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Data for a steel industry model

by

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Abstract

SNF has recently developed a new model of the steel market and some of the major factor markets connected to the steel industry. The aim of the model has been to study how regulations of the emissions of carbon dioxide (CO2) in the steel industry might affect the structure of the industry. It has also been an objective to investigate how structural changes in the steel industry might influence on the industry's demand for transport services.

This paper outlines the details about the data that enter the model. It describes the procedures that has been used and highlights some of the main data on production, factor use, factor prices, industry costs, trade, trade costs and CO2-emissions in the steel industry.

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1. Introduction

Background

SNF has recently developed a new model of the steel market and some of the major factor markets connected to the steel industry. The aim of the model has been to study how regulations of the emissions of carbon dioxide (CO2) from the steel industry might affect the structure of the industry. It has also been an objective to investigate how structural changes in the steel industry might influence on the industry's demand for transport services. This paper outlines the details about the data that enter the model. For a full description of the model and the results from our analysis, see separate reports by Mathiesen (2000), Mæstad (2000), and Mathiesen and Mæstad (2001).

The Kyoto Protocol, which puts binding limits of the emissions of greenhouse gases in the industrialised countries, forces the industrialised countries to implement policies that reduce the emissions of greenhouse gases, including carbon dioxide. Several policy options are available, such as emission taxes, a system of tradable emission quotas and direct regulation. Market based solutions, such as taxes or tradable emission quotas, are preferable from an efficiency point of view.

The steel industry is a heavy source of emissions of carbon dioxide. Huge amounts of coal are combusted in the blast furnace process. In addition, the electric arc furnace is an indirect source of carbon emissions through consumption of large amounts of electricity, which in most countries is produced by fossil fuels. Finally, there are substantial emissions related to the production of directly reduced iron, which is based on iron ore and huge amounts of natural gas.

If the steel industry in the industrialised countries will have to pay for their emissions of carbon dioxide, either through emission taxes or through a system of tradable emission quotas, the cost of steel production might increase quite substantially in these regions. This might lead to a restructuring of the steel industry along several dimensions. First, higher production costs and higher steel prices might reduce steel demand. Second, higher costs of polluting factors might lead to substitution towards a less polluting input mix. Third, reduced competitiveness of steel producers in the industrialised countries might increase the market shares of other regions, for example some Asian countries. Finally, since steel can be produced through several different processes with quite different input requirements, we may foresee a restructuring of production between different processes. The model is designed in order to capture these kinds of structural shifts and to derive the implications of these changes for some of the important international trades related to the steel industry; the transport of iron ore, coal and steel products.

So much for the model. We now turn to the topic of this paper; the data. We shall provide an overview of the data sources and the methods used in collecting and computing the data. In addition, we will present some of the key data that enter the model.

Data sources

The data are collected from a number of different sources. These are:

- The CRU database

This data source contains firm level data from 73 steel production plants around the world, representing around 10% of total steel production. The database contains details about production volumes and capacities, the use of inputs at different stages of production, input prices and costs.

- Steel Statistical Yearbook 1996, International Iron and Steel Institute
- GTAP version 4

GTAP (Global Trade Analysis Project) is a global database containing data on production, consumption, trade, trade policy and factor usage in a number of industry sectors and countries/regions.

- IEA Energy balance (1998)
- IEA Coal Information (1997)
- R. S. Platou Economic Research a.s
- Joachim Grieg & Co
- Selected publications
- Expert comments

The regional split

In the model, the world is divided into ten regions:

- EU13 (EU except Finland and Sweden)
- Rest of Western Europe
- Eastern Europe and Former Soviet Union (including Turkey)
- North America (USA, Canada, Mexico)
- South America (Rest of America)
- Japan
- China
- Rest of Asia
- Australia (Australia and New Zealand)
- Rest of world (Africa and Middle East)

The borders between regions are drawn in order to capture several important aspects; (1) regional differences in production technology and factor use, (2) seaborne trade flows between regions both in input markets and in the market for steel products, and (3) we want to have the opportunity to differentiate the climate policies between regions, in particular between countries that are members of the Kyoto Protocol and countries that are not.

