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Economic 'Responsibility' for CO_2 emissions

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Abstract

The Leontief input-output model has been applied for macro environmental analysis since the 1970s. Recently, global warming (greenhouse effect) and its consequences become one of the hottest topics in the world agenda. The Kyoto Protocol principles and the rules for greenhouse gas emission trading within the European Union can be cited as the most important contributions which try to limit the countries' emissions within a time horizon in order to reduce the negative effects of global warming, in a cost-effective and economically efficient manner.

Using data for the Portuguese economy, this paper explores an extended environmental input–output model to study the interactions between energy, environment and economic activities in order to support strategies that respect and promote a balanced management of the dynamics between energy supply, environmental protection and economic growth.

Thus, from the empirical analysis of primary energy flows, sets of energy intensity coefficients by industry, as well as the energy requirements attributable to given vectors of final demand, are estimated. Then, sources of anthropogenic CO_2 Portuguese emissions and the share of sectors in total emissions are identified, relating this pollution with the use of fossil fuels. Besides, 'CO_2 responsibility', which takes into account the CO_2 content of imports, is estimated. The sectoral CO_2 emissions and CO_2 responsibilities are compared and these two notions are linked to foreign trade. Accordingly, a summary of the key lessons learned and a discussion of their policy relevance will be offered.

Keywords: Hybrid I-O Analysis; Energy; CO_2 Emissions; Portugal.

1. Introduction

The continuous search for a balanced management amid the implicit opportunity costs of three critical goals - availability of energy, environmental protection and economic growth - has guided the energy policy in Portugal and elsewhere in the last few decades. Additionally, any recent energy policy decision, namely in the European Union (EU), cannot ignore the Kyoto Protocol's commitments.

Under the Kyoto Protocol and the related flexible mechanisms designed to allow the signatory countries a more efficient (and cost effective) approach to reduce greenhouse gases emissions (such as the Joint Implementation, the Clean Development Mechanism, and Emissions Trading), in January of 2005 was launched one of the most ambitious multilateral initiatives in the environmental policy history: the European Union CO_2 emissions trading scheme (ETS). This is the first major global scheme of its kind, covering about 12000 installations, which represent almost half of the EU anthropogenic CO_2 emissions, with major evidence for: energy activities (combustion installations with a rated thermal input exceeding 20 MW, mineral oil refineries, coke ovens), production and processing of ferrous metals, mineral industry (cement clinker, glass and ceramic bricks) and pulp, paper and board activities.

During the first phase of the program (relating the period 2005-07), the various Member-States were called to establish their National Allocation Plans (NAPs), i.e., to define the total amounts of CO_2 emission licenses to be allocated (at no cost) to their companies, which could then be sold or bought in the market (cap-and-trade model[1]).

A dominant feature of this process is that both cap-setting and allocation are highly decentralized, negotiated processes. However, the high degree of discretion for Member States has also increased complexity, administrative burdens and transaction costs. Therefore, concerning Phase 2 of NAPs (covering the period 2008-12) some major improvements are being introduced. NAPs 2 are far more stringent than NAPs 1, and are supposed to take into account explicit 'objective' projections based on 2005 verified emissions for all Member States. In January 2008, the European Commission proposed a number of changes to this scheme, including centralized allocation. These changes are still in a draft stage and the potential amendments are only likely to become effective from January 2013 onwards, i.e. in the 3rd Trading Period.

The present research recognizes that the companies already explicitly enclosed within the ETS are major generators of CO_2 emissions and other greenhouse gas emissions due to fossil fuel burning in their production processes. However, one should not ignore that the raw materials and others inputs used by these companies, as well as their corresponding processes of distribution, use and residuals deposition, will involve many other companies, of the same or other economies, that also generate CO_2. That is, CO_2 emissions occur, directly and indirectly, in different phases and multiple industries of the economies. As such, with this research it is intended to explore the multi-sector nature of the production processes regarding the implementation of the mechanisms to estimate and control CO_2 emissions. An abundant literature with various recent

[1] A cap-and-trade model is the preferred option in the emissions trading literature, both for efficiency and effectiveness reasons. Theoretically, cap-and-trade keeps transaction costs low by allocating unambiguous property rights and ensures environmental effectiveness as emissions are capped.

developments (see, for example: Cruz, 2007; Hayami and Nakamura, 2006; Tunc et al., 2007; van Asselt and Biermann, 2007) has contributed to argue that Input-Output (I-O) models are fairly adequate to proceed with this ambitious analysis.

This paper will begin by presenting a brief outline of the basic I-O model, and then there will be succinctly discussed the core aspects of its extensions for the consideration of environmental and energy issues. Then, there will be presented the data sets for the Portuguese empirical model. Next, energy and CO_2 intensity coefficients by industry will be estimated, as well as the energy requirements and the level of CO_2 emissions derived from fossil fuel use attributable to given sets of final demand. Finally, the study’s main conclusions will be presented and the limitations and needs for future research discussed.

2. The I-O framework

In an I-O approach the economic structure is defined in terms of sectors. It can be said that the relative simplicity of such a systematic connection of a set of economic variables provides a modelling framework suitable for calculating economic impacts (over all of the economy) of several human activities.

The basic principle of I-O analysis states that each sector’s production process can be represented by a vector of structural coefficients that describes the relationship between the inputs absorbed and the outputs produced[2]. This is represented through the basic equation of the Leontief static model (in matrix form):

$$\mathbf{x} = (\mathbf{I}-\mathbf{A})^{-1}\mathbf{y} \qquad (1),$$

where **x** is the vector of total outputs for ach sector, **A** is the matrix of the technological coefficients (a_{ij}) and **y** is the vector of final demand. This expression is the fundamental matrix representation of I-O analysis, and the inverse matrix $(\mathbf{I}-\mathbf{A})^{-1}$ is known as the ‘Leontief inverse matrix’ (or also as the ‘multiplier matrix’), whose elements are denoted by α_{ij}, representing the total amount of commodity *i* required both directly and indirectly to deliver one unit of final demand of commodity *j*.

By decomposing equation (1) (which can be seen as the result of an iterative process that shows the progressive adjustments of output to final demand and input requirements), one can separate out the direct from the indirect requirements for production, which are necessary to satisfy a certain vector of final demand commodities:

$$\mathbf{x} = \mathbf{y} + \mathbf{A}\mathbf{y} + \mathbf{A}^2\mathbf{y} + \ldots + \mathbf{A}^n\mathbf{y} + \ldots \qquad (2).$$

So, we can decompose the total demand for the *n* goods produced in the economy as follows:

- **y** is required for final demand. This is the direct effect.

