
26	11 Other non-metallic mineral products	26	12 Other non-metallic mineral products	26	15 Other non-metallic mineral products	26	17 Non-Metallic Minerals
271 2731	12 Iron & steel	271 2731	13 Iron & steel	271 2731	18 Iron & steel	271 2731	14 Iron and Steel
272 2732	13 Non-ferrous metals	272 2732	14 Non-ferrous metals	272 2732	19 Non-ferrous metals	272 2732	16 Non-Ferrous Metals
28	14 Fabricated metal products, except machinery & equipment	28	15 Fabricated metal products, except machinery & equipment	28	20 Fabricated metal products, except machinery & equipment	28-32	19 Machinery
29	15 Machinery & equipment, n.e.c.	29	16 Machinery & equipment, nec	29	22 Machinery & equipment, nec		
30	16 Office, accounting & computing machinery	30	17 Office, accounting & computing machinery	30	24 Office, accounting & computing machinery		
31	17 Electrical machinery & apparatus, nec	31	18 Electrical machinery & apparatus, nec	31	25 Electrical machinery & apparatus, nec		
32	18 Radio, television & communication equipment	32	19 Radio, television & communication equipment	32	26 Radio, television & communication		
33	19 Medical, precision & optical instruments	33	20 Medical, precision & optical instruments	33	27 Medical, precision & optical instruments	33	26 Non-Specified Industry
34	20 Motor vehicles, trailers & semi-trailers	34	21 Motor vehicles, trailers & semi-trailers	34	29 Motor vehicles, trailers & semi-trailers	34-35	18 Transport Equipment
351	21 Building & repairing of ships & boats	351	22 Building & repairing of ships & boats	351	30 Building & repairing of ships & boats		
353	22 Aircraft & spacecraft	353	23 Aircraft & spacecraft	353	31 Aircraft & spacecraft		
352+359	23 Railroad equipment & transport equip n.e.c.	352+359	24 Railroad equipment & transport equip n.e.c.	352+359	33 Railroad equipment & transport equip n.e.c.		
36-37	24 Manufacturing nec; recycling (include Furniture)	36-37	25 Manufacturing nec; recycling (include Furniture)	36-37	34 Manufacturing nec; recycling (include	37	26 Non-Specified Industry
401	25 Electricity, gas and water supply	401	26 Production, collection and distribution of electricity	40-41	35 Electricity, gas and water supply	40	7 Own Use
402		402	27 Manufacture of gas; distribution of gaseous fuels through mains				
403		403	28 Steam and hot water supply				
41		41	29 Collection, purification and distribution of water			41	38 Commercial and Public Services
45	26 Construction	45	30 Construction			45	24 Construction
50-52	27 Wholesale & retail trade; repairs	50-52	31 Wholesale & retail trade; repairs			50-55	38 Commercial and Public Services
55	28 Hotels & restaurants	55	32 Hotels & restaurants				
60	29 Transport	60	33 Land transport; transport via pipelines			60-62	28 Transport
61		61	34 Water transport				
62		62	35 Air transport				
63		63	36 Supporting and auxiliary transport activities; activities of travel			63-99	38 Commercial and Public Services
64	30 Post & telecommunications	64	37 Post & telecommunications				
65-67	31 Finance & insurance	65-67	38 Finance & insurance				
70	32 Real estate activities	70	39 Real estate activities				
71	33 Renting of machinery & equipment	71	40 Renting of machinery & equipment				
72	34 Computer & related activities	72	41 Computer & related activities				
73	35 Research & development	73	42 Research & development				
74	36 Other Business Activities	74	43 Other Business Activities				
75	37 Public admin. & defense; compulsory social security	75	44 Public admin. & defense; compulsory social security				
80	38 Education	80	45 Education				
85	39 Health & social work	85	46 Health & social work				
90-93	40 Other community, social & personal services	90-93	47 Other community, social & personal services				
95-99	41 Private households with employed persons & extra-territorial organizations & bodies	95-99	48 Private households with employed persons & extra-territorial organizations & bodies				

Table A. 2. Direct CO_2 emission factor by country and sector (kg-CO_2/USD, mid-1990s)