2. Production data

The data source for the production data is Steel Statistical Yearbook 1996 (IISI, 1997a). In IISI (1997a), production of steel is split on three different processes:

- Oxygen Blown Converters
- Open Hearth Furnace
- Electric Arc Furnace

Oxygen Blown Converters are the dominating technology, accounting for 57.8 % of world steel production in 1995. The process is based on (1) making of pig iron from iron and coke, (2) making of steel from pig iron, with the inclusion of a certain amount of scrap. Open Hearth Furnace is based on the same input factors as Oxygen Blown Converters but is a more old-fashioned production process. Open Hearth Furnace is by now completely abolished in most countries, except in the Former Soviet Union, China, and a few other developing countries. In 1995, this process accounted for 8% of world steel production. In our model, Open Hearth Furnace is not treated as a separate process but is included together with Oxygen Blown Converters in the OB-process. The output of this production process is called Oxygen Blown Steel (OBS-steel).

In most areas, the Electric Arc Furnace is based on inputs of scrap and electricity. But in some regions directly reduced iron (DRI) is used as well. The production of DRI requires vast amounts of natural gas. Therefore, electric arc furnace based on DRI is fundamentally different from the more common electric arc process based on scrap. We treat these processes as two different ones. Electric Arc Steel (EAS) is thus produced either solely based on scrap (SB-process) or by a combination of scrap and DRI (DR-process).

There are thus two products (OBS and EAS) produced by three different processes (OB, SB and DR).

Production data for OBS-steel and EAS-steel are readily obtained form IISI (1997a). In order to split the EAS production data on the SB and DR processes, the following procedure was applied: Production based on DRI is negligible in Rest of Western Europe, Japan, China and Australia, and this process is therefore ignored in these regions. Production in the remaining regions is calculated by using data from IISI (1997a) on apparent consumption of DRI and by combing these data with an estimate of the amount of DRI used in the DR-process. The latter has been obtained from the CRU database, which reports the share of DRI in total metal used as input in the DR-process.

The production data divided by region and process are as follows:

Table 2.1. Crude steel production (mill. tonnes), 1995

	OB	SB	DR	**Total**
EU13	95.846	50.386	1.440	**147.672**
RoWEur	5.621	4.419	-	**10.040**
EastE&FSU	101.473	23.204	1.467	**126.144**
NorthAm	70.162	40.159	11.431	**121.752**
SouthAm	23.777	3.809	8.016	**35.602**
Japan	68.842	32.798	-	**101.640**
China	77.250	18.110	-	**95.360**
RoAsia	48.813	30.520	8.817	**88.150**
Australia	8.030	1.272	-	**9.302**
RoW	9.331	2.935	9.536	**21.802**
Total	509.145	207.612	40.707	**757.464**

3. Factor use in steel production

The data on factor use have been obtained as follows:

Iron ore:

Iron ore is used in the production of pig iron in the blast furnace process and in the production of directly reduced iron (DRI). For most regions, the input of iron ore in the production of pig iron is taken from the CRU database. The exception is China, where the consumption of iron ore per ton pig iron is calculated by assuming that the "quality adjusted" ore input in China equals the world average, and then adjusting for the fact that much of the iron ore input in China is of inferior quality.

In order to calculate the input of pig iron in the OB process, we used the data on apparent consumption of pig iron from IISI (1997a).[1] The data for China is stipulated based on the assumption that the production process in China is relatively inefficient compared to other regions.[2]

The use of iron ore in the DR process has been calculated by using the data from CRU on the consumption of ore per ton DRI and on the use of DRI in the DR process.

Coal:

For most regions, data on coal consumption per unit of pig iron are constructed on the basis of data from CRU. We have used data on coke rates, data on the amount of coal needed to produce coke and data on PCI consumption. However, for China and Eastern Europe and Former Soviet Union, we have used coal consumption data from IEA (1998b).

Scrap:

Scrap is used in all three processes. Scrap rates have been constructed on the basis of data from IISI (1997a), CRU and the IISI (1997b).

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[1] It is implicitly assumed that no pig iron is used in scrap based industry. This is not perfectly correct, implying that the pig iron rate in the OB-process is slightly overestimated.

[2] The low rate of pig iron consumption in China in the IISI (1997a) data may suggest that there is a correspondingly high rate of scrap consumption in the OB process, due to substantial production by the Open Hearth Process in this country. However, as the discussion below shows, the implied scrap rate in OB-production in China is very low. Hence, we have chosen to adjust the pig iron rate upwards.

Total scrap consumption in each region has been taken from IISI (1997a) (after subtracting the amount of scrap that goes to foundry production[3]).

