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An Input-Output Approach for the Turkish Economy

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Abstract

Recently, global warming (greenhouse effect) and its effects have become one of the hottest topics in the world agenda. There have been several international attempts to reduce the negative effects of global warming. Kyoto Protocol can be cited as the most important agreement which tries to limit the countries' emissions within a time horizon. For this reason it becomes important to calculate the greenhouse gas emissions of countries. The aim of this study is to estimate the amount of CO2 -the most important greenhouse gas- emissions, for the Turkish economy. An extended input-output model is estimated by using 1996 data in order to identify the sources of CO2 emissions and to discuss the share of sectors in total emission. Besides 'CO2 responsibility', which takes into account the CO2 content of imports, is estimated for the Turkish economy. The sectoral CO2 emissions and CO2 responsibilities are compared and these two notions are linked to foreign trade volume. One of the main conclusions is that the manufacturing industry has the first place in both of the rankings for CO2 emissions and CO2 responsibilities; while agriculture and husbandry has the last place.

Keywords: CO2 responsibility, Turkey, input-output analysis

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1. Introduction

The long-term increase in earth's temperature is known as the global warming or the greenhouse effect. The accelerating use of fossil fuels since the Industrial Revolution, and the rapid destruction of forests cause a significant increase in the anthropogenic greenhouse gases. Among these anthropogenic greenhouse gases, carbon dioxide (CO2) is held responsible for approximately 60 % of the greenhouse gas effect.

As a result of this extensive increase in the emission of greenhouse gases some international steps have been taken. As an important first step UN Conference on Environment and Development is held in Rio de Janeiro in 1992, and has formed the UNFCCC to protect the earth's climate system against the effects of greenhouse gases and global warming. Kyoto Protocol, signed in 1997 and enacted on February 16, 2005, after being ratified by Russian Parliament, is the first agreement which tries to bring constraints to emissions and requires a time table for realization of the reductions. According to this, developed countries agree to reduce their total greenhouse gas emissions to 5.2% lower than 1990 level during 2008-2012 period. The Protocol does not bring any limitations for developing countries (Gilpin 2000; Meyerson 1998; Ziesing, 2001).

In terms of CO2 emissions in the world Turkey's place is gradually ascending: while she is in the 31st place in 1960, she becomes 25th in 1996 and 23rd in 2000, as can be observed from Table 1. In the same period, the United States which has the highest CO2 emissions decreases her share from 32% in 1960 to 24.4 % in 2000. In the meantime the share of Turkey increases from 0.2% in 1960 to 1% in 2000. Due to the projected increase in energy demand in the future this share is expected to increase further.

Insert Table 1

Turkey joined UNFCCC on May 24, 2004, but she is not a party to Kyoto Protocol yet. Considering the increasing emission rates and the possibility of ratifying the

Kyoto Protocol in the process of becoming a member of EU, it may be vital to revise the existing energy use plans and to bring on the agenda the policies that will reduce greenhouse gas emissions. For this reason, proper estimation of CO2 emissions and analysis of the relationship between fuel use and CO2 emissions are essential as well.

In terms of the Turkish economy the only known study is Lise (2005). The study analyzes CO2 emissions for the Turkish economy for the period 1980-2003 by dividing the economy into four aggregate sectors as agriculture, industry, transport and services and finds that CO2 emissions have increased considerably in all sectors. The decomposition results show that the expansion of the economy (scale effect) is responsible for most of CO2 emissions. The composition of the economy and the carbon intensity are the other factors identified in CO2 emissions.

One method of investigating the relationship between economic and ecological systems and particularly, economic activities and energy-environment relationship is the input-output analysis (Forssell and Polenske, 1998; Perman et al., 2003). In this study an input-output model which tries to focus on the relationship between economic activities and fuel usage and carbon dioxide emissions for the Turkish economy for 1996, is developed. Within the framework of the model, the CO2 emissions and its components as a result of energy use of domestic economic activities as well as the CO2 embodied in imports are investigated.

Another point stressed in the study is the distinction between CO2 emissions and CO2 responsibility. In general, a country uses energy to produce in order to satisfy both domestic and export demand, which leads to pollution. In a similar fashion, during the production of imported goods, energy is used and pollution is created. Therefore, when considered together the country which imports the products should be responsible from the pollution generated during the production process of these goods. In this study, the distinction

between ‘CO2 emissions’ as a result of production to satisfy both domestic final demand together with export demand, and ‘CO2 responsibility’ that includes CO2 emitted during the production of imported goods and their components is investigated.

The study is composed of five sections. Following the introduction, in the second section the model developed in the study is introduced. The data set used for the empirical application of the model is introduced in the third section. The empirical findings are discussed in the fourth section. As usual, the last section concludes the study.

2. Methodology

The input-output models that examine the interaction between energy-environment and economic activities from different perspectives exist in the economics literature since the late 1960s[1].

As it is well known, input-output analysis mainly allows the calculation of the necessary direct and indirect amounts of total production in each productive sector to satisfy a certain level of final demand[2]. In input-output analysis the total demand and total supply identities can be expressed through equations (1-3):

Total demand = Intermediate demand + Domestic final demand + Exports (1)

Total supply = Total domestic production + Imports (2)

Total demand = Total supply (3)

Using matrix algebra, the material balance equation can be expressed as:

$$X = AX + D + E - M \quad (4)$$

where X, D, E and M are sectoral gross output, domestic final demand, export and import matrices, respectively. A is the Leontief technical coefficients matrix representing the constant ratio between inputs and outputs. To decompose the domestic components of

equation (4), it is assumed that the ratio of intermediate imports to total intermediate demand and the ratio of final demand imports to total final demand is constant[3]. This way, import vector can be written as:

$$M = \hat{m}^{w} AX + \hat{m}^{f} D \quad (5)$$

where $\hat{m}^{w}$ and $\hat{m}^{f}$ are the diagonal matrices of the ratio of imported intermediate goods to total intermediate demand and imported final demand to total final demand, respectively. With this assumption equation (4) can be written as:

$$X = (I - \hat{m}^{w}) AX + (I - \hat{m}^{f}) D + E \quad (6)$$

To simplify equation (6), $\hat{\alpha}^{w}$ and $\hat{\alpha}^{f}$ can be defined as diagonal matrices that represent the supply of domestic intermediate goods and the supply of domestic final demand, respectively:

$$\hat{\alpha}^{w} = (I - \hat{m}^{w}) \text{ and } \hat{\alpha}^{f} = (I - \hat{m}^{f})$$