[2] General assumptions of the basic I-O model are: homogeneity (i.e. each sector or industry produces a single product) and linear production functions (which implies proportionality of inputs with outputs in each sector and excludes both the possibility of economies or diseconomies of scale, and of substitution between production factors).

- $\mathbf{Ay}$ is the production necessary to allow the production of a final demand vector, $\mathbf{y}$. This is the 'first-round indirect effect'.

- $\mathbf{A}^2\mathbf{y} = \mathbf{A}(\mathbf{Ay})$ is needed to produce the goods $\mathbf{Ay}$. This is the 'second-round indirect effect'.

- $\mathbf{A}^t\mathbf{y} = \mathbf{A}(\mathbf{A}^{t-1}\mathbf{y})$ is needed to produce the goods $\mathbf{A}^{t-1}\mathbf{y}$. This is the '$t^{th}$-round indirect effect'.

Clearly, the total indirect effects (or intermediate demand) are the sum of the first-round, second-round, etc. (Proops *et al.* 1996: 230).

3. Extensions of the basic model to account for energy-economy-environment interactions

Having established the basic I-O framework, it is time to move on to discuss some extensions of this technique, in order to make explicit the link between the level of economic activity in a country, its corresponding impact on the environment, and/or the corresponding energy interactions.

Extensions of the application of I-O models to the examination of interactions between economic activity and environmental issues date back to the late 1960s and early 1970s[3]. These studies can be considered as benchmarks of an approach that would be further developed by some energy analysts during the 1970s and the 1980s, extending the use of I-O analysis to consider energy-economy interactions[4].

But, over time, the modelling approaches have become more and more complex, to allow, for example, the consideration of global environmental issues such as the greenhouse effect and the 'resulting' climate change problem. This has led to the development of numerous theoretical models and empirical studies that combine both perspectives, making it hard to distinguish between environment and energy models, and therefore it become usual to talk about 'energy-economy-environment' models (Faucheaux and Levarlet, 1999: 1123).

Thus, it is not surprising that also the I-O models have been extended to deal with both environmental and energy issues. Therefore, in this section, it is intended to illustrate some of the potentialities of the energy-economy-environment models, applying the I-O technique to the structural analysis of energy requirements and CO_2 emissions by economies, relating this pollution with the use of fossil fuels. This will be done using an approach very similar to the one used by Cruz (2002) and Proops *et al.* (1993).

To start, it is important to note that we need to introduce two kinds of distinctions into the analysis:

[3] Detailed surveys of environmental I-O models, with many references, including theoretical extensions and applications are provided, for example, by: Barata (2007), Cruz *et al.* (2005), Hawdon and Pearson (1995), Miller and Blair (1985, Chapter 7).
[4] A detailed survey of energy I-O analysis is presented, for example, by Miller and Blair (1985, Chapter 6); more recent contributes and references can be seen in Cruz (2002, Chapter 6).

- 1. The division of the fossil fuel use, and the corresponding pollution emissions, in what concerns to energy directly demanded by household consumers (for lighting, cooking, heating/cooling, transport, etc.), and energy (directly and indirectly) demanded by industrial and agricultural producers of goods to 'power' the production processes. The former will be designated as 'direct consumption demand' and the latter as (direct plus indirect) 'production demand'.

- 2. The distinction between various forms of primary (fossil) fuels[5], namely solid (coal), liquid (oil) and gaseous (natural gas), since they have different pollution emissions per unit mass, and per unit of energy delivered.

Lets consider: matrix $\mathbf{C}_{3xn}$, whose generic element (c_{fi}) represents the (physical) quantity of fuel f used by sector i per unit of total output (i.e. the 'energy intensities corresponding to direct production demand'); matrix $\mathbf{P}_{3xn}$, which has only three non-zero elements, one for each fuel type, expressing the (physical) quantity of fossil fuel use per unit of final demand (i.e. the 'energy intensities corresponding to direct consumption demand'); and a diagonal matrix $\mathbf{H}_{nxn}$, with only three non-zero elements, which are the ratios of the sum of 'final consumption of households' and 'collective consumption', to total final demand, for the three fossil fuel sectors[6]. Accordingly, in this model total (primary) energy requirements by an economy (given by the 3-vector $\mathbf{f}$) can be considered as the sum of the production energy requirements (given by the 3-vector [$\mathbf{f_{ind}}=\mathbf{C}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$]), and final demand energy requirements (given by the 3-vector [$\mathbf{f_{dem}}=\mathbf{PHy}$]), i.e.:

$$\mathbf{f} = \mathbf{f_{ind}} + \mathbf{f_{dem}} = \mathbf{C}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y} + \mathbf{PHy} \qquad (3)$$ [7].

Moreover, anthropogenic CO_2 emissions are produced when carbon-based fuels are burned. Therefore, after adjusting primary energy figures, it is possible to estimate CO_2 emissions from fuel combustion, by considering the carbon contents of each type of fuel. For this purpose, conversion factors from primary energy to CO_2 were applied. These conversion factors were calculated following the IPCC's default methodology to make countries' greenhouse gas emissions inventories (IPCC, 2006), and were arranged in a vector of CO_2 emission per unit (tonnes of oil equivalent - toe) of fuel burnt (vector $\mathbf{e}$). Accordingly, it is assumed that each toe of coal, oil and natural gas burnt generates 3.88, 3.04 and 2.34 tonnes of CO_2, respectively[8].

[5] Applying an I-O approach to fuel use, as it is the case, 'only primary fuels need be consider directly', since the use of secondary fuels is 'dealt with automatically within the interindustry demand structure' (Gay and Proops, 1993: 116). This means that the manufacture of secondary fuels (such as, e.g. electricity or gasoline) should be ignored in the main calculation of CO_2 emissions so that double counting is avoided (IPCC, 2006).

[6] The final demand for fossil fuels corresponding to investment is not used (burnt), and consequently do not correspond to CO_2 emissions. Furthermore, the final demand for fossil fuels corresponding to exports, as these fuels leave the country concerned, are used elsewhere and therefore does not corresponds to domestic CO_2 emissions. Thus, as interest is directed towards only those fuels which were burnt (Proops *et al*., 1993: 154), there is need to consider only the final consumption ('final consumption of households' plus 'collective consumption'). Accordingly, we can 'modify' the final demand vector (**y**) to 'exclude' the investment and export components, by premultiplying it by a suitable scaling matrix, $\mathbf{H}_{nxn}$, and therefore using a modified final demand vector (**Hy**).