Australia - Hungary	AUS	AUT	BEL	CAN	CZE	DNK	FIN	FRA	DEU	GRC	HUN
Agriculture, hunting, forestry and fishing	0.30	0.20	0.42	0.51	0.66	0.30	0.23	0.18	0.20	0.33	0.40
Mining, quarrying and petroleum refining	0.63	1.35	0.92	1.28	1.25	0.88	0.84	0.73	1.10	0.75	1.04
Food products, beverages and tobacco	0.14	0.06	0.05	0.03	0.24	0.11	0.07	0.07	0.08	0.12	0.19
Textiles, textile products, leather & footwear	0.07	0.06	0.07	0.02	0.27	0.05	0.07	0.05	0.07	0.10	0.12
Wood, wood products and cork	0.09	0.05	0.05	0.07	0.16	0.05	0.05	0.02	0.05	0.11	0.17
Paper, paper products, printing & publishing	0.16	0.14	0.07	0.38	0.41	0.04	0.18	0.09	0.11	0.22	0.16
Chemicals and chemical products	0.59	0.82	0.42	1.05	1.30	0.11	0.49	0.42	0.50	0.40	1.40
Other non-metallic mineral products	1.55	0.55	0.83	1.14	1.45	1.06	1.33	0.69	0.76	3.47	1.66
Iron and Steel	1.91	0.85	0.78	1.94	1.82	0.12	0.88	0.78	0.86	0.97	1.89
Non-ferrous metals	3.15	..	..	..	0.55	0.10	..	..	..	..	..
Fabricated metal products, machinery & equipment	0.05	0.02	0.03	0.02	0.15	0.03	0.03	0.04	0.03	0.06	0.07
Transport equipment	0.03	0.10	0.02	0.01	0.16	0.04	0.05	0.02	0.03	0.09	0.04
Rubber, plastics products and other manufacturing	0.42	0.18	0.42	1.17	1.41	0.03	0.16	0.14	0.10	0.49	0.23
Utility	8.01	0.71	1.88	4.35	7.32	4.87	3.66	0.34	3.10	9.42	5.72
Construction	0.16	0.12	0.13	0.46	0.19	0.12	0.18	0.11	0.09	0.16	0.13
Transport and storage	0.20	0.06	0.10	0.29	0.12	0.11	0.24	0.21	0.07	0.48	0.14
All other services	0.03	0.03	0.05	0.10	0.16	0.02	0.02	0.05	0.04	0.05	0.15
Household final consumption	0.09	0.08	0.13	0.21	0.48	0.09	0.09	0.08	0.12	0.05	0.47
Iceland - Poland	ISL	IRL	ITA	JPN	KOR	LUX	MEX	NLD	NZL	NOR	POL
Agriculture, hunting, forestry and fishing	0.30	0.11	0.25	0.17	0.23	0.07	0.26	0.36	0.18	0.28	0.74
Mining, quarrying and petroleum refining	0.88	0.65	1.21	0.47	0.90	8.03	0.67	0.77	0.66	0.43	1.91
Food products, beverages and tobacco	0.11	0.08	0.06	0.02	0.09	0.04	0.08	0.07	0.07	0.08	0.41
Textiles, textile products, leather & footwear	0.05	0.09	0.06	0.01	0.14	0.00	0.07	0.07	0.07	0.11	0.37
Wood, wood products and cork	0.05	0.03	0.02	0.01	0.09	0.02	0.05	0.02	0.06	0.09	0.41
Paper, paper products, printing & publishing	0.04	0.00	0.12	0.07	0.20	0.02	0.25	0.06	0.10	0.10	0.48
Chemicals and chemical products	0.11	0.11	0.42	0.49	1.30	0.59	0.74	0.76	1.21	0.68	2.22
Other non-metallic mineral products	1.06	1.14	0.73	0.33	1.29	2.33	0.93	0.46	0.73	1.11	2.92
Iron and Steel	0.12	1.62	0.46	0.41	0.36	0.96	1.09	0.63	1.86	0.51	3.80
Non-ferrous metals	0.10	..	..	0.08	0.14	..	0.72	..	..	..	..
Fabricated metal products, machinery & equipment	0.03	0.01	0.04	0.01	0.03	0.06	0.04	0.03	0.06	0.13	0.27
Transport equipment	0.04	0.03	0.01	0.00	0.03	0.01	0.02	0.03	0.03	0.18	0.27
Rubber, plastics products and other manufacturing	0.03	0.25	0.07	0.13	0.33	0.57	0.42	0.34	1.60	0.29	0.29
Utility	0.02	5.50	2.36	1.40	3.88	0.12	3.16	2.10	0.79	0.10	15.25
Construction	0.12	0.31	0.05	0.05	0.05	0.53	0.05	0.04	0.16	0.10	0.18
Transport and storage	0.11	0.06	0.09	0.06	0.22	0.14	0.40	0.12	0.09	0.04	0.27
All other services	0.02	0.06	0.05	0.03	0.17	0.00	0.08	0.03	0.05	0.02	0.13
Household final consumption	0.09	0.15	0.14	0.04	0.13	0.16	0.06	0.13	0.10	0.03	0.68
Portugal - United States, Argentina, Brazil, China	PRT	SVK	ESP	SWE	CHE	TUR	GBR	USA	ARG	BRA	CHN
Agriculture, hunting, forestry and fishing	0.21	0.41	0.18	0.23	0.02	0.23	0.11	0.35	0.49	0.26	0.35
Mining, quarrying and petroleum refining	1.11	1.18	0.90	0.51	0.74	0.66	0.84	1.39	1.09	0.67	1.68
Food products, beverages and tobacco	0.06	0.03	0.08	0.07	0.05	0.15	0.11	0.12	0.06	0.08	0.62
Textiles, textile products, leather & footwear	0.05	0.03	0.08	0.09	0.10	0.13	0.09	0.11	0.03	0.07	0.44
Wood, wood products and cork	0.07	0.04	0.03	0.03	0.00	0.01	0.04	0.13	0.08	0.05	1.40
Paper, paper products, printing & publishing	0.14	0.08	0.13	0.11	0.14	0.26	0.09	0.22	0.10	0.25	1.37
Chemicals and chemical products	0.74	0.39	0.64	0.26	0.52	1.00	0.39	1.07	0.28	0.74	2.51
Other non-metallic mineral products	1.17	0.16	1.11	0.96	1.16	0.51	0.57	1.46	1.19	0.93	3.58
Iron and Steel	0.51	2.15	0.81	0.63	0.34	1.36	0.64	1.16	0.85	1.09	4.03
Non-ferrous metals	..	..	..	..	..	1.33	..	0.71	0.64	0.72	..
Fabricated metal products, machinery & equipment	0.02	0.02	0.04	0.03	0.02	0.02	0.04	0.05	0.02	0.04	0.36
Transport equipment	0.02	0.01	0.03	0.02	0.01	0.02	0.06	0.05	0.03	0.02	0.33
Rubber, plastics products and other manufacturing	0.10	2.92	0.20	0.10	0.07	2.44	0.23	0.22	0.99	0.42	1.29
Utility	2.57	6.09	2.55	0.86	0.13	6.75	2.55	4.94	1.82	0.33	28.13
Construction	0.15	0.14	0.05	0.17	0.29	0.34	0.08	0.22	0.23	0.05	0.20
Transport and storage	0.16	0.08	0.17	0.10	0.01	0.41	0.14	0.55	0.41	0.40	0.29
All other services	0.04	0.26	0.03	0.03	0.03	0.02	0.06	0.05	0.03	0.08	0.31
Household final consumption	0.10	0.44	0.11	0.07	0.02	0.25	0.18	0.17	0.16	0.06	0.92
Chinese Taipei - OPEC, Rest of the World	TWN	HKG	IND	IDN	ISR	MYS	PHL	RUS	SGP	ZAF	OPC	ROW
Agriculture, hunting, forestry and fishing	0.17	0.03	0.05	0.13	0.14	0.16	0.14	1.03	0.03	0.66	0.13	0.26
Mining, quarrying and petroleum refining	0.83	0.79	1.87	1.34	0.87	0.83	0.92	7.12	0.79	0.42	1.34	0.67
Food products, beverages and tobacco	0.07	0.02	0.20	0.06	0.03	0.02	0.14	0.42	0.02	0.03	0.06	0.08
Textiles, textile products, leather & footwear	0.18	0.01	0.40	0.23	0.02	0.01	0.13	0.21	0.01	0.04	0.23	0.07
Wood, wood products and cork	0.02	0.01	0.05	0.04	0.03	0.02	0.26	0.62	0.01	0.06	0.04	0.05
Paper, paper products, printing & publishing	0.25	0.01	1.36	0.31	0.02	0.02	0.75	..	0.01	0.07	0.31	0.25
Chemicals and chemical products	0.85	0.41	2.43	1.64	0.53	1.48	0.26	3.70	0.41	2.48	1.64	0.74
Other non-metallic mineral products	1.45	0.09	5.57	3.22	0.59	0.73	4.61	1.80	0.09	1.88	3.22	0.93
Iron and Steel	0.93	0.04	5.73	1.39	0.05	0.21	0.87	10.92	0.04	2.91	1.39	1.09
Non-ferrous metals	0.16	0.13	1.69	1.50	0.04	1.37	1.37	1.40	0.13	0.65	1.50	0.72
Fabricated metal products, machinery & equipment	0.01	0.01	0.17	0.15	0.02	0.02	0.03	0.36	0.01	0.06	0.15	0.04
Transport equipment	0.02	0.02	0.07	0.01	0.01	0.01	0.04	..	0.02	0.03	0.01	0.02
Rubber, plastics products and other manufacturing	0.10	0.15	2.46	0.46	0.38	0.91	0.69	2.20	0.15	1.31	0.46	0.42
Utility	4.68	7.66	17.16	6.46	8.29	6.62	4.99	20.04	8.44	21.64	6.46	0.33
Construction	0.13	0.08	0.13	0.48	0.08	0.11	0.18	0.46	0.08	0.26	0.48	0.05
Transport and storage	0.21	0.04	0.57	0.26	0.18	0.20	0.83	0.59	0.04	0.29	0.26	0.40
All other services	0.03	0.01	0.12	0.05	0.06	0.04	0.13	0.44	0.01	0.08	0.05	0.08
Household final consumption	0.06	0.05	0.43	0.18	0.06	0.17	0.10	0.90	0.05	0.23	0.18	0.06

Table A. 3. Direct CO_2 emission factor by country and sector (kg-CO_2/USD, early 2000s)