Solving equation (6) for gross output yields:

$$X = (I - \hat{\alpha}^{w} A)^{-1} (\hat{\alpha}^{f} D + E) \quad (7)$$

If $A_0 = \hat{\alpha}^{w} A$ and $Y = \hat{\alpha}^{f} D$, then total production is:

$$X = (I - A_0)^{-1} (Y + E) \quad (8)$$

The model is further extended to incorporate the relationships among economic activities, fuel use and CO2 emissions. In line with the basic assumption of input-output analysis it is assumed that there is a linear relationship between sectoral gross production

and fuel use during the production process. Following Gay and Proops (1993) and Cruz (2002), energy requirements in an economy can be classified as requirements for production activities and for final demand. More explicitly, fuel use can be classified as for: (i) production to satisfy domestic final demand, (ii) production to satisfy export demand, and (iii) direct final private consumption and public consumption.

With matrix notation, in an economy, total fuel demand, F is:

$$F = f\,(I - A_0)^{-1}\,(Y) + f\,(I - A_0)^{-1}\,E + g\,(T+K) \qquad (9)$$

In equation (9), f is the matrix representing the amounts of different fuels necessary to produce one Turkish Lira (TL) worth of sectoral production. Another term that needs to be explained in equation (9) is 'g (T +K)'. One of the components of final demand is investments (inclusive of stock changes). Since in the current period, investment expenditures do not cause any fuel consumption, no CO2 is emitted. Hence, investments are not taken into account. In line with the purpose of the analysis, direct final private consumption (T) and public consumption (G) show fuel consumption for lighting, transportation, heating purposes. g, shows the amounts of different types of fuel necessary for one TL worth of sectoral direct final domestic consumption and public consumption.

Parallel to total fuel consumption, the sources of total CO2 emissions can be determined as production made to satisfy domestic final demand, export demand, direct final private consumption and direct public consumption. In this respect the sources of CO2 emissions due to consumption of different fuels can be decomposed as follows:

$$C = c'f\,(I - A_0)^{-1}\,(Y) + c'f\,(I - A_0)^{-1}\,E + c'g\,(T+K) \qquad (10)$$

In equation (10), C denotes total amount of CO2 emissions and c is CO2 emissions per unit of different fuels. To sum up, in an economy, sources of CO2 emissions are defined as:

$c'f\ (I - A_0)^{-1}\ (Y)$: production to meet domestic final demand, PDFD

$c'f\ (I - A_0)^{-1}\ E$: production to meet export demand, PED

$c'g\ (T+K)$: direct private consumption and public consumption, DTK

However, to find out the amount of CO2 that a country is responsible from, the imports of a country should be taken into consideration. Starting with the amount of fuel requirements, F_M shows the amount of fuel requirements of imported goods[4].

$$F_M = f\ (I - A_0)^{-1}\ B(I - A_0)^{-1}\ (Y+E) + f\ (I - A_0)^{-1}\ (T_M + K_M) \quad (11)$$

In equation (11), B, T_M and K_M demonstrate import matrix, import vector of private consumption goods and import vector of public consumption goods, respectively. Therefore, the sources of fuel demand of imports are identified as fuel demand for: (i) imported intermediate goods to be used in domestic production, (ii) imported goods for private consumption and (iii) imported goods for public consumption. In this way, the country that consumes imported goods becomes responsible from CO2 emissions during the production of them. The CO2 responsibility (CO_{2S}) of an economy can be defined as domestic CO2 emissions (CO_{2D}) and imported CO2 emissions (CO_{2M}).

$$CO_{2S} = CO_{2D} + CO_{2M} \quad (12)$$

$$CO_{2D} = c'\ f\ (I - A_0)^{-1}\ (Y) + c'g\ (T+K) \quad (13)$$

$$CO_{2M} = c'\ f\ (I - A_0)^{-1}\ B(I - A_0)^{-1}\ (Y+E) + c'f\ (I - A_0)^{-1}\ (T_M + K_M) \quad (14)$$

From equations (13) and (14), CO2 responsibility of an economy can be identified as:

$c'\ f\ (I - A_0)^{-1}\ (Y)$: production to meet domestic final consumption, PDFD

$c'\ g\ (T+K)$: direct private consumption and public consumption, DTK

$c' f (I - A_0)^{-1} B(I - A_0)^{-1} (Y+E)$: use of imported intermediate inputs for domestic production, MII

$c' f (I - A_0)^{-1} (T_M + K_M)$: imported private consumption goods and imported public consumption goods, MTK

3. Data Set

The basic data source of this study is 1996 input-output table prepared by State Institute of Statistics (SIS). The other source is 'Energy Consumption in the Manufacturing Industry' statistics prepared by the same institution for the same year. The study is conducted for 1996 because of the fact that both data sets are available for that year.

For 1996, SIS prepared both Supply Table and Use Table[5]. To be consistent with the energy statistics of the manufacturing industry, using 'industry-technology' assumption for 97 sectors, 'sector-by-sector' symmetric 1996 input-output table is prepared[6].

For the division of imported intermediate and final goods 1996 imports matrix is used. However, imports matrix covers only imports of goods to satisfy intermediate imports and final demand. Therefore, the difference between the imports column of the input-output table and imports matrix accounts for imported services. In the study, it is assumed that this difference (all imports of services) satisfies final demand. In construction of $\hat{m}^w$ and $\hat{m}^f$ matrices, the values in the imports matrix are taken into account.

As presented in Appendix Table A1, input-output table is aggregated to 43 sectors[7]. In this process, the most important criterion is decomposition of fuel / energy sectors. For this purpose, energy sectors are taken from 205 sectors table prepared by SIS. The 'Electricity production, transmission and distribution' sector is decomposed into as 'thermal electricity' and 'electricity produced from renewable sources and distribution' by using shares of these types of electricity produced in Turkey in 1996.