[7] This expression is also the result of some considerations, namely: *n* activity sectors; three types of fossil fuels: natural gas, coal and oil; and the assumption that the use of fossil fuels by any sector remains proportional to the total output from that sector.

[8] These figures clearly show that the amounts of CO_2 emitted directly depend on the fuel, with more CO_2 being emitted per unit of energy content for coal than for oil and for natural gas.

Considering $\mathbf{e}'$ as the transpose of vector $\mathbf{e}_{3x1}$, whose generic element (e_f) represents the amount of CO_2 emission per unit of fuel f, total CO_2 emissions by an economy (given by the scalar c) can be considered as the sum of the production CO_2 emissions [$c_{ind} = \mathbf{e}'\mathbf{C}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$] and final demand CO_2 emissions [$c_{dem} = \mathbf{e}'\mathbf{PHy}$][9], that is:

$$c = c_{ind} + c_{dem} = \mathbf{e}'\mathbf{C}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y} + \mathbf{e}'\mathbf{PHy} \Leftrightarrow c = [\mathbf{e}'\mathbf{C}(\mathbf{I}-\mathbf{A})^{-1} + \mathbf{e}'\mathbf{PH}]\,\mathbf{y} \qquad (4)$$[10].

Moreover, as will be shown, according to the ‘components’ of the (total) final demand considered, it will be possible to distinguish energy requirements and CO_2 emissions attributable to the domestic consumption of goods and services produced in a country, from that attributable to exports, as well as to estimate the levels of energy and CO_2 emissions ‘embodied’ in the country’s imports. It will then be possible to estimate primary energy and CO_2 emissions ‘embodied’ in a country’s international trade, as well as the country’s ‘responsibility’ for CO_2 emissions and the CO_2 emissions produced by the country’s economy.

Usually, total final demand for goods and services produced in a country[11] (given by the n-vector $\mathbf{y}$) has four main components: ‘household consumption’, ‘government consumption’, ‘investment’ (‘changes in stocks’ plus ‘gross fixed capital formation’), and ‘exports’. The first three categories constitute the domestic final demand (given by the n-vector $\mathbf{y_{dom}}$), while the last one represents foreign demand, for goods and services produced in the country under consideration (given by the n-vector $\mathbf{y_{exp}}$). Additionally, lets consider a diagonal matrix $\mathbf{Z}_{nxn}$, with only three non-zero elements, which are the ratios of the sum of ‘final consumption of households’ and ‘collective consumption’, to domestic final demand, for the three fossil fuel sectors.

Accordingly, equations (3) and (4), representing total primary energy requirements by an economy, as well as the corresponding total CO_2 emissions, respectively, can be rewritten as:

$$\mathbf{f} = \mathbf{f_{dom}} + \mathbf{f_{exp}} = [\mathbf{C}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y_{dom}} + \mathbf{PZy_{dom}}] + [\mathbf{C}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y_{exp}}] \qquad (5),$$

and

[9] For reasons of completeness, other minor sources of CO_2 emissions – other then fossil-fuel burning – should have been included in the analysis. Proops et al. (1993) do this in their analysis. However, in this specific study, and because of a lack of detailed information for Portugal, the production of CO_2 emissions from non-fuel sources will not be covered, which can be considered as a shortcoming of this work.

[10] If we use $\hat{\mathbf{e}}$ (where $\hat{\mathbf{e}}$ is a (3x3) matrix, with the vector $\mathbf{e}$ on the diagonal) instead of $\mathbf{e}'$, the fuel sources fundamentally responsible for CO_2 emissions are explicitly identified, since a vector of pollution intensities for each of the fuels combusted in the economy is estimated. If we use $\mathbf{e}'$, as is the case here, then the scalar of pollution obtained represents pollution intensities for the total fuels burnt.

[11] It is important to recall that what is considered in the I-O table is the domestic output by sector (i.e., imports are excluded); therefore, the energy requirements (and consequent CO_2 emissions) correspond to goods and services produced in the country.

$$c = c_{dom} + c_{exp} = [\mathbf{e'C}(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{y_{dom}} + \mathbf{e'PZy_{dom}}] + [\mathbf{e'C}(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{y_{exp}}] \qquad (6)$$ [12].

Equation (6) can be interpreted as follows. The term $(\mathbf{e'C}(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{y_{dom}})$ corresponds to the CO_2 emissions attributable to fossil fuel use for producing goods and services for domestic final demand. The term $(\mathbf{e'PZy_{dom}})$ corresponds to the CO_2 emissions attributable directly to (domestic) households. Finally, the term $(\mathbf{e'C}(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{y_{exp}})$ represents the CO_2 emissions attributable to the (domestic) production of goods and services to export[13].

However, if one intends to determine only the CO_2 emissions for which one country is 'responsible', the country's emissions attributable to exports should not be considered, and the CO_2 emissions taking place in foreign countries, but resulting from the satisfaction of the country's imports, should be added on (Gay and Proops, 1993: 130).

Regarding an accurate calculation of CO_2 emissions because of imports, the task is not so straightforward as for exports, since new energy intensity coefficients should be estimated based on I-O tables of the relevant countries from which the imports come. Evidently, this would be a major task, if not operationally impossible. However, as Machado (2000: 5) remarks, if the aim is to assess the energy 'saved' by a country, by importing non-primary energy goods, then the appropriate energy intensity coefficients to be used in assessing the energy embodied in imports are the same estimated for domestic industrial production.