Scrap consumption has been split on processes in the following way. First, we separate out scrap for the two electric arc processes (SB and DR). This is done by using data on scrap consumption in the EAF sector from IISI (1997b). However, the scrap rates in EAF production in Western Europe have been taken directly from the CRU database, since the quality of these data is particularly good. Finally, the rest of the scrap consumption is allocated to the OB process.

This procedure leads to negative consumption of scrap in the OB-process in China and Australia. For both these regions, the scrap rate has been arbitrarily stipulated to 50 kg per ton of steel.

We need to split the scrap consumption in electric arc processes on the SB and the DR processes. For this purpose we use data from CRU. We start with data on total metals input in EAF and assume that total metal use is the same for both the SB and the DR process. We then observe the share of DRI in total metal input in the DR process and calculate the scrap rate in the DR process as the difference between total metal input and the use of DRI. The rest of the EAF scrap consumption is allocated to the SB process.

Electricity:

Electricity consumption in the OB process is taken from CRU data. As for electric arc production, we need to split the data from CRU on the two processes (DR and SB). For this purpose we use a simple econometric procedure (ordinary OLS) in order to estimate electricity consumption as a function of the share of DRI in the production process. In the SB process, there is no use of DRI. In the DR process, the share of DRI varies between regions. This information is used to estimate the consumption of electricity in each region as a function of the amount of DRI in the production of steel.

[3] Scrap consumption in foundry production has been set to 500 kg per ton based on expert advice. In most regions foundry production is negligible, but not in China. With our assumptions about scrap rates in foundry,

Gas:

Gas consumption rates are obtained from CRU.

Comments on the data:

- In the OB process, there seems to be a clear substitution between scrap and pig iron; in regions where pig iron rates are high, scrap rates are typically low. Scrap rates are typically higher in regions with rich supplies of scrap. High scrap rates in Former Soviet Union can be partly explained by relatively more Open Hearth Furnace in this region.
- Due to the low Fe-content of Chinese iron ore, consumption rates of iron ore are relatively high in China.
- Coal consumption is relatively high in Eastern Europe & FSU and in China due to low energy efficiency.
- Electricity consumption is very small in the OB process compared to the other processes.
- The DR process is very energy intensive; first huge amounts of gas are used to reduce the iron, and secondly the consumption of electricity is typically higher than in pure scrap based processes.
- SB processes in Japan are relatively energy efficient, while the opposite is the case in Eastern Europe & FSU. These differences may be explained by the energy prices.
- In the DR process, the inputs of electricity and gas vary substantially between regions. The differences can be partly explained by differences in the DRI/scrap mix. Gas consumption is directly linked to the DRI content. Furthermore, electricity is positively linked to the DRI content as well.
- The low metal input in the SB process in certain regions (Japan, Rest of Asia and Rest of World) can at least partly be explained by the fact that in these regions, there is some consumption of pig iron in the SB process (not included in our data).

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there will be no scrap left for the OB process in China. This may indicate that the assumed scrap rate in foundry production may be too high.

Table 3.1. OB process: Factor use per ton crude steel and per ton pig iron

	Factor use per ton crude steel			Factor use per ton pig iron	
	Pig iron (t)	Scrap (t)	Electricity (kWh)	Ore (t)	Coal (t)
EU13	0.963	0.252	33	1.455	0.678
RoWEur	0.973	0.133	25	1.426	0.655
EEoFSU	0.807	0.388	69	1.655	1.141
NorthAm	0.927	0.322	61	1.537	0.643
SouthAm	0.976	0.135	89	1.428	0.849
Japan	1.109	0.157	40	1.510	0.726
China	1.200	0.050	69	2.386	1.244
RoAsia	1.199	0.071	59	1.523	0.761
Austral	1.015	0.157	73	1.457	0.785
RoW	1.038	0.050	64	1.457	0.859

Table 3.2. SB process: Factor use per ton crude steel

	Scrap (t)	Electricity (kWh)
EU13	1.026	523
RoWEur	1.075	536
EEoFSU	1.031	569
NorthAm	1.085	530
SouthAm	1.143	534
Japan	0.994	411
China	1.160	569
RoAsia	0.912	541
Austral	1.179	530
RoW	0.749	462

Table 3.3. DR process: Factor use per ton crude steel

	Scrap (t)	Ore (t)	Electricity (kWh)	Gas (t)
EU13	0.579	0.852	707	7.199
EEoFSU	0.466	1.042	941	9.333
NorthAm	0.563	0.815	716	6.494
SouthAm	0.243	1.419	1039	12.766
RoAsia	0.462	1.013	756	8.601
RoW	0.231	1.333	845	10.868

4. Factor prices

Factor price data are based on the CRU database.