For manufacturing industries, the amount of fuel used per unit of production in tons of oil equivalent (TOE) is obtained from 'Energy Consumption in Manufacturing Industry' statistics. For the rest of the sectors, the following method is employed: the amount of fuels consumed in manufacturing industry is deducted from total amount of fuels used in 1996, and the rest is distributed by using fixed input-output coefficients. Hence, it is assumed that the ratio of the amount of fuels used per TL worth of output is equal to the fixed Leontief input-output coefficients for the energy inputs [8, 9].

In calculation of CO2 emissions of different types of fuels Intergovernmental Panel on Climate Change (IPCC) manual is used (Houghton et al., 1996). Carbon equivalence of each fuel type for each sector is calculated using IPCC manual.

To avoid double counting in calculation of CO2 emissions and responsibility, only primary fuels (coal, lignite, crude petroleum and natural gas) are taken into consideration[10].

4. Empirical Findings

Tables 2 – 4 summarize the results of the study in five aggregated sectors (agriculture and husbandry, energy and mining, manufacturing industry, transportation and other services). When 1996 input-output table is considered, it is seen in Table 2 that manufacturing industry has the highest share in intermediate demand (39%), final demand (36%), exports (40%), imports (%75) and total volume of trade (58%).

Insert Table 2

Table 3 demonstrates sources of total CO2 emissions for aggregated sectors. From the table it is seen that 299.7 mega tons (mt) of CO2 is emitted in the Turkish economy in 1996. 75% of this amount is due to production to satisfy domestic final demand, 11% is due to the production to satisfy export demand and 13% is due to direct final private consumption and public consumption. The amount of CO2 emitted as a result of

manufacturing industry production to satisfy domestic final demand is more than one fourth of the total amount (27%). Similarly, energy and mining sector is responsible for 17%, other services sector for 14%, transportation sector for 13% and agriculture and husbandry sector for 5% of total CO2 emissions. The CO2 emissions of the manufacturing industry production to satisfy export demand comprise 5% of the total. Transportation sector is responsible for 3% and other services sector for 2% of CO2 emissions for this reason. The share of other sectors is negligible. The third source of CO2 emissions is defined as direct final private consumption and public consumption to satisfy transportation, lighting, heating etc needs. This consumption is met by energy and mining sector.

In total CO2 emissions, manufacturing industry has the highest share (32%). Energy and mining sector follows manufacturing industry (30%); transportation and other services sectors each have 16% share. The agriculture and husbandry sector has the lowest share (6%).

Insert Table 3

Sources of CO2 responsibility for aggregated sectors are presented in Table 4. According to Table 4, in 1996 total CO2 responsibility is 341.7 mt. 266 mt of this amount is from domestic sources and 75.8 mt is from imports. The table also shows that 66% of total responsibility, is due to domestic production to meet domestic final demand, 12% is due to direct final private consumption and public consumption, 17% is due to imported intermediate goods for domestic production and rest is due to imports for final private consumption and public consumption. When domestic component of total responsibility is investigated, it is seen that energy and mining sector is in the lead with a share of 26% and manufacturing is the second (23%). In this ranking other services sector is the third (12%), transportation sector is the fourth (11%) and agriculture and husbandry (6%) is the last sector. When import component is analyzed, the ranking changes as follows: manufacturing

industry (11%), energy and mining sector (7%), other services and agriculture and husbandry sectors (2% each) and transportation (1%) sector.

Of total responsibility, 35% is due to manufacturing industry, 33% is due to energy and mining sector, 14% due to other services sector, 12% due to transportation sector and 6% is due to agriculture and husbandry sector.

Insert Table 4

The sizes of the sectors defined in the study are significantly different from each other. To avoid any kind of bias in interpretation of results some tables are presented for one TL worth of sectoral production[11]. When Table 5, which shows CO2 emissions per TL worth of sectoral production, is examined energy sectors appear to be the leading polluters in general. Additionally, cement, lime and plaster, fertilizers and other mining sectors have higher places in the ranking. Wood products and furniture, manufacturing of basic iron and steel, ceramic products and basic chemicals industries are others that produce most of the CO2 per TL worth of output. These sectors are the main intermediate input suppliers to the manufacturing industry. In general, services (other services, public services and ownership of dwelling) emit the lowest CO2 per TL worth of production. Among other low CO2 emitting sectors office, accounting and computing machinery, radio, TV and communication apparatus, domestic appliances, professional and scientific equipments and agriculture and husbandry sectors can be cited.

In another study by the authors (Akbostancı et al., 2005) clean and dirty sectors in the Turkish manufacturing industry are identified by using dirtiness indexes based on solid and liquid wastes statistics. According to this study, manufacture of basic industrial chemicals, except fertilizers, manufacture of fertilizers and pesticides, iron and steel basic industries, non-ferrous metal basic industries, manufacture of pulp, paper and paperboard and manufacture of structural metal products industries are found out to be the dirtiest sectors.

On the other hand manufacture of office, computing, accounting machinery and repairing, manufacture of cocoa, chocolate, and sugar confectionery, tire and tube industry, manufacture of engines and turbines, manufacture of radio, TV and communication equipment and apparatus industries are determined to be the cleanest sectors. To a large extent these sectors are consistent with the sectors that are identified in this study in terms of CO2 emissions.

Insert Table 5

Table 6 presents the CO2 responsibility per TL worth of sectoral production for both domestic and imported components. Examination of the table reveals that out of forty three sectors, only fifteen of them have similar rankings in terms of their domestic and import components. It may be argued that this difference is mainly due to different intensities of imported inputs used in the production processes of sectors. Energy sectors are leading in the domestic component of CO2 responsibility. They are followed by cement, lime and plaster, fertilizers, wood products and furniture, other mining, and manufacture of basic iron and steel industries. This ranking is mainly the same for imports component of CO2 responsibility. However, there is a difference in the ranking, especially for office, accounting and computing machinery, other electrical apparatus, other manufacturing and cleaning materials and cosmetics industries.

Insert Table 6

There is not a significant difference among the industries with the lowest CO2 responsibility in terms of their domestic and import components. In general, service and agriculture and husbandry sectors have the lowest CO2 responsibility. Beside those, office, accounting and computing machinery, radio, TV and communication apparatus, domestic appliances, professional and scientific equipment, other manufacturing, textile, wearing

apparel and leather and other electrical apparatus sectors appear to have low CO2 responsibility. In terms of import component; radio, TV and communication apparatus, food, beverages and tobacco, textile, wearing apparel and leather, transportation, cocoa, chocolate and others and sawmills, plaining and other wood mills industries have the lowest share.