Therefore, considering that **B** is the imports coefficient matrix, and that $\mathbf{y_{imp}}$ represents the country's (final demand) imports vector[14], total energy 'embodied' in a country's imports (given by the 3-vector $\mathbf{f_{imp}}$) will be given by

$$\mathbf{f_{imp}} = \mathbf{C}(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{B}(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{y_{dom}} + \mathbf{C}(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{y_{imp}} \qquad (7).$$

Thus, the level of CO_2 emissions that occurs in foreign countries in order to meet the domestic and the imported final demand of a country is given by:

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[12] The reader will note that the terms $(\mathbf{PHy_{exp}})$ and $(\mathbf{e'PHy_{exp}})$ (implicit in equations (3) and (4), respectively) have been suppressed, as this would have no sensible interpretation. Moreover, the reader will also note that terms of the type $(\mathbf{PHy_{dom}})$ and $(\mathbf{e'PHy_{dom}})$ do not 'come out', but instead there appear the terms $(\mathbf{PZy_{dom}})$ and $(\mathbf{e'PZy_{dom}})$, respectively. This change, from matrix **H** to matrix **Z**, can be understood through the analysis of their own definitions. Indeed, as explained concerning final demand energy requirements (equation (3)), the final demand vector (**y**) was 'modified' to 'exclude' the investment and export components, by premultiplying it by the (nxn) scaling matrix **H**, and therefore using a modified final demand vector (**Hy**). Therefore, as what is now under consideration is the domestic final demand vector $(\mathbf{y_{dom}})$ (that does not include exports), only the investment component needs to be excluded. This can be done by premultiplying the domestic final demand vector $(\mathbf{y_{imp}})$ by a suitable scaling matrix, **Z**, and therefore using a modified final demand vector $(\mathbf{Zy_{dom}})$.

[13] Of course, the interpretation of equation (5) is similar, but concerning energy requirements instead of CO_2 emissions.

[14] Concerning the (intermediate demand) imports coefficients matrix (**B**), it is achieved by dividing the imports used to satisfy the intermediate demand of the country's sectors by the domestic total inputs (=total outputs) by industry. Concerning the imported direct final demand, as interest is directed towards only those fuels which are burnt, only its domestic final consumption is considered. Therefore, the final demand vector $(\mathbf{y_{imp}})$ considered in the study includes only the imported final demand components: 'final consumption of households' plus 'collective consumption'. A detailed analysis of the calculation of CO_2 attributable to imports can be found in Proops *et al.* (1993: Section 8.4.3).

$$c_{imp} = \mathbf{e'C(I\text{-}A)^{-1}B(I\text{-}A)^{-1}y_{dom}} + \mathbf{e'C(I\text{-}A)^{-1}y_{imp}} \quad (8)$$[15]

Finally, combining the results achieved above concerning CO_2 emissions, it is also possible to determine:

- the country's 'responsibility' for CO_2 emissions (given by the scalar c_{resp}), i.e. the CO_2 emissions attributable to consumption by one country's residents, whether arising from domestic or from foreign goods and services; as well as

$$c_{resp} = \mathbf{e'C(I\text{-}A)^{-1}y_{dom}} + \mathbf{e'PZy_{dom}} + \mathbf{e'C(I\text{-}A)^{-1}B(I\text{-}A)^{-1}y_{dom}} + \mathbf{e'C(I\text{-}A)^{-1}y_{imp}} \quad (9).$$

- the CO_2 emissions produced by the country's economy (given by the scalar c_{emis}), i.e. the CO_2 emissions attributable to the production made in the country's economy, whether demanded by national or by foreign final consumers and industries.

$$c_{emis} = \mathbf{e'C(I\text{-}A)^{-1}y_{dom}} + \mathbf{e'PZy_{dom}} + \mathbf{e'C(I\text{-}A)^{-1}y_{exp}} \quad (10)$$[16].

4. The Portuguese Case

In this section, there will be presented an I-O empirical application of the energy-economy-environment interactions for Portugal, namely concerning the energy intensities and CO_2 emissions derived from fossil fuels use, according to the modelling approach described above.

4. 1. Used data

4. 1. 1. Portuguese national accounts and the I-O table

A number of adjustments needs to be made to the way figures are presented by the Portuguese system of economic accounts, published by the National Institute of Statistics (INE), to achieve a valuation of the supply and use flows as consistently and homogenously as possible, and obtain the I-O tables that are the basis for the empirical analysis to be performed in this work. However, Portuguese national accounts have not been producing the 'auxiliary' data to perform the required treatments, surveyed with a breakdown of all interindustry transactions (by industries and by products) and of final uses by product. Thus we will use the most recent symmetric (product by product) I-O

[15] The first term corresponds to foreign CO_2 emissions attributable to one country's imports that will be used as intermediate consumption, i.e., attributable to imported products that will be introduced in the country's production processes in order to satisfy domestic final demand (which is given by vector $\mathbf{y_{dom}}$). The second term corresponds to foreign CO_2 emissions that occur to meet the country's imported final demand (imports for direct final consumption, which is given by vector $\mathbf{y_{imp}}$).
[16] This representation of the total CO_2 emissions produced by an economy is no more than the rewriting of the expression used in equation (6). Alternatively, one can represent CO_2 emissions produced by the country's economy considering its dependence on total final demand, which is no more than the expression used in equation (4).

table at basic prices available for Portugal, produced by Martins (2004), for 1999[17], as the basis for the analysis performed in this study.

It is also important to mention that in order to be able to explore alternative scenarios (in future work), namely concerning eventual impacts of changes in electricity generation, or impacts of changes in the use of different transport modes, we disaggregated sectors 40 and 60 (according to the classification of the economic activities proposed by the System of European Accounts - SEA95) as follows:

40 - Electricity, gas, steam and hot water supply

40101A - Production of electricity from fossil fuels

40101B - Production of electricity from renewable sources

40102 - Distribution and trade of Electricity

40201 – Manufacture of gas

40202 – Distribution and trade of gaseous fuels

60 - Land transport and transport via pipeline services

601 – Transport via railways

602 – Other land transports

603 - Transport via pipelines

This disaggregation was performed according to data from supply and use tables for 1999 (INE, 2007). However, as there is no official data for some of the sub-sectors, we have assumed that the proportion of each sub-sector in relation to the total of the sector presented in the supply and use tables would be acceptable to disaggregate the corresponding values in the symmetric I-O table (Martins, 2004).

Moreover, to perform the disaggregation of sector 401, following Proops et al. (1993), it is assumed that: the two generating sectors (40101A and 40101B) sell all of their output to the distribution sector (40102)[18]; the fuel inputs to electricity are attributed entirely to fossil fuel generation[19], and all other inputs are split between the two generating sectors in proportion to their total output; and all purchases of electricity by the remaining sectors and by final demand are supplied by electricity distribution. Analogues hypothesis were taken to disaggregate the gas sector (402).