Australia - Hungary	AUS	AUT	BEL	CAN	CZE	DNK	FIN	FRA	DEU	GRC	HUN
Agriculture, hunting, forestry and fishing	0.28	0.26	0.45	0.46	0.29	0.52	0.27	0.23	0.27	0.42	0.46
Mining, quarrying and petroleum refining	0.73	1.07	0.45	0.86	1.63	0.56	0.79	0.58	1.02	0.83	0.67
Food products, beverages and tobacco	0.14	0.14	0.06	0.04	0.27	0.13	0.06	0.11	0.11	0.14	0.15
Textiles, textile products, leather & footwear	0.10	0.08	0.06	0.03	0.23	0.06	0.10	0.06	0.08	0.12	0.04
Wood, wood products and cork	0.08	0.07	0.05	0.10	0.13	0.07	0.04	0.02	0.08	0.15	0.13
Paper, paper products, printing & publishing	0.18	0.17	0.09	0.35	0.24	0.05	0.24	0.11	0.12	0.27	0.11
Chemicals and chemical products	0.61	0.53	0.40	1.04	2.11	0.13	0.73	0.45	0.63	0.67	1.29
Other non-metallic mineral products	1.56	0.63	0.73	1.02	1.26	1.36	0.62	0.75	0.82	2.89	1.39
Iron and Steel	2.50	1.37	1.06	1.68	4.02	0.16	0.95	0.65	1.02	1.37	1.91
Non-ferrous metals	3.45	..	..	0.25	..	..	..	..	..	..	..
Fabricated metal products, machinery & equipment	0.05	0.03	0.03	0.02	0.09	0.04	0.01	0.03	0.04	0.07	0.03
Transport equipment	0.04	0.07	0.02	0.02	0.09	0.03	0.02	0.02	0.03	0.13	0.03
Rubber, plastics products and other manufacturing	0.46	0.25	0.67	0.73	0.87	0.04	0.13	0.17	0.11	0.43	0.19
Utility	8.83	1.06	2.40	5.25	7.80	4.51	4.80	0.71	4.63	10.71	6.13
Construction	0.14	0.22	0.09	0.36	0.18	0.15	0.16	0.12	0.11	0.19	0.11
Transport and storage	0.17	0.13	0.24	0.28	0.13	0.13	0.29	0.21	0.15	0.60	0.36
All other services	0.04	0.03	0.06	0.12	0.16	0.02	0.04	0.03	0.04	0.06	0.15
Household final consumption	0.12	0.11	0.17	0.22	0.36	0.05	0.07	0.17	0.15	0.06	0.44

Iceland - Poland	ISL	IRL	ITA	JPN	KOR	LUX	MEX	NLD	NZL	NOR	POL
Agriculture, hunting, forestry and fishing	0.52	0.17	0.26	0.18	0.38	0.10	0.29	0.50	0.13	0.34	0.98
Mining, quarrying and petroleum refining	0.56	0.63	0.47	0.58	1.05	1.92	0.58	0.66	0.98	0.22	1.29
Food products, beverages and tobacco	0.13	0.10	0.09	0.03	0.09	0.05	0.09	0.09	0.05	0.10	0.30
Textiles, textile products, leather & footwear	0.06	0.14	0.06	0.01	0.18	0.00	0.06	0.09	0.04	0.10	0.19
Wood, wood products and cork	0.07	0.02	0.02	0.00	0.13	0.01	0.06	0.05	0.05	0.09	0.33
Paper, paper products, printing & publishing	0.05	0.00	0.13	0.08	0.22	0.03	0.25	0.08	0.08	0.09	0.28
Chemicals and chemical products	0.13	0.08	0.31	0.52	0.98	0.31	0.76	0.88	3.69	1.15	2.16
Other non-metallic mineral products	1.36	1.55	0.87	0.36	1.59	4.59	1.30	0.52	1.23	1.05	1.67
Iron and Steel	0.16	1.86	0.50	0.52	0.52	0.41	1.06	0.72	2.26	0.59	3.73
Non-ferrous metals	..	..	..	0.11	0.16	..	0.81	..	..	..	..
Fabricated metal products, machinery & equipment	0.04	0.01	0.05	0.01	0.03	0.06	0.04	0.03	0.10	0.10	0.19
Transport equipment	0.03	0.04	0.01	0.00	0.09	0.01	0.03	0.02	0.03	0.09	0.11
Rubber, plastics products and other manufacturing	0.04	0.42	0.08	0.24	0.45	1.04	0.64	0.50	1.41	0.17	0.26
Utility	0.01	6.16	2.69	1.64	4.20	0.16	3.81	2.75	1.28	0.12	13.13
Construction	0.15	0.22	0.06	0.04	0.05	0.59	0.05	0.04	0.11	0.08	0.08
Transport and storage	0.13	0.01	0.08	0.18	0.34	0.16	0.61	0.21	0.02	0.06	0.21
All other services	0.02	0.05	0.04	0.03	0.11	0.00	0.12	0.04	0.13	0.02	0.09
Household final consumption	0.05	0.19	0.17	0.05	0.15	0.18	0.07	0.14	0.04	0.04	0.33

Portugal - United States, Argentina, Brazil, China	PRT	SVK	ESP	SWE	CHE	TUR	GBR	USA	ARG	BRA	CHN
Agriculture, hunting, forestry and fishing	0.36	0.48	0.29	0.28	0.02	0.25	0.17	0.38	0.49	0.29	0.31
Mining, quarrying and petroleum refining	0.98	1.27	0.77	0.39	0.74	0.98	0.91	0.86	1.09	0.58	0.89
Food products, beverages and tobacco	0.10	0.05	0.09	0.07	0.05	0.18	0.09	0.11	0.06	0.09	0.24
Textiles, textile products, leather & footwear	0.10	0.02	0.11	0.06	0.10	0.12	0.10	0.12	0.03	0.06	0.14
Wood, wood products and cork	0.11	0.04	0.06	0.03	0.00	0.02	0.03	0.15	0.08	0.06	0.26
Paper, paper products, printing & publishing	0.24	0.04	0.17	0.12	0.14	0.19	0.06	0.16	0.10	0.25	0.52
Chemicals and chemical products	1.13	0.60	0.77	0.25	0.52	1.09	0.32	0.88	0.28	0.76	1.05
Other non-metallic mineral products	1.77	0.19	1.49	0.96	1.16	0.53	0.31	1.15	1.19	1.30	2.85
Iron and Steel	0.60	1.96	0.79	0.68	0.34	1.19	0.53	1.10	0.85	1.06	2.60
Non-ferrous metals	..	..	..	..	..	1.51	..	..	0.64	0.81	0.82
Fabricated metal products, machinery & equipment	0.02	0.01	0.05	0.02	0.02	0.02	0.03	0.04	0.02	0.04	0.12
Transport equipment	0.03	0.00	0.04	0.02	0.01	0.02	0.04	0.05	0.03	0.03	0.12
Rubber, plastics products and other manufacturing	0.10	3.76	0.18	0.13	0.07	2.62	0.26	0.18	0.99	0.64	0.71
Utility	3.02	4.91	3.62	0.84	0.13	6.89	1.99	7.13	1.82	0.57	11.13
Construction	0.16	0.11	0.04	0.14	0.29	0.26	0.04	0.16	0.23	0.05	0.21
Transport and storage	0.24	0.16	0.21	0.11	0.01	0.36	0.16	0.43	0.41	0.61	0.33
All other services	0.04	0.17	0.04	0.03	0.03	0.01	0.04	0.06	0.03	0.12	0.18
Household final consumption	0.11	0.39	0.15	0.08	0.02	0.21	0.14	0.13	0.16	0.07	0.41