Inspection of total CO2 responsibility shows that similar to CO2 emissions, energy sectors take the lead. They are followed by fertilizers, cement, lime and plaster, other electrical apparatus, basic chemicals, wood products and furniture, manufacture of basic iron and steel sectors. In terms of total CO2 responsibility, the sectors that have the lowest share as in CO2 emissions are services and agriculture and husbandry industries. Additionally, within the manufacturing industry, radio, TV and communication apparatus, textile, wearing apparel and leather, domestic appliances, professional and scientific equipment and food, beverages and tobacco appear to be the industries that have lower responsibility.

When per TL worth of sectoral production of CO2 emissions and CO2 responsibility are compared, there is not much difference in the rankings of agriculture and husbandry and services sectors. However, there are some differences in the ordering of other mining, some of manufacturing and transportation industries. Other mining is in the ninth place in emissions and it is the fourteenth in responsibility. Transportation sector is in the seventeenth place in emissions and twenty-seventh in responsibility. Among manufacturing industries, cocoa, chocolate and others, textile, wearing apparel and leather, cleaning materials and cosmetics, office accounting and computing machinery other electrical apparatus, transportation vehicles and other manufacturing industry sectors have different rankings in terms of emissions and responsibility.

In terms of CO2 emissions industries are ranked as manufacturing industry, energy and mining, transportation, other services, and agriculture and husbandry sectors. However, in CO2 responsibility ranking of other services and transportation industries are reversed.

When rankings of trade volumes, CO2 emissions and CO2 responsibility of sectors are considered, manufacturing industry and agriculture and husbandry sectors' rankings are consistent. In other words, manufacturing industry appears to be the first in trade volume, CO2 emissions and CO2 responsibility. Similarly, agriculture and husbandry is in the last place in all three categories. Ranking of the transportation sector is also consistent. On the other hand, services industry which comprises 20% of trade volume (second place) is in the fourth place in CO2 emissions and in the third place in CO2 responsibility. Energy and mining sector which is in the second place both in CO2 emissions and CO2 responsibility is the fourth sector in trade volume. This can be explained by high volume of imports of this sector in relation to limited volume of exports. Hence, a sheer part of imported CO2 is the responsibility of energy and mining sector even though its share in trade volume is limited.

5. Conclusion

Increased use of fossil fuels as a result of rapid industrialization can be cited as one of the reasons of global warming. Increased international consciousness regarding the long-term implications of global warming, has lead to international cooperation in the reduction of greenhouse gas emissions. In this context, it becomes extremely important to measure accurately the greenhouse gas emissions of countries.

In this study, an input-output model that focuses on the relationship between production, fuel use and CO2 emissions is developed. The model is applied to the Turkish economy by using 1996 data. Production to satisfy domestic final demand, production to satisfy export demand and direct private consumption and public consumption are

identified as the sources of total CO2 emission. In the study it is estimated that 299.7 mt of CO2 is emitted by the Turkish economy in 1996. This amount is 1.6 times of that published in World Bank resources (188.2 mt) and 1.3 times that of SIS (1999b) estimate (231.4 mt). It is found that 75% of this amount is due to production to satisfy domestic final demand, 11% is due to production to satisfy export demand and 13% is due to direct private consumption and public consumption.

In the study, CO2 emissions of 43 sectors are calculated as well. In general, the manufacturing industry is responsible for almost one third (32%) of the total CO2 emissions. Manufacturing industry is followed by energy and mining (30%), transportation (16%) and other services (16%) sectors. Agriculture and husbandry sector has the lowest share (6%).

Additionally the CO2 responsibility of the Turkish economy is calculated in this study. This concept includes the CO2 emitted during the production of imported goods for domestic production and consumption activities of the Turkish economy. The domestic component of CO2 responsibility includes production to satisfy domestic final demand and direct private consumption and public consumption. Imported intermediate demand for domestic production and imported goods for private consumption and public consumption purposes are the elements that comprise the foreign component of CO2 responsibility.

The amount of CO2 responsibility estimated for the Turkish economy in 1996 is 341.7 mt in the study. Of this amount, 66% is due to domestic production to satisfy domestic final demand; 12% is due to direct private consumption and public consumption; 17% is due to imported intermediate goods to be used in domestic production and the rest is due to imported goods to satisfy private and public consumption.

One of the key contributions of this paper is separate estimations of CO2 emissions and CO2 responsibility. It is found that CO2 responsibility is 14% higher than CO2

emissions for Turkey. Wyckoff and Roop (1994) argue that the greenhouse gas emissions in international trade flows have increasingly become more significant in the global economy. They estimate that 13% of the total carbon emissions of the six largest OECD countries are embodied in their imports of manufactured goods. Similarly, Mongelli et al. (2006) argue that unless the carbon emissions embodied in imported goods of a country are taken into account, there will be underestimation of national greenhouse gas emissions. This underestimation is due to carbon leakage, which is the carbon embodied in the imports from countries which do not have any greenhouse gas reduction targets, i.e. mostly developing countries.

Consequently ignoring international trade flows in greenhouse gas emissions might lead to misleading conclusions. A direct conclusion is that in terms of international restrictions of greenhouse gases based on emission levels might be unreliable. Taking into account the fact that large industrialized economies, which are the highest polluters of the world, are also the largest importers, CO2 responsibility appears to be the appropriate measure rather than emission levels.

Another point in this respect is the consideration of national policies with respect to CO2 reduction from the perspective of CO2 responsibility. Munksgaard and Pedersen (2001) argue that the embodiment of CO2 in goods traded internationally raise the issue of consumer responsibility vs. producer responsibility in emitting CO2 to the atmosphere. Since CO2 responsibility accounts for the CO2 emitted from the imported goods used in the domestic economy, environmental policies based on CO2 responsibility may imply consumption driven environmental measures. However, this argument is based on the assumption that imported goods are basically consumer goods.