This resulted in the use of a (*63*x*63*) product-by-product I-O table, for Portugal, in 1999. From this table was derived the matrix **A**, by dividing inter-industry flows by

[17] Of course, the absence of more up-to-date data may constitute a drawback to providing useful information for practical policy decisions. However, the basic economic structure of the economy changes relatively slowly over time and therefore, for many aspects, the table(s) will be relevant over a reasonable period of time (Miller and Blair, 1985: 269). Nevertheless, the performance of the analysis for more recent years and the research about the reasons explaining the changes which might have occurred (through structural decomposition analysis), should be explored as soon as the information becomes available, particularly concerning National Accounts.

[18] This means that the two electricity-generating sectors have zero final demand.

[19] Which means that electricity generation through renewable sources and the distribution side of electricity are recorded as using no fossil fuel at all, which is clearly an underestimation (Gay and Proops, 1993: 123).

the total inputs by industry at basic prices, as usual. It was also from this table that were derived the matrices **H** and **Z**, as well as the various vectors according to the different components of final demand considered, i.e.: $\mathbf{y}$, $\mathbf{y}_{\mathbf{dom}}$, $\mathbf{y}_{\mathbf{exp}}$, and $\mathbf{y}_{\mathbf{imp}}$.

4. 1. 2. The physical quantities of primary fossil fuels used in the Portuguese economy

To perform the study there is also the need to consider the (physical) quantities of primary fossil fuels used by each industry per unit of total output, as well as the quantities of fossil fuels used per unit of final demand. However, such data was generally not directly available in the appropriate, or consistent, form. Therefore, there was need to make some assumptions and estimations in order to make consistent the different data sources, namely the I-O table (provided by Martins, 2004) and the energy balance statistics (supplied by the Portuguese Directorate General of Energy and Geology – DGEG, 2006).

According to the 'Energy Balance' statistics for 1999 (DGEG, 2006), the Portuguese economy total consumption of oil and natural gas was of 15,895,604 and 1,995,821 tonnes of oil equivalent (toe), respectively. Excluding the values of their consumption for final use as raw materials, as well as the ones of the item 'reconciliation' it was considered that total use of energy, to distribute by the 63 sectors and by final consumption, was of 15,654,154 and 1,962,716 toe of oil and natural gas, respectively. These values were considered as credible totals of domestic energy use (by type of fuel) and it was from these, combined with monetary data from the symmetric I-O table, that were derived the physical quantities of oil and gas used by each of the 63 sectors and by final consumers in 1999[20]. Then, dividing these values by the corresponding element of the total input vector or by the final demand vector, it was possible to determine the primary energy intensities (or requirements) per unit of total output by sector (matrix $\mathbf{C}_{2x63}$) and per unit of final demand (matrix $\mathbf{P}_{2x63}$).

4. 2. Assessment of primary energy requirements

In this section there will first be determined (both by sector and in aggregated terms) the primary energy intensities per unit of total output and per unit of final demand, in terms of toe/million of Euro, and then the corresponding energy requirements will be estimated[21].

Before the presentation of the main results, it is important to note that the numbers which were estimated through the performance of this study are not exact, but carry some degree of inaccuracy with them. This is not only because of the level of (in)accuracy on the data used as 'inputs' to the model, but also because of the several

[20] It is important to note that, as presented in Section 3, the use of coal (as a fossil fuel), which according to the 'Energy Balance' statistics was of 3,747.155 toe in 1999, should also have been considered in this analysis. However, the nil value for this sector's total input in the symmetric I-O table (Martins, 2004) means that it is not technically possible to find a 'production technology' for the coal sector, and it justifies the elimination of this sector from the symmetric I-O table. Accordingly, the estimation of energy requirements and CO_2 emissions will be made considering only two primary energy sources: oil and natural gas. Consequently, matrices **C** and **P** are of dimension (2x63), and vector **e** is a 2-vector.

[21] It is important to note that sector 12-Mining of uranium and thorium ores is considered in our estimations, but we do not offer any kind of interpretation for the corresponding estimated values. Indeed, this sector presents values that can be considered as negligible, and do not present any sell to intermediate consumption of the other sectors. This means that it is still an industry that remains in administrative terms, but in reality we cannot impute into it any kind of production technology.

assumptions made in its construction. Therefore, they should be considered as rough estimates of the energy requirements and CO_2 emissions, mainly to give us a broad idea of the amounts involved and on the inter-industrial distribution.

4. 2. 1. Primary energy intensities

Table 1 (see Appendix) contains the basic data on fuel use (for convenience of presentation, the elements of the matrices are presented in transposed form).

The highest energy intensity for oil is found in sector 23-Manufacture of coke, refined petroleum products, while for natural gas the 1st and 3rd positions are found in sectors 40201-Manufacture of gas, and 40202-Distribution and trade of gaseous fuels, respectively, which clearly results from the importance of oil and natural gas consumption directly by final consumers. The second highest energy intensity for both fuels appears in 40101A-Production of electricity from fossil fuels, mainly because of direct production demand. Sector 40102-Distribution and trade of electricity also presents relatively high energy intensities for both fuels. As expected, the sectors that offer transport services (602-Other land transport, 62-Air transport, 601-Transport via railways, and 61-Water transport) are also high ranking for oil intensity use, while important figures for gas intensity use are also found in sector 26- Manufacture of other non-metallic mineral products. On the other hand, the smallest energy intensity coefficients were generally registered in the services sectors.

Comparing direct and indirect energy intensities corresponding to production demand, it can be seen that concerning the use of gas there are very few sectors presenting values for direct energy intensity. Concerning the use of oil, there are figures for direct intensities for almost all the sectors, although they are almost negligible for the services sectors. Therefore, it is clear that, generally speaking, the indirect production energy intensities are typically larger than the direct ones. This result clearly emphasizes the importance of the use of an inter-sectoral analysis.

4. 2. 2. Primary energy requirements corresponding to domestic consumption

Following equation (5), multiplying the primary energy intensities presented above by the domestic final demand vector, one achieves the primary energy requirements of the economy to satisfy domestic consumption, which are shown in Table 2 (see Appendix). It was estimated that the consumption by the Portuguese of domestic production in 1999 required the use of $9{,}406.7 \times 10^3$ toe of oil and $1{,}394.8 \times 10^3$ toe of natural gas.