The prices of gas and electricity are taken directly from CRU. Note that electricity prices in many regions are higher in oxygen blown production than in electric arc production. Probably, the electricity consumption of the EAF industry is to a greater extent covered by long term contracts, maybe also with an element of state subsidies.

The price of iron ore is based on the lump ore price at the steel mill. Ore price data from China are missing. Assuming that the quality adjusted ore price in China is equal to the world average, we get an ore price estimate of 14 USD/ton in China. Based on expert advice, we have adjusted this number to 18 USD/ton.

Scrap prices in the CRU data vary between processes. Our estimate of the scrap prices is a weighted average. The scrap price in China is stipulated based on expert advice.

The coal price is the weighted average of the delivering price of coking coal and the price of coal used in PCI (pulverised coal injection).

We notice the extremely low gas prices. This reflects partly that the gas used in DRI processes has a low alternative value, but we also suspect that there may be some confusion about the units of account. This does not influence our analysis, however, since gas prices are assumed to be exogenous.

Table 4.1. Factor prices. USD per ton (per kWh in the case of electricity)

	Scrap	Ore	Coal	Electricity (OB)	Electricity (SB and DR)	Gas
EU13	136	33	64	0.081	0.059	4.3
RoWEur	136	30	64	0.064	0.024	8.0
EEoFSU	115	27	52	0.040	0.055	2.3
NorthAm	145	20	53	0.037	0.033	2.4
SouthAm	132	20	63	0.030	0.028	1.8
Japan	153	29	59	0.186	0.113	11.1
China	125	12	49	0.040	0.055	6.7
RoAsia	144	23	65	0.065	0.059	6.7
Austral	119	28	49	0.047	0.047	6.7
RoW	141	21	55	0.028	0.029	0.6

5. Industry costs

An industry cost curve is constructed for each process in each region. Unfortunately, the firm level data in the CRU database do not cover enough firms to make it possible to construct the industry cost curves based on firm data. Instead we use the following procedure:

We assume that each of the 3x10 industry cost curves takes the following functional form:

$$C=a+(q/b)^{e}$$

where q is total production and a, b and e are parameters. In order to calibrate these parameters we use information on

- the production costs of the marginal firm (i.e., the firm with the highest costs)
- the production costs of an average firm
- the elasticity of supply

Cost data are based on CRU data but have been somewhat adjusted on the basis of expert advice. The price elasticities of supply are short run elasticities (1-2 years), and are also based on expert advice:

- Price elasticity of supply, OB process: *0.7*
- Price elasticity of supply, SB and DR processes: *1.2*

Table 5.1. Variable costs of production (USD/ton crude steel)

	Oxygen blown steel (OB)		Electric arc furnace (SB and DR)	
	Average	Marginal firm	Average	Marginal firm
EU13	215	238	245	260
RoWEur	215	215	230	250
EeoFSU	175	200	220	250
NorthAm	220	230	235	260
SouthAm	180	200	215	240
Japan	220	240	250	280
China	185	200	210	230
RoAsia	175	200	245	260
Austral	190	201	235	235
RoW	170	210	200	220

The exact parameter values of the cost function have been calibrated in Maple. In a few cases, the calibrated value of the parameter e is so large that it would be difficult to handle in numerical models. In these cases, the value of e has been fixed at a lower level, but other parameter values have also been altered such that the elasticity properties of the industry cost curves have been retained.

6. Trade data

The model includes trade data for finished and semi-finished steel in addition to the trade data for iron ore and coal. The volume of seaborne scrap trade is relatively small and this trade is therefore ignored.

Trade in finished and semi-finished steel:

The steel trade matrix is obtained from *R. S. Platou Economic Research*. The data have been adjusted to crude steel equivalents, and production for own consumption has been added in order to produce a full production, consumption and trade matrix. Production for own consumption is total production (taken from IISI (1997a)) minus total exports. Some minor adjustments were done in Rest of Western Europe in order to eliminate negative entries.