Chinese Taipei - OPEC, Rest of the World	TWN	HKG	IND	IDN	ISR	MYS	PHL	RUS	SGP	ZAF	OPC	ROW
Agriculture, hunting, forestry and fishing	0.22	0.02	0.03	0.21	0.14	0.28	0.18	1.20	0.02	0.60	0.21	0.29
Mining, quarrying and petroleum refining	0.90	0.66	2.11	1.07	0.87	0.72	0.80	8.91	0.66	0.55	1.07	0.58
Food products, beverages and tobacco	0.10	0.01	0.57	0.09	0.03	0.13	0.13	0.53	0.01	0.05	0.09	0.09
Textiles, textile products, leather & footwear	0.25	0.01	0.32	0.38	0.02	0.03	0.14	0.20	0.01	0.06	0.38	0.06
Wood, wood products and cork	0.02	0.01	0.03	0.10	0.03	0.04	0.10	1.09	0.01	0.05	0.10	0.06
Paper, paper products, printing & publishing	0.23	0.01	1.19	0.43	0.02	0.09	0.72	..	0.01	0.08	0.43	0.25
Chemicals and chemical products	1.36	0.37	1.70	3.96	0.53	0.66	0.46	6.90	0.37	3.33	3.96	0.76
Other non-metallic mineral products	1.58	0.13	4.98	5.33	0.59	1.41	4.10	3.69	0.13	2.22	5.33	1.30
Iron and Steel	1.58	0.02	3.86	3.35	0.05	0.12	1.50	8.96	0.02	3.90	3.35	1.06
Non-ferrous metals	0.23	0.01	1.60	2.63	0.04	0.07	0.65	1.41	0.01	0.80	2.63	0.81
Fabricated metal products, machinery & equipment	0.02	0.00	0.13	0.12	0.02	0.01	0.01	0.63	0.00	0.09	0.12	0.04
Transport equipment	0.02	0.01	0.06	0.03	0.01	0.01	0.04	..	0.01	0.04	0.03	0.03
Rubber, plastics products and other manufacturing	0.11	0.16	1.79	2.77	0.38	2.59	0.24	3.10	0.16	3.07	2.77	0.64
Utility	6.91	3.81	14.31	16.47	8.29	6.43	3.86	29.46	3.82	29.33	16.47	0.57
Construction	0.18	0.01	0.15	0.66	0.08	0.19	0.39	0.75	0.01	0.23	0.66	0.05
Transport and storage	0.29	0.01	0.46	0.34	0.18	0.37	1.14	0.95	0.01	0.34	0.34	0.61
All other services	0.03	0.01	0.07	0.09	0.06	0.06	0.16	0.54	0.01	0.05	0.09	0.12
Household final consumption	0.06	0.07	0.33	0.38	0.06	0.46	0.17	1.28	0.07	0.20	0.38	0.07

Table A. 4. Embodied CO_2 emission factor by sector (base case, kg-CO_2/USD, 1995)

Australia - Hungary	AUS	AUT	BEL	CAN	CZE	DNK	FIN	FRA	DEU	GRC	HUN
Agriculture, hunting, forestry and fishing	0.69	0.28	0.52	0.96	1.65	0.52	0.48	0.31	0.42	0.59	0.92
Mining, quarrying and petroleum refining	1.16	1.97	1.35	1.89	3.15	1.52	1.79	1.31	1.84	1.82	2.20
Food products, beverages and tobacco	0.69	0.23	0.36	0.51	1.41	0.48	0.48	0.24	0.35	0.59	0.86
Textiles, textile products, leather & footwear	0.63	0.28	0.39	0.44	1.38	0.38	0.34	0.22	0.47	0.60	0.59
Wood, wood products and cork	0.57	0.21	0.38	0.61	1.29	0.26	0.42	0.19	0.41	0.56	0.73
Paper, paper products, printing & publishing	0.61	0.33	0.40	0.87	1.45	0.31	0.65	0.26	0.38	0.79	0.71
Chemicals and chemical products	1.40	1.30	1.09	1.69	2.98	0.60	1.16	0.76	0.95	1.21	2.31
Other non-metallic mineral products	2.57	0.83	1.28	1.63	3.25	1.43	1.79	0.96	1.22	4.72	2.59
Iron and Steel	3.36	1.46	1.59	2.94	4.33	0.95	2.04	1.47	1.64	2.89	3.74
Non-ferrous metals	5.18	..	..	..	2.35	0.71	..	..	..	..	..
Fabricated metal products, machinery & equipment	1.03	0.25	0.45	0.73	1.32	0.25	0.33	0.23	0.33	0.65	0.58
Transport equipment	0.67	0.29	0.27	0.35	1.19	0.39	0.39	0.19	0.29	0.42	0.31
Rubber, plastics products and other manufacturing	1.03	0.37	1.27	1.67	2.64	0.45	0.46	0.34	0.57	0.97	0.78

Iceland - Poland	ISL	IRL	ITA	JPN	KOR	LUX	MEX	NLD	NZL	NOR	POL
Agriculture, hunting, forestry and fishing	0.41	0.21	0.44	0.30	0.45	0.27	0.53	0.63	0.40	0.40	2.17
Mining, quarrying and petroleum refining	1.45	0.99	1.98	0.99	1.75	1.63	1.24	1.29	1.28	0.53	3.82
Food products, beverages and tobacco	0.35	0.30	0.35	0.20	0.46	0.29	0.52	0.38	0.38	0.31	1.94
Textiles, textile products, leather & footwear	0.20	0.44	0.30	0.22	0.75	0.22	0.49	0.47	0.36	0.30	1.65
Wood, wood products and cork	0.28	0.51	0.24	0.61	0.63	0.34	0.41	0.39	0.36	0.30	2.29
Paper, paper products, printing & publishing	0.15	0.15	0.37	0.22	0.68	0.37	0.79	0.33	0.37	0.22	1.59
Chemicals and chemical products	0.37	0.37	0.95	0.88	2.07	1.29	1.45	1.36	1.78	1.00	3.23
Other non-metallic mineral products	1.26	1.43	1.16	0.56	2.11	2.37	1.67	0.90	1.07	1.35	4.40
Iron and Steel	0.65	2.31	1.04	1.09	1.72	1.86	2.41	1.33	2.54	1.08	5.82
Non-ferrous metals	0.50	..	..	0.66	1.63	..	1.64	..	..	..	..
Fabricated metal products, machinery & equipment	0.15	0.31	0.28	0.22	0.46	0.39	0.62	0.34	0.50	0.30	1.59
Transport equipment	0.09	0.92	0.26	0.20	0.41	0.78	0.50	0.47	0.46	0.33	1.83
Rubber, plastics products and other manufacturing	0.17	0.55	0.31	0.39	0.95	1.04	0.95	1.13	2.09	0.56	1.89

Portugal - United States, Argentina, Brazil, China	PRT	SVK	ESP	SWE	CHE	TUR	GBR	USA	ARG	BRA	CHN
Agriculture, hunting, forestry and fishing	0.37	1.44	0.39	0.33	0.19	0.46	0.32	0.89	0.76	0.49	1.59
Mining, quarrying and petroleum refining	2.04	2.88	1.65	1.15	0.84	1.05	1.24	2.84	1.65	1.12	5.23
Food products, beverages and tobacco	0.33	1.01	0.40	0.25	0.23	0.56	0.37	0.64	0.50	0.43	2.42
Textiles, textile products, leather & footwear	0.35	0.97	0.38	0.28	0.46	0.67	0.36	0.74	0.29	0.39	2.68
Wood, wood products and cork	0.29	1.25	0.30	0.20	0.25	0.47	0.43	0.61	0.40	0.31	4.82
Paper, paper products, printing & publishing	0.58	0.83	0.47	0.25	0.34	0.78	0.33	0.72	0.37	0.63	4.73
Chemicals and chemical products	1.33	1.44	1.17	0.60	1.11	1.60	0.88	1.97	0.78	1.34	6.81
Other non-metallic mineral products	1.75	1.76	1.58	1.15	1.39	1.32	0.92	2.38	1.71	1.49	8.16
Iron and Steel	1.27	4.10	1.42	1.29	1.24	2.64	1.25	2.95	1.59	2.15	9.34
Non-ferrous metals	..	..	..	..	..	2.30	..	2.25	1.46	1.40	..
Fabricated metal products, machinery & equipment	0.32	0.95	0.50	0.23	0.23	0.58	0.33	0.62	0.49	0.52	4.26
Transport equipment	0.32	0.86	0.35	0.16	0.75	0.51	0.34	0.56	0.28	0.41	3.55
Rubber, plastics products and other manufacturing	0.42	4.06	0.47	0.33	0.78	2.96	0.51	0.74	1.30	0.85	4.47