Focusing on the Turkish case, we show that CO2 responsibility is greater than CO2 emissions; hence, Turkey is a net importer of CO2. However, looking closer to the import

structure of the Turkish economy it can be seen that in 1996, capital goods constitute 23.7% and intermediate goods constitute 65.9% of total manufacture imports where consumption goods only account for 10.1% (SIS, 1997). Similarly, in this study we find that imported final goods demand is only accountable for 5% of total CO2 responsibility. Therefore, for the Turkish case foundation of the national environmental policies based on CO2 responsibility does not directly follow that consumer driven environmental policies for CO2 reduction will be more effective since the major part of CO2 responsibility arise as result of production process.

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Footnotes

1. For different applications of environmental input-output studies see Barata (2002), Machado (2000), Mongelli et al. (2006), Steenge (1999), and Proops et al. (1993).
2. For theoretical studies and empirical applications of input-output analysis, among others one can refer to Miller and Blair (1985).
3. For different views and applications of this assumption, see Banouei et al (2001).
4. It is assumed that production process of imported goods involve the same technology as the domestically produced goods. Inevitably, this identical technologies assumption for domestic and imported goods production might cause bias in empirical results and should be taken into account in interpreting the results.
5. In Use Table, columns demonstrate the payments made to inputs and value added components for the production of an industry and rows show the sales of industries to industries and final demand components. On the other hand Supply Table shows how much of the industry's own product is used by itself and other industries.
6. For alternative assumptions about the construction of symmetric input-output tables, see Bulmer-Thomas (1982) and Miller and Blair (1985).
7. In Appendix Table A2, sectoral production values and percentage shares of total production are presented.
8. The energy prices implied by this assumption might not reflect the actual prices. However, actual energy prices for different sectors for the Turkish economy are not available. The discrepancy between the implied and the actual energy prices might create a bias in empirical results. This point should be taken into account in interpretation of the results.
9. In Appendix Table A3, the amounts and ranks of each fuel type used per TL worth of production is presented.
10. However, in manufacturing industry statistics the figures for petroleum products are provided and since other sectors use petroleum products instead of crude petroleum, in calculations petroleum products are taken into consideration instead of crude petroleum.
11. In Appendix Tables A4 and A5 sectoral total CO2 emissions and sectoral CO2 responsibilities are presented, respectively.

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Appendix 1

Table A1: Sectoral aggregation

Sector no.	Sector	Input-output table codes
1	Agriculture and husbandry	1-7
2	Mining of hard coal	8A
3	Mining of lignite	8B
4	Extraction of crude petroleum	9A
5	Production and distribution of natural gas	9B+70
6	Other mining	10+11+12
7	Food, beverages and tobacco	13-21+23-25
8	Cocoa, chocolate and others	22
9	Textile, wearing apparel and leather	26-32
10	Sawmills, plaining and other wood mills	33
11	Wood products and furniture	34+67
12	Paper and paper products	35
13	Printing, publishing	36+37
14	Coke products	38A
15	Refined petroleum products	38B
16	Basic chemicals	39
17	Fertilizers	40
18	Other chemicals and plastic products	41+42+45
19	Cleaning materials and cosmetics	43
20	Manufacture of tire and rubber products	44
21	Glass and glass products	46
22	Ceramic products	47
23	Cement, lime and plaster	48
24	Non-metallic mineral products	49
25	Manufacture of basic iron and steel	50
26	Manufacture of other metals and casting	51+52
27	Structural metal products	53
28	Fabricated metal products	54
29	Manufacture of machinery	55+56
30	Domestic appliances, professional and scientific equipment	57+61
31	Office, accounting and computer machinery	58
32	Other electrical apparatus	59
33	Radio, TV and communication apparatus	60
34	Transportation vehicles	62-66
35	Other manufacturing	68
36	Thermal electricity production	69A
37	Electricity production from renewable resources and distribution	69B
38	Water and distribution	71
39	Construction	72
40	Transportation	73+78-82
41	Other services	74-77+83-95
42	Public services	96
43	Ownership of dwelling	97

Table A2: Sectoral production

Sector no.	Sector	Total production (Billion TL)	Share (%)
1	Agriculture and husbandry	3483805	12.63
2	Mining of hard coal	12661	0.05
3	Mining of lignite	71748	0.26
4	Extraction of crude petroleum	35	0
5	Production and distribution of natural gas	72856	0.26
6	Other mining	99800	0.36
7	Food, beverages and tobacco	1905059	6.91
8	Cocoa, chocolate and others	218571	0.79
9	Textile, wearing apparel and leather	1706872	6.19
10	Sawmills, plaining and other wood mills	119970	0.43
11	Wood products and furniture	170036	0.62
12	Paper and paper products	171402	0.62
13	Printing, publishing	134280	0.49
14	Coke products	40708	0.15
15	Refined petroleum products	773451	2.8
16	Basic chemicals	195468	0.71
17	Fertilizers	75758	0.27
18	Other chemicals and plastic products	412504	1.5
19	Cleaning materials and cosmetics	178292	0.65
20	Manufacture of tire and rubber products	127606	0.46
21	Glass and glass products	88032	0.32
22	Ceramic products	98627	0.36
23	Cement, lime and plaster	205643	0.75
24	Non-metallic mineral products	47164	0.17
25	Manufacture of basic iron and steel	514508	1.87
26	Manufacture of other metals and casting	143631	0.52
27	Structural metal products	156886	0.57
28	Fabricated metal products	270799	0.98
29	Manufacture of machinery	426932	1.55
30	Domestic appliances, professional and scientific equipment	205841	0.75
31	Office, accounting and computer machinery	9609	0.03
32	Other electrical apparatus	211921	0.77
33	Radio, TV and communication apparatus	159911	0.58
34	Transportation vehicles	580850	2.11
35	Other manufacturing	139635	0.51
36	Thermal electricity production	260625	0.94
37	Electricity production from renewable resources and distribution	164789	0.6
38	Water and distribution	95645	0.35
39	Construction	1964456	7.12
40	Transportation	3517773	12.75
41	Other services	6497552	23.55
42	Public services	1186869	4.3
43	Ownership of dwelling	666832	2.42
	Total	**27585412**	**100**