Table 6.1. Production, consumption and trade in steel, 1995 (mill. ton crude steel equivalents)

	EU13	RoWEur	EastE& FSU	NorthAm	SouthAm	Japan	China	RoAsia	Australia	RoW	**Produc-tion**
EU13	118.98	6.53	1.91	6.85	0.99	0.10	0.70	4.40	0.13	7.09	**147.672**
RoWEur	3.40	3.18	0.25	0.29	0.04	0.10	0.29	1.52	0.00	0.97	**10.040**
EastE&FSU	16.22	3.14	65.72	3.77	0.49	0.65	8.50	22.88	0.11	4.65	**126.144**
NorthAm	0.47	0.00	0.00	116.88	2.33	0.00	0.21	1.39	0.00	0.48	**121.752**
SouthAm	1.21	0.50	0.00	3.43	23.15	0.64	0.62	5.61	0.09	0.35	**35.602**
Japan	0.33	0.23	0.87	3.16	0.29	77.62	3.14	14.19	0.32	1.49	**101.640**
China	0.00	0.00	0.00	0.44	0.00	1.25	82.26	10.55	0.00	0.85	**95.360**
RoAsia	0.20	0.00	0.00	1.76	0.09	5.59	4.43	75.19	0.29	0.60	**88.150**
Australia	0.00	0.00	0.00	0.46	0.00	0.26	0.00	2.74	5.84	0.00	**9.302**
RoW	2.02	0.00	0.00	1.32	0.00	0.00	0.00	3.72	0.25	14.49	**21.802**
Consump-tion	**142.84**	**13.58**	**68.75**	**138.37**	**27.39**	**86.22**	**100.14**	**142.18**	**7.03**	**30.97**	**757.464**

In the model, we need trade data for both oxygen blown steel and electric arc steel. We assume that in each region, the share of the two steel products in exports equals their share of production in the region.

Iron ore trade:

Data on production, consumption and gross trade are collected from IISI (1997a). In order to construct the bilateral trade pattern, we used data from IISI (1995) and Fearnleys (1996) to construct import shares. These shares were then combined with import data from 1995. The resulting trade matrix contains certain inconsistencies with regard to export data. These inconsistencies were corrected first by reconciling the data with the absolute numbers in

Fearnleys (1996). Only small deviations then remained, except in EU13, where internal trade within the region was adjusted down in order to correct for a too high level of total trade. Finally, the remaining (small) residuals on the export side were allocated to the ROW region. This region thus plays the role as a residual in this context.

We also add production for own consumption. This is done in a way that ensures that the total consumption of iron ore in each region is equal to the numbers reported in IISI (1997a).

Table 6.2. Production, consumption and trade in iron ore for steelmaking, 1995 (1000 ton)

	EU13	RoWEur	EastE& FSU	NorthAm	SouthAm	Japan	China	RoAsia	Australia	RoW	**Produc-tion**
EU13	2586	227	1314	147	0	0	60	78	0	0	**4413**
RoWEur	12124	5725	1836	61	0	0	474	619	0	3074	**23912**
EastE&FSU	0	0	138435	0	0	0	0	0	0	2830	**141265**
NorthAm	16656	130	781	91679	0	1058	0	1408	0	1902	**113613**
SouthAm	63648	1298	7475	10698	62026	31233	10110	22027	0	3858	**212374**
Japan	0	0	0	0	0	0	0	0	0	0	**0**
China	0	0	0	0	0	0	215558	0	0	0	**215558**
RoAsia	3135	162	837	0	0	22920	3173	37360	0	3361	**70948**
Australia	20803	292	1648	703	0	59761	24752	22027	14295	0	**144281**
RoW	20252	844	4771	957	0	4732	2585	3376	0	15126	**52643**
Consump-tion	**139205**	**8678**	**157097**	**104245**	**62026**	**119704**	**256712**	**86894**	**14295**	**30150**	**979006**

Coal trade:

The information on coal trade is based in IEA (1998b) and is constructed based on country data of the exports of coking coal. The coke trade is small and is therefore ignored.

Data on the consumption of coal were constructed based on the information in CRU and IEA (1998b) about coal consumption per ton crude steel, in combination with IISI (1997a) data on total production of steel.

By combining consumption figures for coal with the trade data from IEA (1998b), production figures are obtained as residuals. In two cases (Rest of Western Europe and Japan), negative production figures of coking coal were obtained. Production was then set to zero and imports were adjusted down accordingly (proportional reduction from all import sources).