Of this, sectors 40102-Distribution and trade of electricity, 45-Construction, 55-Hotels and restaurants, 51-Wholesale trade and commission trade and 75-Public administration and defence, are the ones that clearly require more natural gas. Indeed, the satisfaction of final demand for the production of sector 40102-Distribution and trade of electricity alone is ultimately responsible for 32.2%, and together with 45-Construction (20%) for more than half, of total natural gas requirements. Moreover, it is also important to emphasize that the natural gas requirements of all these sectors correspond almost entirely to indirect production demand. This result is clear evidence of the ‘value-added’ that the I-O technique may bring to policy analysis, as an approach that takes economic interrelations into account, as on a first ‘thought’ one might have completely excluded these sectors from the ‘list’ of those for whose production is required the use of natural gas.

On the other hand, the satisfaction of final demand for the products from sectors 23-Manufacture of coke, refined petroleum products (14.4%), 45-Construction (14.2%), 602-Other land transport (11%), 40102-Distribution and trade of electricity (10.5%) and 51-Wholesale trade and commission trade (6.1%) are responsible for more than two-thirds of oil needs. Here, in opposition to what happens for natural gas, the 'responsibility' for oil requirements does not have a 'pattern'. Indeed, if for the first sector the main 'guilt' is attributable to direct final consumption (by final consumers, e.g. when households use primary fuels in their private cars), for the second it is mainly attributable to the sector's direct production demand (as fuels are inputs directly required for the production of transport services). Moreover, for the third is mainly attributable to the sector's indirect production demand, but with some 'contribution' of the direct production demand, while for the fourth the 'guilt' is totally attributable to the sector's indirect production demand (as it is assumed that Distribution and trade of electricity does not directly require oil, but the production of this sector requires inputs from other sectors whose production directly or indirectly requires primary fuels).

Relating these results with those from Table 1, one can notice that the sectors that are more highly energy intensive are not necessarily the ones whose total production requires more energy. This is explained by what might be called the 'scale effect' of the final demand (corresponding to the fact that total energy requirements of any sector are given by the product of the intensity per unit of final demand and the level of final demand)[22].

4. 3. Assessment of CO_2 emissions

In this section there will first be calculated the CO_2 intensities corresponding to the primary energy intensities presented in the previous section, in terms of tonnes of CO_2/million Euro. Subsequently, there will be reported the total CO_2 emissions for a given structure of Portuguese final consumption, both in aggregate and disaggregated to 63 sectors.

4. 3. 1. CO_2 Intensities

As derives from the methodology proposed in Section 3, particularly from equation (4), it is possible to estimate CO_2 intensities corresponding to direct and to indirect production demand, as well as to direct consumption demand (for fossil fuels). The figures estimated, expressed in terms of tonnes of CO_2 emitted per million Euro of final demand, for each sector, can be found in Table 3 (again, for convenience of presentation, in transpose form - see Appendix)).

Concerning total CO_2 intensities, sectors 23-Manufacture of coke, refined petroleum products, 40101A-Production of electricity from fossil fuels, 602-Other land transport and 40201-Manufacture of gas, are unsurprisingly the ones that appear in the

[22] Indeed, sector 45-Construction and the sectors that offer transport services, for example, which were generally seen to have relatively low energy-intensities, require important amounts of fuels; this happens because these sectors account for important shares of the transactions made in the Portuguese economy. Conversely, for example sectors such as 26-Manufacture of other non-metallic mineral products, and 21-Manufacture of pulp, paper and paper products are quite fuel-intensive, but they do not account for significant amounts of fuels because their final demand is not very considerable (this indicates that most of the energy required in making their products will be recorded as indirect energy requirements for other sector(s)).

upper ranking. The total CO_2 intensity of the top sector (23-Manufacture of coke, refined petroleum products) is dominated (in 76.8%) by the intensities corresponding to direct consumption demand. For all the other sectors (except sector 40202-Distribution and trade of gaseous fuels), the CO_2 intensities correspond only to production demand (on the clear majority of them mainly to indirect production demand).

4. 3. 2. CO_2 emissions corresponding to domestic consumption

As derives from equation (4), multiplying the CO_2 intensities determined above by the domestic final demand figures, one achieves the corresponding tonnes of CO_2 emitted by each sector. The results obtained are reported in Table 4 (see Appendix). According to the estimation made through the model, the production of CO_2 emissions by the consumption of domestic production by the residents in Portugal was, in 1999, of $31{,}852.3\text{x}10^3$ tonnes. The estimation of this total value for CO_2 emissions, although similar to the ones estimated by alternative methods, should be highlighted mainly because of the way it was obtained, namely the fact that it can be decomposed according to the sectors considered.

The top five sectors 'responsible' for those CO_2 emissions are 45- Construction (14.8%), 23-Manufacture of coke, refined petroleum products (13%), 40102-Distribution and trade of electricity (12.7%), 602-Other land transport (9.9%), and 51-Wholesale trade and commission trade (5.9%). This means that the final demand for the products of these sectors account for more than half of total CO_2 emissions attributable to production in the Portuguese economy.

Moreover, as the CO_2 emissions by sector 23-Manufacture of coke, refined petroleum products, are mainly associated with the use of private cars, and as the production of CO_2 emissions by sector 602-Other land transport is mainly connected with freight and passengers transport, one can say that (personal and public) transport (of passengers and goods) was 'responsible' for almost one-fifth of all the emissions that occurred in Portugal in 1999.

Another key result is the significant importance of the indirect production demand (of fuels) for production (by industries) in the generation of CO_2 emissions. Indeed, more than two-thirds (68.3%) of the CO_2 emissions are attributable to indirect demand, while only 21.7 per cent of the emissions are attributable to direct demand for fossil fuels by industries; the remaining 10% are directly attributable to household demand for fossil fuels (mainly associated with fuel use in private cars, and at a much smaller scale with the use of cooking and heating equipment). Accordingly, it is noticeable that the great majority of industries are 'responsible' for much more CO_2 production indirectly than directly[23]. Again, this type of result clearly reinforces the importance of using an approach that considers inter-industrial relations when analysing CO_2 emissions.

Similarly to what was observed in relation to energy requirements, relating these results with those concerning CO_2 intensities (comparing results from tables 3 and 4), one can notice that sectors that are more highly CO_2 intensive are not necessarily the

[23] Unsurprisingly, the exceptions, i.e. the sectors that have a significant (direct) production element are: 05-Fishing, fish farming and related service activities, 26-Manufacture of other non-metallic mineral products, and the sectors that offer transport services (601-Transport via railways, 602-Other land transport, 61-Water transport, and 62-Air transport).

ones whose production generates more CO_2 emissions, again explained by the ‘scale effect’ of the final demand (corresponding to the fact that total CO_2 emissions of any sector are given by the product of the intensity per unit of final demand and the level of final demand).