Table A3: Fuel use

Sector no.	Sector	Hard coal		Lignite		Petroleum products		Natural gas		Total Fuel	
		TOE/TL[a]	rank	TOE/TL[a]	rank	TOE/TL[a]	rank	TOE/TL[a]	rank	TOE/TL[a]	rank
1	Agriculture and husbandry	2.1	34	1.5	42	2.2	27	9.8	23	15.5	36
2	Mining of hard coal	3.0	26	5.5	25	1.8	32	78.4	3	88.7	9
3	Mining of lignite	2.5	31	6.1	20	1.8	33	15.1	13	25.5	25
4	Extraction of crude petroleum	1.2	40	3.1	35	0.8	41	7131.9	1	7137.1	1
5	Production and distribution of natural gas	8.1	12	6.7	16	93.3	2	4.3	36	112.4	6
6	Other mining	5.3	18	4.1	32	2.2	26	87.1	2	98.7	7
7	Food, beverages and tobacco	2.9	27	4.0	33	2.4	20	11.3	19	20.7	31
8	Cocoa, chocolate and others	12.4	8	15.9	6	2.1	28	9.2	25	39.5	15
9	Textile, wearing apparel and leather	2.7	28	6.4	19	2.3	25	12.1	17	23.5	27
10	Sawmills, plaining and other wood mills	4.3	21	5.1	28	6.3	11	6.3	32	22.1	29
11	Wood products and furniture	24.9	5	10.9	11	49.0	4	5.9	34	90.7	8
12	Paper and paper products	2.3	33	6.0	22	4.4	12	17.5	11	30.2	23
13	Printing, publishing	2.0	36	4.2	31	2.0	29	12.0	18	20.3	33
14	Coke products	273.0	1	2.6	37	219.1	1	2.5	39	497.2	2
15	Refined petroleum products	15.0	7	1.6	40	13.5	8	1.7	42	31.7	21
16	Basic chemicals	7.2	15	8.7	14	10.4	9	30.8	6	57.1	12
17	Fertilizers	31.7	4	11.4	10	54.6	3	21.5	10	119.1	5
18	Other chemicals and plastic products	2.6	29	4.8	29	2.4	22	15.5	12	25.3	26
19	Cleaning materials and cosmetics	9.1	11	5.4	26	2.4	24	10.5	21	27.4	24
20	Manufacture of tire and rubber products	4.6	20	5.8	23	2.4	23	9.5	24	22.2	28
21	Glass and glass products	6.5	16	12.0	8	3.9	14	22.3	8	44.6	13
22	Ceramic products	7.5	14	14.6	7	14.9	6	22.2	9	59.3	11
23	Cement, lime and plaster	32.6	3	50.3	2	14.2	7	46.5	4	143.7	4

24	Non-metallic mineral products	7.8	13	5.7	24	7.8	10	13.0	15	34.3	18
25	Manufacture of basic iron and steel	17.6	6	24.3	3	3.2	17	27.7	7	72.7	10
26	Manufacture of other metals and casting	3.5	24	11.6	9	4.1	13	14.2	14	33.4	19
27	Structural metal products	12.0	9	9.4	13	2.0	31	11.3	20	34.7	17
28	Fabricated metal products	9.9	10	16.7	5	2.6	19	9.1	26	38.4	16
29	Manufacture of machinery	3.3	25	6.0	21	2.0	30	7.3	30	18.7	34
30	Domestic appliances, professional and scientific equipment	2.5	30	4.4	30	1.2	37	6.9	31	15.0	37
31	Office, accounting and computer machinery	1.1	42	1.7	39	1.4	35	3.1	37	7.2	41
32	Other electrical apparatus	4.2	22	7.4	15	1.7	34	7.6	29	20.9	30
33	Radio, TV and communication apparatus	1.1	41	2.4	38	0.6	42	2.5	40	6.6	42
34	Transportation vehicles	3.6	23	6.7	17	2.4	21	7.7	28	20.3	32
35	Other manufacturing	1.9	37	5.2	27	2.6	18	6.3	33	15.9	35
36	Thermal electricity production	33.8	2	227.3	1	17.5	5	7.9	27	286.5	3
37	Electricity production from renewable resources and distribution	1.8	38	6.4	18	1.1	38	4.4	35	13.6	38
38	Water and distribution	2.5	32	17.0	4	1.4	36	9.8	22	30.7	22
39	Construction	6.4	17	9.4	12	3.5	16	13.0	16	32.3	20
40	Transportation	5.0	19	1.5	41	3.9	15	33.9	5	44.3	14
41	Other services	2.1	35	3.7	34	1.0	39	3.0	38	9.7	39
42	Public services	0.0	43	0.0	43	0.0	43	0.0	43	0.0	43
43	Ownership of dwelling	1.3	39	3.0	36	0.9	40	2.4	41	7.5	40

a. $x10^{-10}$

Table A4: Total CO2 emission

Sector no.	Sector	CO2 emission (mt)	Rank
1	Agriculture and husbandry	17.06	7
2	Mining of hard coal	3.07	20
3	Mining of lignite	22.09	4
4	Extraction of crude petroleum	0.08	41
5	Production and distribution of natural gas	17.84	6
6	Other mining	3.07	21
7	Food, beverages and tobacco	12.96	10
8	Cocoa, chocolate and others	3.21	19
9	Textile, wearing apparel and leather	13.49	8
10	Sawmills, plaining and other wood mills	0.87	36
11	Wood products and furniture	4.66	14
12	Paper and paper products	1.67	28
13	Printing, publishing	0.89	35
14	Coke products	6.47	13
15	Refined petroleum products	7.84	12
16	Basic chemicals	3.56	17
17	Fertilizers	2.75	23
18	Other chemicals and plastic products	3.41	18
19	Cleaning materials and cosmetics	1.70	27
20	Manufacture of tire and rubber products	0.97	34
21	Glass and glass products	1.34	31
22	Ceramic products	1.90	25
23	Cement, lime and plaster	10.49	11
24	Non-metallic mineral products	0.53	39
25	Manufacture of basic iron and steel	13.41	9
26	Manufacture of other metals and casting	1.64	29
27	Structural metal products	1.96	24
28	Fabricated metal products	3.84	16
29	Manufacture of machinery	2.77	22
30	Domestic appliances, professional and scientific equipment	1.06	33
31	Office, accounting and computer machinery	0.02	42
32	Other electrical apparatus	1.57	30
33	Radio, TV and communication apparatus	0.37	40
34	Transportation vehicles	4.10	15
35	Other manufacturing	0.75	38
36	Thermal electricity production	29.71	2
37	Electricity production from renewable resources and distribution	0.81	37
38	Water and distribution	1.08	32
39	Construction	21.95	5
40	Transportation	48.50	1
41	Other services	22.45	3
42	Public services	0.00	43
43	Ownership of dwelling	1.78	26
Total		299.69	