Table 6.3. Production, consumption and trade of coking coal (1995) (1000 tonnes)

	EU13	RoWEur	EastE&FSU	NorthAm	SouthAm	Japan	China	RoAsia	Australia	RoW	**Production**
EU13	18824	1	0	0	0	0	0	0	1	0	**18825**
RoWEur	0	0	0	0	0	0	0	0	0	0	**0**
EastE&FSU	6130	1445	86372	154	1812	2956	0	585	1	132	**99586**
NorthAm	23002	1653	4642	41199	7603	19388	0	8875	0	1592	**107954**
SouthAm	1079	0	0	420	5413	133	0	0	0	0	**7045**
Japan	0	0	0	0	0	0	0	0	0	0	**0**
China	129	0	125	0	57	1856	115334	2044	0	0	**119545**
RoAsia	214	0	0	0	0	1816	0	8406	0	0	**10435**
Australia	12158	486	2318	7	4369	26435	0	23886	6395	1082	**77136**
RoW	1056	0	0	0	449	2846	0	750	0	5515	**10616**
Consump-tion	**62592**	**3585**	**93457**	**41780**	**19703**	**55429**	**115334**	**44546**	**6397**	**8321**	**451143**

7. Trade costs

Trade costs consist of transport costs, import barriers (tariffs) and export taxes/subsidies.

The steel trade:

Data on import tariffs and export subsidies in the steel industry are obtained from the GTAP database, version 4. The iron and steel sector is accounted for separately in this database. In addition to finished and semi-finished steel products, the iron and steel sector in GTAP includes some of the inputs in steel production (pig iron, scrap and ferro-alloys). Since trade barriers generally are lower for inputs than for finished goods, our data may therefore underestimate the real trade barriers in the steel trade. On the other hand, the trade volumes of these inputs are small compared to the steel trade (about 30% of the volume of steel trade).[4]

Export taxes/subsidies are very small in most regions. One exception is China, where steel export is subsidised by 4% on average.

Table 7.1. Export taxes (% of export values)

	EU13	RoWEur	EE&FSU	NorthAm	SouthAm	Japan	China	RoAsia	Austral	RoW	**Total**
EU13	0.0	0.0	0.5	0.6	0.7	0.5	0.5	0.5	0.4	0.7	**0.2**
RoWEur	0.0	0.0	-0.5	-0.8	-1.1	-0.5	0.0	-0.5	-1.0	-0.4	**-0.1**
EEoFSU	0.1	0.2	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	**0.1**
NorthAm	1.0	0.3	1.4	0.0	0.9	1.1	1.0	1.3	1.0	1.1	**0.5**
SouthAm	0.6	0.8	0.0	0.7	0.6	0.5	0.5	0.5	0.0	0.3	**0.6**
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
China	-4.2	0.0	-3.8	-4.0	-4.9	-4.0	-3.3	-4.1	-3.4	-4.3	**-4.0**
RoAsia	0.4	0.0	0.0	0.3	0.0	0.1	0.2	1.2	1.0	1.2	**0.6**
Austral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
RoW	0.1	0.0	0.0	-0.5	-0.6	-0.8	-0.4	-0.4	0.0	0.3	**-0.2**
Total	**0.0**	**0.0**	**0.3**	**0.1**	**0.5**	**-0.7**	**0.0**	**-0.1**	**0.2**	**0.4**	**0.0**

Transport costs are calculated based on a collection of freight rates on specific trades obtained from *R. S. Platou Economic Research*. A regression is run against distance data obtained from the same source. In this way, we are able to construct freight rates for all bilateral trade routes.

Transport costs vary between a few percent of the *fob*-value on short routes and up to around 15 % on longer distances.

[4] Source: IISI (1997a).