4. 4. Analysis of energy and CO_2 ‘embodied’ in Portuguese international trade

The study performed above concentrates on the appraisal of energy requirements and corresponding CO_2 emissions attributable to the (final and intermediate) consumption by the Portuguese of goods and services produced in Portugal. However, the reality is that Portugal is an open economy, and greenhouse gas emissions and climate change are global phenomena, with transboundary effects. Therefore, it is important to analyse what happens to energy use and CO_2 emissions in what concerns to Portuguese imports and exports of non-primary energy goods and services.

As described above, taking some simplifying assumptions, it is possible to estimate the energy and CO_2 ‘embodied’ in the Portuguese international trade (see Table 5, presented in the Appendix), which can be analysed both at aggregated and at disaggregated levels. It can be said that it was estimated that in 1999 there were $3,881.2 \times 10^3$ toe of oil and 505×10^3 toe of natural gas ‘embodied’ in Portuguese exports. The sectors that contributed the most to these energy requirements were: 602-Other land transport, 62-Air transport, 26- Manufacture of other non-metallic mineral products, 40101A-Production of electricity from fossil fuels, 23-Manufacture of coke, refined petroleum products, 17-Manufacture of textiles and 21-Manufacture of pulp, paper and paper products. While for the generality of these sectors the energy-intensity is relatively high, it is important to mention that the last two (17 and 21) are sectors in the middle of the energy-intensities’ ranking; but its significance in terms of energy ‘embodied’ in exports is not at all surprising, mainly because of the ‘scale effect’, as they are traditionally very important sectors in Portuguese exports.

Moreover, it was estimated that $2,707.4 \times 10^3$ toe of oil and 121×10^3 toe of natural gas were ‘embodied’ in Portuguese imports, which can be interpreted as the quantities of energy that were ‘saved’ by Portugal because it imported the corresponding goods and services instead of producing them in Portugal. In terms of ranking, it is worthwhile to mention sectors 15-Manufacture of food products and beverages, 24-Manufacture of chemicals and chemical products and 34-Manufacture of motor vehicles, trailers and semi-trailers.

Thus, it can be said that in 1999 Portugal faced a positive ‘primary energy trade balance’ (for both oil and natural gas). In other words, one can say that the amount of primary energy ‘embodied’ in Portuguese exports was greater than the amount of primary energy that was ‘saved’ by Portugal because it imported the corresponding goods and services instead of producing them in Portugal. This result can represent an unfavourable situation, particularly taking into account the strong external energy dependence of the Portuguese economy.

Concerning CO_2 emissions, the main results obtained are in accordance to the ones found for energy requirements. Indeed, for example the sectors which contributed the most to CO_2 emissions attributable to Portuguese exports were: 602-Other land transport, 26-Manufacture of other non-metallic mineral products, 62-Air transport, 23-Manufacture of coke, refined petroleum products, 40101A-Production of electricity from fossil fuels, 17-Manufacture of textiles and 21-Manufacture of pulp, paper and paper products. The estimated CO_2 emissions attributable to Portuguese exports were of $12{,}977.5 \times 10^3$ tonnes.

The top three sectors in terms of 'responsibility' for foreign CO_2 emissions in order to satisfy the final demand of the Portuguese were 34-Manufacture of motor vehicles, trailers and semi-trailers, 45-Construction and 15-Manufacture of food products and beverages, not because of their CO_2-intensity, but mainly for the reason that their final demand by the Portuguese was high. It is also important to note that almost two-thirds of the $9{,}701.5 \times 10^3$ tonnes of CO_2 emitted in foreign countries in order to satisfy Portuguese final demand are attributed to imported goods and services that were used in further production (and not to be directly used by final consumers).

Therefore, in 1999, the difference between the emissions that occurred in Portugal to satisfy foreign final demand and the emissions that occurred in foreign countries to satisfy Portuguese final demand was of $3{,}276 \times 10^3$ tonnes, which means that Portugal faced a positive 'CO_2 emissions trade balance'. In other words, one can say that CO_2 emissions released in Portuguese territory to satisfy the final demand of non-residents for goods and services produced in Portugal (exports) are greater than the CO_2 emissions that were not emitted in Portuguese territory because we imported the corresponding goods and services (instead of producing them in Portugal).

As for the 'primary energy trade balance', the sectors which most contributed for this result in the 'CO_2 emissions trade balance' were 602-Other land transport, 26-Manufacture of other non-metallic mineral products and 62-Air transport.

To sum up, one can say that, according to the estimations, in 1999 total exports of goods and services produced in Portugal 'embodied' more energy and CO_2 than total imports made by residents in Portugal.

4. 5. Portuguese 'responsibility' for CO_2 emissions *versus* CO_2 emissions produced by the Portuguese economy

Finally, combining the results achieved in the two previous sections, as shown in Table 6 (see Appendix), it is also possible to determine:

- the Portuguese 'responsibility' for CO_2 emissions (c_{resp} – as results from equation (9)), and

- the CO_2 emissions produced by the Portuguese economy (c_{emis} – as results from equation (10)).

In 1999, 44,829x10^3 tonnes of CO_2 were emitted on Portuguese territory, derived from the use of fossil fuels[24]. This figure corresponds to the CO_2 emissions that were produced by the Portuguese economy in 1999, in order to satisfy the (domestic and foreign) final demand for goods and services domestically produced. Of these, 71.1% occurred in order to satisfy the final demand by Portuguese consumers, while the remaining 28.9% resulted from the satisfaction of the foreign final demand (exports).

It is important to highlight that the five sectors that contributed the most to this amount of CO_2 emissions (602-Other land transport, 23-Manufacture of coke, refined petroleum products, 45-Construction, 40102-Distribution and trade of electricity and 15-Manufacture of food products and beverages) account for almost half of total CO_2 emissions attributable to production in the Portuguese economy. Moreover, as the CO_2 emissions by sector 23-Manufacture of coke, refined petroleum products are mainly associated with the use of private cars, and as the production of CO_2 emissions to satisfy the final demand for 602-Other land transport is mainly connected with freight and passengers transport, one can say that transports are 'responsible' for around one-quarter of all the emissions that occurred to satisfy the final demand in 1999.