Table A5: Total CO2 responsibility

Sector no.	Sector	CO2 responsibility (mt)	Rank
1	Agriculture and husbandry	21.56	6
2	Mining of hard coal	3.58	22
3	Mining of lignite	22.77	5
4	Extraction of crude petroleum	0.08	42
5	Production and distribution of natural gas	35.24	2
6	Other mining	2.41	27
7	Food, beverages and tobacco	13.08	9
8	Cocoa, chocolate and others	2.95	23
9	Textile, wearing apparel and leather	9.70	12
10	Sawmills, plaining and other wood mills	0.98	38
11	Wood products and furniture	5.04	17
12	Paper and paper products	2.73	26
13	Printing, publishing	1.50	32
14	Coke products	7.33	15
15	Refined petroleum products	12.43	10
16	Basic chemicals	5.84	16
17	Fertilizers	4.40	19
18	Other chemicals and plastic products	4.36	20
19	Cleaning materials and cosmetics	2.88	24
20	Manufacture of tire and rubber products	1.03	36
21	Glass and glass products	1.23	34
22	Ceramic products	1.89	30
23	Cement, lime and plaster	10.27	11
24	Non-metallic mineral products	0.53	40
25	Manufacture of basic iron and steel	14.24	8
26	Manufacture of other metals and casting	2.12	29
27	Structural metal products	2.25	28
28	Fabricated metal products	4.56	18
29	Manufacture of machinery	3.93	21
30	Domestic appliances, professional and scientific equipment	1.34	33
31	Office, accounting and computer machinery	1.02	37
32	Other electrical apparatus	8.34	14
33	Radio, TV and communication apparatus	0.44	41
34	Transportation vehicles	8.69	13
35	Other manufacturing	2.75	25
36	Thermal electricity production	27.73	3
37	Electricity production from renewable resources and distribution	0.97	39
38	Water and distribution	1.10	35
39	Construction	24.97	4
40	Transportation	41.60	1
41	Other services	20.11	7
42	Public services	0.00	43
43	Ownership of dwelling	1.79	31
Total		341.72	

Table 1: CO2 Emission Shares

	1960 %	Rank	1970 %	Rank	1980 %	Rank	1990 %	Rank	1996 %	Rank	2000 %	Rank
Low income countries	3.6		4.2		5.5		7.8		8.6		9.0	
China	8.5	3	5.4	3	7.9	3	11.3	3	14.5	2	12.1	2
India	1.3	9	1.4	10	1.9	10	3.2	5	4.4	6	4.7	6
Middle income countries	34.1		33.3		40.3		43.1		41.6		39.7	
Low-middle income countries	27.3		26.0		31.8		35.5		33.2		30.9	
Turkey	0.2	31	0.3	30	0.4	28	0.7	23	0.8	25	1.0	23
High-middle income countries	6.7		7.3		8.5		7.6		8.4		8.7	
Low and middle income countries	37.7		37.5		45.8		50.7		50.0		48.7	
High income countries	62.3		62.3		54.3		49.3		49.6		51.3	
Australia	1.0	13	1.0	12	1.1	13	1.2	13	1.4	18	1.5	15
Canada	2.1	8	2.3	7	2.3	8	2.0	7	2.0	9	1.9	9
European Union	16.3	2	15.9	2	14.2	2	11.6	2	10.6	3	10.5	3
USA	31.9	1	29.9	1	24.9	1	22.6	1	22.9	1	24.4	1
World	100.0		100.0		100.0		100.0		100.0		100.0	

Source: World Development Indicators Online

Table 2: Input-output table and trade volume

		Agriculture and Husbandry	Energy and Mining	Manufacturing Industry	Transportation	Other Services	Total
Total Intermediate Demand	Billion TL	1540157	1702101	4526888	1214421	2768787	11752353
	%	13	14	39	10	24	100
Total Final Domestic Demand	Billion TL	1949473	264878	5801329	1769999	6524040	16309718
	%	12	2	36	11	40	100
Exports	Billion TL	165480	46744	1443738	679031	1318243	3653236
	%	5	1	40	19	36	100
Total Demand	Billion TL	3655110	2013723	11771954	3663450	10611070	31715307
	%	12	6	37	12	33	100
Imports	Billion TL	171305	517049	3096148	145677	199715	4129895
	%	4	13	75	4	5	100
Sectoral Total Production	Billion TL	3483805	1496674	8675806	3517773	10411354	**27585412**
	%	13	5	31	13	38	100
Trade Volume	Billion TL	336785	563793	4539886	824708	1517959	7783131
	%	4	7	58	11	20	100

Table 3: Sources of CO2 emission

Sector	**PDFD**	**%**	**PED**	**%**	**DTK**	**%**	**TOTAL**	**%**
Agriculture and Husbandry	16.19	5.4	0.88	0.3	0.00	0.0	17.06	5.7
Energy and Mining	49.62	16.6	1.39	0.5	39.97	13.3	90.98	30.4
Manufacturing Industry	79.56	26.5	16.32	5.4	0.00	0.0	95.88	32.0
Transportation	38.34	12.8	10.16	3.4	0.00	0.0	48.50	16.2
Other Services	42.28	14.1	4.99	1.7	0.00	0.0	47.26	15.8
Total	225.98	75.4	33.74	11.3	39.97	13.3	299.69	100.0