Table 7.2. Transport costs (% of export value plus export taxes)

	EU13	RoWEur	EE&FSU	NorthAm	SouthAm	Japan	China	RoAsia	Austral	RoW
EU13	1.9	2.2	2.0	5.8	6.9	14.1	13.0	13.3	13.7	5.8
RoWEur	2.0	2.0	2.6	6.3	7.5	15.4	14.1	14.4	14.8	5.1
EEoFSU	3.3	3.5	0.0	8.0	8.9	14.4	14.0	13.4	14.1	5.6
NorthAm	5.9	5.9	6.8	0.0	5.9	12.0	12.6	12.3	12.1	7.0
SouthAm	7.8	7.8	8.5	6.6	0.0	15.5	14.8	14.8	11.7	8.3
Japan	13.7	14.2	11.0	11.5	13.1	0.0	2.3	2.3	6.1	8.4
China	15.9	15.2	16.5	15.2	16.0	3.0	0.0	3.0	7.0	10.3
RoAsia	15.6	16.2	15.6	13.4	14.4	2.7	2.7	2.7	6.3	8.7
Austral	13.7	13.7	14.4	13.7	11.8	6.7	6.7	6.7	0.0	10.5
RoW	6.7	5.4	6.1	8.7	12.0	10.0	9.1	9.3	10.6	9.3

Import tariffs vary between 0 % and 22 %. The average tariff level is 4.7 %. The highest tariffs are observed in developing countries and in transition economies.

Table 7.3. Import taxes (% of cif value)

	EU13	RoWEur	EE&FSU	NorthAm	SouthAm	Japan	China	RoAsia	Austral	RoW	**Total**
EU13	0.0	0.0	4.3	4.9	10.1	2.2	8.3	21.6	7.3	13.4	**2.7**
RoWEur	0.0	0.0	2.2	5.2	8.7	2.0	9.9	10.9	7.3	10.8	**1.5**
EEoFSU	3.3	2.4	5.2	3.7	8.5	2.3	7.6	9.3	0.0	13.8	**6.3**
NorthAm	3.5	0.8	2.7	0.0	10.3	0.9	7.5	8.5	6.5	14.0	**3.2**
SouthAm	3.9	3.7	5.9	3.1	8.6	1.5	10.8	9.3	6.3	12.0	**6.3**
Japan	4.7	4.3	17.3	4.6	9.9	0.0	9.9	11.4	6.3	14.2	**10.1**
China	4.0	0.0	11.5	4.4	9.5	1.6	2.6	6.5	6.7	14.6	**5.2**
RoAsia	3.9	3.2	8.2	4.6	10.5	1.7	9.0	12.0	6.7	16.5	**8.0**
Austral	4.8	0.0	0.0	4.3	9.5	1.2	3.0	9.3	0.0	14.7	**7.0**
RoW	3.9	2.9	4.3	2.0	7.8	1.6	5.8	15.2	0.0	10.8	**7.7**
Total	**0.6**	**0.4**	**4.8**	**2.8**	**9.4**	**1.6**	**8.7**	**11.7**	**5.7**	**13.4**	**4.7**

The trade in coal and iron ore:

Data on freight rates on the most important trades have been obtained from shipbroker *Joachim Grieg & Co*. The missing data have been constructed through regression analysis, by coupling data on distance with known freight rates.

8. Transport distances

Data on transport distances for iron ore and coal on the most important routes are obtained from Fearnleys (1996). We have made our own estimates for some routes with low trade volumes on the basis of rough information about the relative distances on these routes compared to other routes with known distances.

Distance data for steel transport have been obtained from *R. S. Platou Economic Research*.

9. CO_2-emissions

We calculate the CO2-emissions related to steel production in each region. We take into account CO2-emission related to the use of coal, fuel oil and gas, and we calculate the implicit CO2-emission related to the use of electric power (to the extent that electricity is produced by fossil fuels).

Data on CO2-emission in power production are obtained by combining data on the input of fossil fuels in power production (IEA, 1998a) with estimates of carbon emissions from the combustion of coal, oil and gas from the IPCC guidelines.

Data on the emission of CO2 per ton of coal are obtained by combining the IPCC estimate of the CO2 emissions per toe of coal with IEA data on the calorific content of coal in various regions (IEA, 1998a).

When it comes to gas and oil, we use the IPCC guidelines for CO2 emissions, implying emissions factors of 2.34 and 3.04 tonnes of CO2 per ton gas and oil, respectively.

The consumption of fuel oil in Oxygen Blown Converters is not modelled explicitly. We incorporate the CO2 emissions related to this consumption as an exogenous factor. The same is true for some small amounts of coal that is used in EAF processes and some natural gas used in Oxygen Blown Converters.

CO2 emissions from rolling and finishing processes have been included as well. We follow the same procedure as in IEA (2000), i.e., we assume that energy consumption in rolling and finishing is the same in all processes in all regions. Furthermore, we assume that the energy consumption consists of 20% electricity and that the rest is a mix of fossil fuels with an emission factor of 0.08 tons of CO2 per gigajoule. Differences in emission rates for electricity are due to different production processes for electricity in different regions.