Chinese Taipei - OPEC, Rest of the World	TWN	HKG	IND	IDN	ISR	MYS	PHL	RUS	SGP	ZAF	OPC	ROW
Agriculture, hunting, forestry and fishing	0.43	0.32	0.81	0.28	1.27	0.28	0.29	3.29	0.33	1.58	0.28	0.49
Mining, quarrying and petroleum refining	1.62	1.90	3.61	1.69	1.80	1.10	1.68	11.90	1.88	2.04	1.70	1.11
Food products, beverages and tobacco	0.39	0.31	1.46	0.29	0.59	0.29	0.43	3.08	0.30	1.15	0.29	0.43
Textiles, textile products, leather & footwear	0.86	0.67	2.68	0.76	0.42	0.53	0.55	3.24	0.43	1.10	0.76	0.39
Wood, wood products and cork	0.33	0.24	1.14	0.33	0.43	0.34	0.63	4.38	0.42	1.27	0.33	0.31
Paper, paper products, printing & publishing	0.92	0.37	4.24	0.80	0.34	0.83	1.30	..	0.27	1.26	0.80	0.63
Chemicals and chemical products	1.98	1.18	5.69	2.61	1.29	2.31	0.98	10.46	1.12	4.25	2.61	1.34
Other non-metallic mineral products	2.18	0.87	8.43	4.04	1.37	1.26	5.59	7.08	0.66	3.47	4.04	1.49
Iron and Steel	2.56	1.38	10.72	2.46	0.97	1.13	2.63	19.03	1.25	5.67	2.47	2.15
Non-ferrous metals	1.10	1.04	6.24	2.36	0.42	1.86	2.30	5.13	1.18	4.99	2.36	1.42
Fabricated metal products, machinery & equipment	0.45	0.57	3.52	0.61	0.29	0.37	0.51	5.02	0.34	2.08	0.61	0.52
Transport equipment	0.49	0.88	3.46	0.48	0.36	0.53	1.14	..	0.77	1.46	0.48	0.41
Rubber, plastics products and other manufacturing	0.69	0.71	5.48	0.93	1.03	1.57	1.15	6.13	0.59	2.40	0.93	0.86

Table A. 5. Embodied CO_2 emission factor by sector (base case, kg-CO_2/USD, 2000)

Australia - Hungary	AUS	AUT	BEL	CAN	CZE	DNK	FIN	FRA	DEU	GRC	HUN
Agriculture, hunting, forestry and fishing	0.70	0.44	0.58	0.88	1.12	0.75	0.55	0.41	0.51	0.73	1.03
Mining, quarrying and petroleum refining	1.41	1.73	1.45	1.37	3.39	0.98	1.98	1.33	2.00	1.86	2.04
Food products, beverages and tobacco	0.77	0.35	0.40	0.49	1.07	0.56	0.48	0.35	0.43	0.65	0.83
Textiles, textile products, leather & footwear	0.72	0.31	0.44	0.41	0.95	0.46	0.42	0.39	0.50	0.62	0.54
Wood, wood products and cork	0.59	0.27	0.35	0.55	0.93	0.31	0.43	0.32	0.49	0.63	0.66
Paper, paper products, printing & publishing	0.64	0.38	0.42	0.85	1.00	0.29	0.71	0.37	0.41	0.75	0.64
Chemicals and chemical products	1.44	1.07	1.29	1.79	3.35	0.74	1.45	1.12	1.23	1.67	2.25
Other non-metallic mineral products	2.92	0.92	1.20	1.56	2.28	1.71	1.02	1.14	1.33	3.98	2.29
Iron and Steel	4.48	1.99	1.91	3.03	6.49	1.05	1.77	1.50	1.76	3.19	3.16
Non-ferrous metals	5.33	..	..	0.70	..	..	..	..	..	..	..
Fabricated metal products, machinery & equipment	1.13	0.31	0.42	0.51	0.95	0.30	0.34	0.38	0.38	0.86	0.52
Transport equipment	0.70	0.23	0.29	0.27	0.46	0.34	0.27	0.25	0.30	0.31	0.31
Rubber, plastics products and other manufacturing	1.00	0.59	1.64	1.22	1.81	0.51	0.51	0.90	0.69	0.97	0.81

Iceland - Poland	ISL	IRL	ITA	JPN	KOR	LUX	MEX	NLD	NZL	NOR	POL
Agriculture, hunting, forestry and fishing	0.69	0.35	0.44	0.32	0.67	0.33	0.67	0.79	0.46	0.46	2.36
Mining, quarrying and petroleum refining	0.93	1.09	1.33	1.32	2.18	1.49	1.31	1.44	1.41	0.27	2.76
Food products, beverages and tobacco	0.45	0.37	0.40	0.20	0.61	0.36	0.65	0.46	0.39	0.35	1.67
Textiles, textile products, leather & footwear	0.28	0.43	0.35	0.33	0.86	0.27	0.57	0.49	0.44	0.34	1.06
Wood, wood products and cork	0.25	0.52	0.25	0.47	0.91	0.18	0.54	0.44	0.45	0.31	1.47
Paper, paper products, printing & publishing	0.14	0.05	0.41	0.27	0.80	0.40	0.83	0.34	0.49	0.20	1.20
Chemicals and chemical products	0.47	0.32	0.93	0.98	2.14	1.47	1.63	1.65	4.43	1.52	3.86
Other non-metallic mineral products	1.57	2.05	1.32	0.60	2.54	4.14	2.17	1.02	1.85	1.28	3.33
Iron and Steel	0.40	2.47	1.07	1.24	1.99	1.69	2.48	1.43	3.07	0.96	5.91
Non-ferrous metals	..	..	..	0.65	1.72	..	2.07	..	..	..	..
Fabricated metal products, machinery & equipment	0.16	0.32	0.30	0.26	0.54	0.36	0.73	0.38	0.56	0.29	1.46
Transport equipment	0.11	1.02	0.25	0.24	0.60	0.74	0.58	0.49	0.42	0.25	0.89
Rubber, plastics products and other manufacturing	0.20	0.82	0.35	0.55	1.19	1.50	1.31	1.53	2.05	0.52	1.43