Table 4: Sources of CO2 responsibility

		Agriculture and Husbandry	Energy and Mining	Manufacturing Industry	Transportation	Other Services	Total
PDFD	mt	16.19	49.62	79.56	38.34	42.28	225.98
	%	4.7	14.5	23.3	11.2	12.4	66.1
DTK	mt	0.00	39.97	0.00	0.00	0.00	39.97
	%	0.0	11.7	0.0	0.0	0.0	11.7
CO2D	mt	16.19	89.59	79.56	38.34	42.28	**265.95**
	%	4.7	26.2	23.3	11.2	12.4	**77.8**
MII	mt	4.43	15.20	32.22	2.10	4.02	57.97
	%	1.3	4.4	9.4	0.6	1.2	17.0
MTK	mt	0.95	7.73	6.28	1.16	1.67	17.80
	%	0.3	2.3	1.8	0.3	0.5	5.2
CO2M	mt	5.38	22.94	38.50	3.26	5.69	**75.77**
	%	1.6	6.7	11.3	1.0	1.7	**22.2**
CO2S	mt	21.56	112.52	118.06	41.60	47.97	**341.72**
	%	6.3	32.9	34.5	12.2	14.0	100.0

Table 5: CO2 emission

Sector no.	Sector	kt/TL	rank
1	Agriculture and husbandry	4.9	38
2	Mining of hard coal	242.6	4
3	Mining of lignite	307.8	2
4	Extraction of crude petroleum	2169.7	1
5	Production and distribution of natural gas	244.9	3
6	Other mining	30.8	9
7	Food, beverages and tobacco	6.8	32
8	Cocoa, chocolate and others	14.7	15
9	Textile, wearing apparel and leather	7.9	27
10	Sawmills, plaining and other wood mills	7.2	30
11	Wood products and furniture	27.4	10
12	Paper and paper products	9.7	24
13	Printing, publishing	6.7	33
14	Coke products	159.0	5
15	Refined petroleum products	10.1	23
16	Basic chemicals	18.2	13
17	Fertilizers	36.3	8
18	Other chemicals and plastic products	8.3	26
19	Cleaning materials and cosmetics	9.5	25
20	Manufacture of tire and rubber products	7.6	28
21	Glass and glass products	15.2	14
22	Ceramic products	19.2	12
23	Cement, lime and plaster	51.0	7
24	Non-metallic mineral products	11.2	22
25	Manufacture of basic iron and steel	26.1	11
26	Manufacture of other metals and casting	11.4	19
27	Structural metal products	12.5	18
28	Fabricated metal products	14.2	16
29	Manufacture of machinery	6.5	34
30	Domestic appliances, professional and scientific equipment	5.2	36
31	Office, accounting and computer machinery	2.4	41
32	Other electrical apparatus	7.4	29
33	Radio, TV and communication apparatus	2.3	42
34	Transportation vehicles	7.1	31
35	Other manufacturing	5.4	35
36	Thermal electricity production	114.0	6
37	Electricity production from renewable resources and distribution	4.9	37
38	Water and distribution	11.3	20
39	Construction	11.2	21
40	Transportation	13.8	17
41	Other services	3.5	39
42	Public services	0.0	43
43	Ownership of dwelling	2.7	40

Table 6: Decomposition of CO2 responsibility

Sector no.	Sector	CO2D (kt/TL)	CO2D rank	CO2M (kt/TL)	CO2M rank	CO2S (kt/TL)	CO2S rank
1	Agriculture and husbandry	4.6	37	1.5	28	6.2	37
2	Mining of hard coal	242.6	4	40.2	3	282.8	4
3	Mining of lignite	307.8	2	9.6	11	317.4	3
4	Extraction of crude petroleum	2169.7	1	16.8	7	2186.6	1
5	Production and distribution of natural gas	244.8	3	238.9	1	483.7	2
6	Other mining	22.9	10	1.3	32	24.1	14
7	Food, beverages and tobacco	6.0	29	0.9	38	6.9	35
8	Cocoa, chocolate and others	12.5	15	1.0	34	13.5	25
9	Textile, wearing apparel and leather	4.8	36	0.9	37	5.7	39
10	Sawmills, plaining and other wood mills	7.1	26	1.0	33	8.2	33
11	Wood products and furniture	25.8	9	3.8	19	29.6	12
12	Paper and paper products	9.1	24	6.8	15	15.9	20
13	Printing, publishing	5.8	32	5.3	18	11.1	30
14	Coke products	153.5	5	26.5	5	180.1	5
15	Refined petroleum products	9.8	21	6.3	16	16.1	19
16	Basic chemicals	15.8	13	14.1	9	29.9	11
17	Fertilizers	35.5	8	22.6	6	58.1	8
18	Other chemicals and plastic products	7.6	25	3.0	22	10.6	31
19	Cleaning materials and cosmetics	6.0	30	10.2	10	16.1	18
20	Manufacture of tire and rubber products	6.5	27	1.5	30	8.0	34
21	Glass and glass products	11.8	17	2.1	25	13.9	24
22	Ceramic products	16.2	12	2.9	23	19.1	16
23	Cement, lime and plaster	48.5	7	1.4	31	49.9	9
24	Non-metallic mineral products	9.6	22	1.6	27	11.2	29
25	Manufacture of basic iron and steel	19.3	11	8.3	13	27.7	13
26	Manufacture of other metals and casting	9.4	23	5.3	17	14.7	22
27	Structural metal products	11.8	16	2.5	24	14.4	23

28	Fabricated metal products	13.0	14	3.8	20	16.8	17
29	Manufacture of machinery	5.9	31	3.3	21	9.2	32
30	Domestic appliances, professional and scientific equipment	4.5	38	2.1	26	6.5	36
31	Office, accounting and computer machinery	1.8	42	104.0	2	105.8	7
32	Other electrical apparatus	5.5	33	33.8	4	39.4	10
33	Radio, TV and communication apparatus	2.0	41	0.8	39	2.7	41
34	Transportation vehicles	6.0	28	8.9	12	15.0	21
35	Other manufacturing	4.8	35	14.8	8	19.7	15
36	Thermal electricity production	113.6	6	7.2	14	106.4	6
37	Electricity production from renewable resources and distribution	4.9	34	1.0	35	5.9	38
38	Water and distribution	11.2	18	0.3	41	11.5	28
39	Construction	11.2	19	1.5	29	12.7	26
40	Transportation	10.9	20	0.9	36	11.8	27
41	Other services	2.7	39	0.4	40	3.1	40
42	Public services	0	43	0	43	0	43
43	Ownership of dwelling	2.5	40	0.2	42	2.7	42