Table 9.1. CO2 emissions in the OB process (ton CO2 per ton crude steel)

	Crude steel production				Rolling and finishing		**Total**
	Coal	Gas	Fuel oil	Electricity	Fossil fuels	Electricity	
EU13	1.80	0.00	0.05	0.01	0.17	0.06	**2.10**
RoWEur	1.67	0.00	0.17	0.00	0.17	0.01	**2.03**
EeoFSU	1.96	0.04	0.06	0.05	0.17	0.11	**2.40**
NorthAm	1.61	0.09	0.02	0.03	0.17	0.08	**2.00**
SouthAm	2.34	0.00	0.00	0.01	0.17	0.02	**2.54**
Japan	2.27	0.00	0.00	0.01	0.17	0.05	**2.50**
China	3.48	0.00	0.00	0.07	0.17	0.14	**3.86**
RoAsia	2.10	0.00	0.00	0.04	0.17	0.10	**2.41**
Austral	2.11	0.12	0.00	0.05	0.17	0.10	**2.55**
RoW	2.30	0.04	0.14	0.04	0.17	0.10	**2.78**

Table 9.2. CO2 emissions in the SB process (ton CO2 per ton crude steel)

	Crude steel production		Rolling and finishing		**Total**
	Coal	Electricity	Fossil fuels	Electricity	
EU13	0.04	0.22	0.17	0.06	**0.50**
RoWEur	0.02	0.04	0.17	0.01	**0.23**
EeoFSU	0.04	0.43	0.17	0.11	**0.76**
NorthAm	0.04	0.28	0.17	0.08	**0.56**
SouthAm	0.04	0.07	0.17	0.02	**0.30**
Japan	0.04	0.14	0.17	0.05	**0.41**
China	0.05	0.54	0.17	0.14	**0.91**
RoAsia	0.05	0.35	0.17	0.10	**0.67**
Austral	0.05	0.35	0.17	0.10	**0.67**
RoW	0.07	0.30	0.17	0.10	**0.64**

Table 9.3. CO2 emissions in the DR process (ton CO2 per ton crude steel)

	Crude steel production			Rolling and finishing		**Total**
	Coal	Gas	Electricity	Fossil fuels	Electricity	
EU13	0.04	0.40	0.30	0.17	0.06	**0.98**
EeoFSU	0.04	0.52	0.72	0.17	0.11	**1.57**
NorthAm	0.04	0.36	0.37	0.17	0.08	**1.02**
SouthAm	0.04	0.71	0.14	0.17	0.02	**1.09**
RoAsia	0.05	0.48	0.49	0.17	0.10	**1.29**
RoW	0.07	0.61	0.55	0.17	0.10	**1.49**

10. Demand elasticities

At the top level, the elasticity of steel demand is set to –0.3. This is in line with other studies of the steel market (e.g., Winters, 1995).

The elasticity of substitution between steel types is set to 0.5. The number is calibrated based on interviews with industry experts.

The elasticity of substitution between steel from different regions is set to 5. There is no evidence on the value of this parameter, apart from a general understanding that the elasticity of substitution between regions is high.

11. Checking the data

Our data set is based to a great extent on firm level data. If our sample is biased, we run the risk of misrepresenting aggregate data. We have not performed any in depth investigations of how our data match with aggregate data from other data sources, but a quick analysis leads to the following results:

Coal:
Our coal consumption estimate is 1 % lower than the IEA figures for aggregate coal consumption in steel production (derived from IEA (1998a)).

Iron ore:
Our consumption estimate for iron ore is 7 % lower than the figures in IISI (1997a) for aggregate ore consumption after deducting iron ore used for foundry. However, due to uncertainty about the amount of iron ore in foundry, this figure may differ somewhat from the true deviation.

Pig iron:
Total use of pig iron in our data set is 5 % higher than world pig iron production according to IISI (1997a). Part of the difference may be due to stock changes.

CO2 emissions:
Our estimate of aggregate CO2 emission from the steel industry is almost identical to the estimate presented by the IEA Greenhouse Gas Research Group (IEA, 2000).

Steel production and scrap consumption are based on authoritative aggregate data, and no check is needed there. Other input data are difficult to check against alternative sources.

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