Portugal - United States, Argentina, Brazil, China	PRT	SVK	ESP	SWE	CHE	TUR	GBR	USA	ARG	BRA	CHN
Agriculture, hunting, forestry and fishing	0.61	1.24	0.57	0.41	0.19	0.46	0.36	0.92	0.76	0.60	1.24
Mining, quarrying and petroleum refining	2.04	2.79	1.71	1.33	1.24	1.30	1.38	1.73	1.65	1.17	2.89
Food products, beverages and tobacco	0.46	0.82	0.51	0.25	0.24	0.63	0.29	0.59	0.50	0.51	1.39
Textiles, textile products, leather & footwear	0.45	0.62	0.47	0.35	0.47	0.64	0.31	0.62	0.29	0.44	1.44
Wood, wood products and cork	0.45	0.85	0.38	0.20	0.25	0.51	0.28	0.60	0.40	0.37	2.02
Paper, paper products, printing & publishing	0.59	0.76	0.54	0.25	0.33	0.67	0.23	0.47	0.37	0.62	2.46
Chemicals and chemical products	1.89	2.16	1.41	0.63	1.26	1.91	0.76	1.54	0.81	1.50	3.94
Other non-metallic mineral products	2.51	1.63	2.05	1.15	1.43	1.33	0.61	1.78	1.71	1.91	5.73
Iron and Steel	1.73	3.59	1.48	1.26	0.83	2.74	1.06	1.96	1.57	2.16	6.40
Non-ferrous metals	..	..	..	..	..	2.83	..	..	1.54	1.67	4.20
Fabricated metal products, machinery & equipment	0.32	0.73	0.53	0.20	0.23	0.58	0.29	0.43	0.51	0.59	2.34
Transport equipment	0.27	0.23	0.36	0.15	0.65	0.38	0.24	0.40	0.26	0.45	2.19
Rubber, plastics products and other manufacturing	0.51	4.60	0.49	0.35	0.85	3.21	0.49	0.62	1.31	1.17	2.75

Chinese Taipei - OPEC, Rest of the World	TWN	HKG	IND	IDN	ISR	MYS	PHL	RUS	SGP	ZAF	OPC	ROW
Agriculture, hunting, forestry and fishing	0.59	0.32	0.48	0.39	1.27	0.50	0.35	3.48	0.32	1.94	0.39	0.60
Mining, quarrying and petroleum refining	1.97	2.07	3.84	1.45	1.93	1.08	1.54	13.78	1.85	2.42	1.46	1.17
Food products, beverages and tobacco	0.56	0.33	1.62	0.42	0.59	0.85	0.51	3.33	0.31	1.57	0.42	0.51
Textiles, textile products, leather & footwear	1.31	0.79	2.91	1.41	0.46	0.70	0.51	3.01	0.46	1.40	1.41	0.44
Wood, wood products and cork	0.56	0.30	1.42	0.67	0.41	0.52	0.51	4.74	0.78	1.28	0.67	0.37
Paper, paper products, printing & publishing	0.90	0.36	3.49	1.24	0.33	0.71	1.24	..	0.23	1.25	1.24	0.62
Chemicals and chemical products	3.04	0.97	4.23	5.06	1.35	1.60	1.30	13.54	0.93	4.87	5.07	1.50
Other non-metallic mineral products	2.58	1.33	7.23	6.81	1.38	2.37	5.46	9.62	0.95	3.74	6.81	1.91
Iron and Steel	3.36	1.63	7.25	5.89	0.93	1.82	3.39	15.51	1.52	6.19	5.91	2.16
Non-ferrous metals	2.05	0.96	5.03	3.92	0.48	1.00	2.30	5.66	0.99	5.75	3.92	1.69
Fabricated metal products, machinery & equipment	0.60	0.58	2.86	1.06	0.30	0.45	0.42	4.97	0.38	1.65	1.06	0.59
Transport equipment	0.64	0.86	3.16	0.94	0.29	1.19	0.73	..	0.46	0.95	0.94	0.45
Rubber, plastics products and other manufacturing	0.85	0.78	4.23	3.83	1.10	3.35	0.95	6.79	0.64	4.34	3.83	1.17

Table A. 6. Consumption and production-based CO_2 (base case, 1995, Mt CO_2)

	Consumption by domestic industry	Emissions from domestic industry	Exported	Imported	Balance	Emissions for final use	Consumption basis CO_2	Production basis CO_2
by country	(a)	(b)	(c)	(d)	(b)-(a)=(c)-(d)	(e)	(a)+(e)	(b)+(e)
Australia	242	255	112	53	14	17	258	272
Austria	81	50	69	59	(31)	10	91	60
Belgium	117	97	112	138	(21)	18	135	114
Canada	336	399	236	116	64	62	398	461
Czech Republic	87	110	60	23	23	11	98	121
Denmark	65	51	42	38	(14)	7	72	58
Finland	50	52	41	25	2	5	55	56
France	451	293	312	259	(158)	65	515	358
Germany	851	732	497	401	(119)	143	994	874
Greece	85	70	34	26	(15)	4	88	73
Hungary	48	47	29	19	(1)	10	58	58
Ireland	37	32	27	28	(5)	5	42	38
Italy	426	329	246	192	(98)	84	511	413
Japan	1,248	969	504	408	(279)	129	1,377	1,098
Korea	372	328	195	137	(43)	34	405	362
Luxembourg	8	7	9	11	(1)	1	10	8
Netherlands	159	147	152	158	(12)	25	184	172
New Zealand	28	22	19	13	(6)	3	31	25
Norway	39	31	42	30	(8)	2	41	33
Poland	260	287	70	27	27	46	306	333
Portugal	65	42	39	33	(23)	7	71	49
Slovak Republic	31	37	24	11	6	4	35	41
Spain	238	199	132	95	(39)	37	275	236
Sweden	68	47	59	52	(22)	8	76	54
Switzerland	69	41	59	88	(29)	3	73	44
Turkey	144	139	43	25	(5)	33	176	172
United Kingdom	504	415	290	222	(89)	119	623	533
United States	4,644	4,267	1,255	845	(377)	846	5,489	5,112
Argentina	113	99	47	32	(14)	27	140	126
Brazil	231	218	73	45	(13)	21	252	239
China	2,168	2,668	686	99	500	308	2,477	2,977
Chinese Taipei	155	158	119	74	3	9	164	167
India	570	620	110	31	50	79	649	699
Indonesia	167	174	75	37	6	28	195	202
Israel	50	44	28	23	(6)	3	53	46
Malaysia	70	69	77	49	(1)	7	77	76
Philippines	64	54	28	23	(10)	6	70	59
Russia	1,011	1,437	521	51	426	152	1,163	1,589
Singapore	44	37	47	54	(7)	1	45	38
South Africa	197	234	69	17	36	18	215	251
ROW	1,161	1,315	677	451	154	126	1,287	1,440
by region								
EU4	2,232	1,768	1,345	1,074	(464)	411	2,643	2,179
Other OECD Europe	1,653	1,486	1,045	886	(167)	236	1,890	1,722
NAFTA	5,132	4,919	1,634	990	(213)	919	6,051	5,837
OECD Asia/Oceania	1,889	1,574	830	612	(314)	182	2,071	1,757
Non-OECD	5,846	6,871	2,409	954	1,024	772	6,618	7,643
World	16,752	16,618	7,263	4,515	(134)	2,520	19,272	19,138

Table A. 7. Consumption and production-based CO_2 (base case, 2000, Mt CO_2)

	Consumption by domestic industry	Emissions from domestic industry	Exported	Imported	Balance	Emissions for final use	Consumption basis CO_2	Production basis CO_2
by country	(a)	(b)	(c)	(d)	(b)-(a)=(c)-(d)	(e)	(a)+(e)	(b)+(e)
Australia	277	294	133	62	16	25	302	319
Austria	81	53	71	63	(28)	11	92	64
Belgium	123	99	118	163	(24)	19	143	118
Canada	416	454	299	179	39	77	492	531
Czech Republic	89	109	60	26	20	9	98	118
Denmark	57	47	41	38	(10)	3	60	50
Finland	49	52	43	28	3	3	52	55
France	399	265	270	309	(134)	115	514	380
Germany	830	683	564	489	(147)	150	981	834
Greece	95	78	34	26	(16)	5	99	83
Hungary	48	45	33	26	(3)	10	59	56
Ireland	43	34	34	38	(9)	7	50	41
Italy	450	323	281	231	(127)	103	554	427
Japan	1,325	1,013	586	471	(312)	146	1,471	1,159
Korea	397	383	257	175	(14)	45	442	428
Luxembourg	10	6	9	12	(3)	2	11	8
Netherlands	163	150	155	181	(13)	23	186	173
New Zealand	37	30	24	16	(7)	1	38	32
Norway	39	32	43	31	(7)	2	41	34
Poland	248	262	99	48	14	31	279	293
Portugal	80	52	46	40	(28)	8	88	60
Slovak Republic	29	34	24	13	5	4	33	38
Spain	282	233	178	131	(50)	48	330	280
Sweden	71	41	66	62	(30)	8	79	50
Switzerland	73	41	63	97	(32)	3	76	44
Turkey	152	154	49	25	2	28	180	182
United Kingdom	599	403	385	317	(196)	123	722	526
United States	5,657	4,799	1,598	1,276	(858)	907	6,564	5,707
Argentina	113	99	48	32	(14)	27	140	126
Brazil	301	280	96	61	(21)	23	325	304
China	2,326	2,713	768	207	387	221	2,547	2,935
Chinese Taipei	185	212	155	84	27	11	195	223
India	734	790	173	60	56	92	826	882
Indonesia	178	242	121	33	64	37	215	279
Israel	52	44	29	26	(8)	3	54	46
Malaysia	64	93	73	45	29	14	78	108
Philippines	71	61	30	28	(10)	8	79	69
Russia	780	1,365	670	48	586	148	928	1,513
Singapore	53	36	58	74	(17)	3	56	39
South Africa	228	283	90	26	55	15	243	299
ROW	2,195	2,597	1,291	704	402	251	2,446	2,848
by region								
EU4	2,278	1,674	1,499	1,346	(604)	492	2,770	2,166
Other OECD Europe	1,733	1,524	1,169	1,053	(209)	226	1,959	1,750
NAFTA	6,446	5,849	2,220	1,519	(597)	1,006	7,453	6,855
OECD Asia/Oceania	2,037	1,720	999	724	(317)	217	2,254	1,937
Non-OECD	6,904	8,218	3,275	1,362	1,314	831	7,735	9,049
World	19,399	18,985	9,163	6,005	(414)	2,772	22,171	21,757

Table A. 8. Simulation results: simulation case for increased international trade case (1995, Mt CO_2)

	Consumption by domestic industry	Emissions from domestic industry	Exported	Imported	Balance	Emissions for final use	Consumption basis CO_2	Production basis CO_2
by country	(a)	(b)	(c)	(d)	(b)-(a)=(c)-(d)	(e)	(a)+(e)	(b)+(e)
Australia	233	248	120	57	15	17	250	264
Austria	79	49	70	59	-30	10	89	59
Belgium	118	96	118	144	-22	18	136	113
Canada	325	443	293	118	118	62	387	505
Czech Republic	82	104	60	23	22	11	93	115
Denmark	64	50	42	38	-14	7	71	57
Finland	51	50	44	29	-1	5	56	55
France	454	287	326	275	-168	65	519	351
Germany	845	706	519	424	-139	143	988	849
Greece	82	67	35	27	-15	4	86	71
Hungary	46	46	29	19	-1	10	57	56
Ireland	36	31	26	27	-5	5	41	37
Italy	422	314	256	204	-108	84	506	399
Japan	1,312	914	622	536	-398	129	1,441	1,043
Korea	363	314	203	148	-49	34	396	347
Luxembourg	8	15	17	12	6	1	10	16
Netherlands	154	140	149	156	-15	25	179	165
New Zealand	27	23	22	15	-4	3	30	26
Norway	39	31	43	31	-8	2	40	32
Poland	251	289	88	31	38	46	297	335
Portugal	67	64	64	44	-3	7	73	70
Slovak Republic	30	37	25	11	7	4	34	41
Spain	233	190	137	100	-43	37	269	227
Sweden	72	48	63	56	-24	8	79	56
Switzerland	75	45	67	93	-30	3	78	48
Turkey	196	660	526	56	464	33	228	692
United Kingdom	502	428	324	236	-73	119	620	547
United States	4,528	4,014	1,341	961	-514	846	5,374	4,860
Argentina	113	98	54	36	-15	27	140	125
Brazil	231	206	86	58	-24	21	252	227
China	1,983	2,427	683	127	444	308	2,292	2,736
Chinese Taipei	151	148	117	77	-3	9	160	157
India	537	631	168	39	93	79	616	709
Indonesia	163	168	79	40	6	28	191	197
Israel	49	42	28	24	-6	3	51	45
Malaysia	69	77	86	50	8	7	76	84
Philippines	62	53	29	24	-10	6	68	58
Russia	940	1,367	538	61	427	152	1,092	1,519
Singapore	42	35	45	53	-7	1	43	36
South Africa	188	221	69	19	33	18	206	239
ROW	1,146	1,247	705	491	101	129	1,274	1,375
by region								
EU4	2,223	1,736	1,424	1,138	-487	411	2,633	2,146
Other OECD Europe	1,684	2,012	1,607	957	328	236	1,920	2,248
NAFTA	5,003	4,695	1,777	1,117	-308	918	5,921	5,613
OECD Asia/Oceania	1,935	1,498	967	755	-437	182	2,117	1,680
Non-OECD	5,522	6,479	2,539	1,059	957	776	6,298	7,255
World	16,366	16,419	8,314	5,027	53	2,523	18,890	18,942

Table A. 9. Simulation results: simulation case for increased international trade case (2000, Mt CO_2)

	Consumption by domestic industry	Emissions from domestic industry	Exported	Imported	Balance	Emissions for final use	Consumption basis CO_2	Production basis CO_2
by country	(a)	(b)	(c)	(d)	(b)-(a)=(c)-(d)	(e)	(a)+(e)	(b)+(e)
Australia	268	286	142	67	18	25	293	311
Austria	79	52	71	63	-27	11	90	63
Belgium	119	98	119	162	-21	19	139	117
Canada	404	496	352	181	92	77	480	573
Czech Republic	84	104	59	26	20	9	94	113
Denmark	55	46	41	38	-10	3	59	49
Finland	48	50	44	29	2	3	51	53
France	403	262	282	317	-140	115	518	377
Germany	809	662	566	490	-147	150	960	813
Greece	92	75	34	27	-16	5	97	80
Hungary	47	44	32	25	-3	10	57	54
Ireland	41	32	33	37	-9	7	48	39
Italy	441	308	285	238	-133	103	545	412
Japan	1,361	956	678	573	-406	146	1,507	1,101
Korea	383	366	261	184	-17	45	428	411
Luxembourg	10	11	13	13	2	2	11	13
Netherlands	157	143	151	176	-14	23	181	167
New Zealand	35	33	28	16	-3	1	37	34
Norway	38	31	43	31	-7	2	40	33
Poland	240	260	110	51	19	31	271	290
Portugal	80	79	76	54	-2	8	88	87
Slovak Republic	28	33	24	14	5	4	32	37
Spain	273	221	178	133	-52	48	321	269
Sweden	72	43	68	64	-30	8	81	51
Switzerland	78	45	70	101	-33	3	81	49
Turkey	213	730	578	58	517	28	241	758
United Kingdom	589	406	406	326	-184	123	712	529
United States	5,517	4,546	1,671	1,373	-971	907	6,424	5,453
Argentina	113	102	58	37	-11	27	140	129
Brazil	300	265	113	77	-35	23	323	288
China	2,161	2,455	778	262	294	221	2,383	2,677
Chinese Taipei	177	199	151	86	23	11	188	210
India	698	794	239	74	96	92	790	887
Indonesia	173	236	124	36	63	37	210	273
Israel	50	43	30	27	-8	3	53	45
Malaysia	62	109	90	46	46	14	76	123
Philippines	69	59	31	28	-10	8	77	67
Russia	730	1,323	685	54	592	148	878	1,471
Singapore	50	34	56	71	-17	3	53	36
South Africa	216	266	88	28	50	15	231	281
ROW	2,151	2,449	1,318	769	299	270	2,421	2,719
by region								
EU4	2,243	1,639	1,538	1,371	-604	492	2,734	2,130
Other OECD Europe	1,757	2,102	1,752	1,108	345	225	1,982	2,328
NAFTA	6,285	5,596	2,342	1,635	-689	1,006	7,292	6,603
OECD Asia/Oceania	2,048	1,641	1,109	839	-407	217	2,265	1,857
Non-OECD	6,585	7,775	3,439	1,511	1,190	850	7,435	8,625
World	18,918	18,753	10,180	6,465	-165	2,790	21,708	21,543

Table A. 10. Simulation results: simulation case for improved emission factors in BRICs (1995, Mt CO_2)

	Consumption by domestic industry	Emissions from domestic industry	Exported	Imported	Balance	Emissions for final use	Consumption basis CO_2	Production basis CO_2
by country	(a)	(b)	(c)	(d)	(b)-(a)=(c)-(d)	(e)	(a)+(e)	(b)+(e)
Australia	233	255	104	43	22	17	249	272
Austria	78	50	66	55	-28	10	88	60
Belgium	113	97	107	129	-16	18	130	114
Canada	326	399	227	104	73	62	388	461
Czech Republic	84	110	57	19	26	11	95	121
Denmark	63	51	39	35	-12	7	70	58
Finland	47	52	37	21	5	5	51	56
France	429	293	290	236	-136	65	494	358
Germany	816	732	462	355	-84	143	958	874
Greece	82	70	31	23	-12	4	85	73
Hungary	45	47	26	15	2	10	55	58
Ireland	36	32	26	25	-3	5	41	38
Italy	409	329	228	172	-80	84	493	413
Japan	1,153	969	409	309	-184	129	1,282	1,098
Korea	351	328	174	112	-23	34	384	362
Luxembourg	8	7	9	10	-1	1	10	8
Netherlands	152	147	145	146	-5	25	177	172
New Zealand	26	22	17	12	-4	3	29	25
Norway	37	31	40	27	-6	2	39	33
Poland	256	287	66	22	31	46	302	333
Portugal	63	42	37	32	-21	7	70	49
Slovak Republic	29	37	22	9	8	4	34	41
Spain	230	199	123	85	-31	37	266	236
Sweden	66	47	57	49	-19	8	73	54
Switzerland	67	41	56	83	-26	3	70	44
Turkey	137	139	36	17	2	33	169	172
United Kingdom	485	415	271	200	-70	119	604	533
United States	4,256	3,976	1,005	664	-280	846	5,102	4,822
Argentina	110	99	44	29	-11	27	137	126
Brazil	276	265	63	38	-10	21	296	286
China	365	384	156	74	19	308	674	693
Chinese Taipei	150	158	113	67	8	9	159	167
India	153	142	42	27	-11	79	232	221
Indonesia	163	174	71	33	10	28	191	202
Israel	49	44	27	22	-6	3	52	46
Malaysia	67	69	74	46	2	7	74	76
Philippines	62	54	26	20	-8	6	67	59
Russia	228	254	113	47	26	152	380	406
Singapore	41	37	45	50	-5	1	43	38
South Africa	196	234	67	15	38	18	213	251
ROW	1,124	1,315	640	335	191	129	1,253	1,443
by region								
EU4	2,138	1,768	1,251	962	-370	411	2,549	2,179
Other OECD Europe	1,591	1,486	983	802	-105	236	1,827	1,722
NAFTA	4,734	4,628	1,374	796	-106	918	5,653	5,546
OECD Asia/Oceania	1,763	1,574	704	476	-188	182	1,945	1,757
Non-OECD	2,831	2,973	1,335	772	142	776	3,607	3,750
World	13,057	12,430	5,647	3,808	-627	2,523	15,580	14,953

Table A. 11. Simulation results: simulation case for improved emission factors in BRICs (2000, Mt CO_2)

	Consumption by domestic industry	Emissions from domestic industry	Exported	Imported	Balance	Emissions for final use	Consumption basis CO_2	Production basis CO_2
by country	(a)	(b)	(c)	(d)	(b)-(a)=(c)-(d)	(e)	(a)+(e)	(b)+(e)
Australia	267	294	123	52	26	25	292	319
Austria	78	53	67	58	-24	11	89	64
Belgium	119	99	114	155	-20	19	138	118
Canada	400	454	283	159	54	77	477	531
Czech Republic	86	109	57	22	23	9	95	118
Denmark	55	47	39	35	-8	3	58	50
Finland	46	52	40	24	6	3	49	55
France	380	265	251	284	-115	115	495	380
Germany	792	683	526	438	-109	150	942	834
Greece	93	78	32	24	-14	5	97	83
Hungary	46	45	30	22	-1	10	56	56
Ireland	41	34	33	35	-7	7	48	41
Italy	432	323	263	210	-108	103	535	427
Japan	1,208	1,013	468	346	-195	146	1,354	1,159
Korea	373	383	233	142	9	45	418	428
Luxembourg	9	6	8	12	-3	2	11	8
Netherlands	153	150	146	165	-3	23	177	173
New Zealand	34	30	21	13	-4	1	35	32
Norway	36	32	40	28	-4	2	38	34
Poland	243	262	94	43	19	31	274	293
Portugal	78	52	45	39	-26	8	86	60
Slovak Republic	28	34	22	11	6	4	32	38
Spain	272	233	167	119	-39	48	319	280
Sweden	68	41	62	58	-26	8	76	50
Switzerland	69	41	58	90	-28	3	72	44
Turkey	146	154	43	19	8	28	174	182
United Kingdom	563	403	348	277	-160	123	685	526
United States	5,899	5,350	1,382	1,001	-548	907	6,806	6,257
Argentina	111	99	45	30	-12	27	138	126
Brazil	291	274	78	49	-17	23	314	298
China	595	619	262	133	24	221	816	840
Chinese Taipei	179	212	149	76	33	11	190	223
India	253	223	82	57	-29	92	345	316
Indonesia	176	242	119	30	66	37	213	279
Israel	51	44	28	24	-7	3	53	46
Malaysia	62	93	71	41	31	14	77	108
Philippines	70	61	28	26	-9	8	78	69
Russia	143	176	108	43	33	148	291	324
Singapore	50	36	55	67	-14	3	53	39
South Africa	226	283	89	24	57	15	242	299
ROW	2,141	2,597	1,237	542	456	270	2,411	2,867
by region								
EU4	2,166	1,674	1,387	1,209	-492	492	2,658	2,166
Other OECD Europe	1,667	1,524	1,102	960	-142	225	1,892	1,750
NAFTA	6,670	6,400	1,987	1,223	-271	1,006	7,677	7,406
OECD Asia/Oceania	1,883	1,720	845	553	-163	217	2,100	1,937
Non-OECD	3,974	4,362	2,027	1,080	388	850	4,824	5,212
World	16,360	15,680	7,349	5,023	-680	2,790	19,151	18,471