Concerning the CO_2 emissions whose 'responsibility' is attributed to the consumption of the residents in Portugal[25], whether of goods and services domestically produced or imported, the amount estimated was of 41.553,8x10^3. To be illustrative, one can say, in a simplified way, that from these CO_2 emissions that occurred throughout the world because of the consumption of residents in Portugal, only 76.7% were released in Portuguese territory, while the remaining 23.3% were released in foreign countries.

Thus, incorporating the flows of international trade in the analysis, one can notice that, in 1999, the CO_2 emissions 'released in Portuguese territory' (i.e. attributable to the satisfaction of both domestic and foreign final demand for goods and services produced in Portugal) were (slightly) higher than the ones that were 'released throughout the world' to satisfy the final demand of the residents in Portugal.

This type of analysis can be of great importance in the context of the Kyoto Protocol, as it draws attention to the possibility that some countries may be tempted to reduce their greenhouse gas emissions 'artificially', mostly by stopping producing certain (energy and CO_2 intensive) goods to import them from other countries[26]

[24] This figure is slightly higher (0,4%) than alternative estimates made by IA (2007) (*Instituto do Ambiente* - body of the Portuguese Ministry of Environment), following the 'IPCC Guidelines' (IPCC, 2006), which reports that the total production of CO_2 derived from oil and natural gas combustion, in 1999, was of 44,650.7x10^3 tonnes of CO_2. Moreover, according to IA (2007), there were generated 14,444.3x10^3 tonnes of CO_2 as result of the use of coal. Thus, this figure for CO_2 emissions resulting from coal combustion can be considered as a good estimate of the emissions which we have not accounted for in this study (indeed, as mentioned before, for reasons of application of the I-O technique to the Portuguese data it was not possible to incorporate in this analysis the assessment of coal requirements and corresponding CO_2 emissions).

[25] The top five sectors in terms of contribution to these emissions were the same top five sectors mentioned above for the emissions of CO_2 produced by the Portuguese economy in 1999 (although not exactly by the same order).

[26] Conversely, the results achieved in this work illustrate the circumstance that Portugal might be penalised in terms of its efforts to reduce CO_2 emissions, required to accomplish the Kyoto Protocol's requirements, relatively to what might be considered its ecological responsibility (since Portugal is 'responsible' for less CO_2 emissions than it actually emits).

(Machado, 2000: 1). On a first approach one can admit that such kind of attitude can eventually attenuate the problem at the internal level, but the result might be the same at the global level (i.e., the CO_2 emissions produced by the world economy will be similar). However, this will not be true if the imports of those goods and services become from countries where they are produced with more efficient technologies (in terms of energy requirements and/or making use of 'cleaner' fuels).

5. Policy Relevance

In this study, an extensive I-O analysis was used to investigate energy flows and CO_2 emissions in the Portuguese economy, for 1999. The approach adopted allowed the distinction between the 'direct consumption demand' (by final consumers), and the (direct and indirect) 'production demand' (by industries) for primary energy fuels.

One of the key results found was the significant importance of the indirect production demand for fuels in the production of CO_2. Indeed, it was seen that around two-thirds of the CO_2 emissions are attributable to indirect demand for fossil fuels to satisfy the domestic final demand for goods and services produced in Portugal. These results 'indicate how crucial it is to use an approach which takes economic interrelations into account when analysing CO_2 production' (Gay and Proops, 1993: 123), and therefore show that the analysis here performed has clear policy relevance.

Indeed, it appears that there is significant general awareness about the CO_2 emissions that occur from direct energy use in households and private cars, as well as about the CO_2 emitted directly in energy industries and by the transport sectors[27]. Thus, it looks almost 'natural' that important reductions in CO_2 emissions in Portugal can be achieved by focusing policies on transport and on the production and use of electricity.

However, the major importance of industries' indirect production demand for fuels, and consequently the fact that the great majority of direct consumption is 'responsible' for much more CO_2 production indirectly than directly is generally ignored by producers, consumers and policy-makers. For example, the results of this approach indicate the singular importance associated with the flows of energy and CO_2 emissions explained by the final demand for the production of sector 45-Construction. However, until now the authorities did not gave it special attention. Indeed, if we observe, for example, the sectors included in ETS, it becomes evident the absence of this sector, since the scheme consider the sectors which are 'responsible' for emissions according to direct use of fuels in their production activity (as, e.g., the industries of glass, cement and ceramics).

The study here performed also revealed that the sectors that are more highly energy (or CO_2) intensive are not necessarily the ones whose production requires more energy (or which produce more CO_2 emissions), which is explained by what might be called as the 'scale effect' of the final demand. At this level, it is important to highlight, e.g., that sectors 26-Manufacture of other non-metallic mineral products and 21-Manufacture of pulp, paper and paper products, which represent an important part of the

[27] For example, it was not surprising the estimation that, in a broad sense, transports were 'responsible' for about one quarter of all the emissions that occurred in 1999 in order to satisfy domestic demand. These findings mean that the reductions in the final demand for these sector's outputs are the ones that would be most worthwhile for reducing Portuguese CO_2 emissions.

economic units included in the ETS, where there included considering their 'apparent' energy intensity, but the analysis made in this study indicates that in terms of responsibility for emissions they only assume relevance in Portugal when considering the final demand by non-residents (i.e., only considering the 'scale effect' of exports).

Moreover, as shown, according to the 'components' of the (total) final demand considered, it is possible to discuss the flows of energy and CO_2 emissions associated with international trade. This represents also an important contribution to establish strategies and to support policy-makers in current international negotiation processes, such as, e.g., the post-Kyoto negotiations and eventually Phase 3 of the ETS. The analysis of such flows also alert us for the possibility, in a near future, of a possible confront with logics of international specialization where one of the dimensions taken into account results from 'comparative advantage' in terms of energy efficiency and CO_2 emissions.

Therefore, the analysis performed here may help policy-makers in dealing with the problem of CO_2 emissions as they are better informed about the root causes of some outcomes. Thus, it is possible to claim that one of the key accomplishments of the use of this type of modelling, which integrates economic, energy and environmental interactions in an I-O framework, is that it allows the analysis of how energy, and therefore CO_2 emissions, are related to industrial production, and ultimately to final demand, making it a tool particularly important for (*ex ante*[28] and/or *ex post*) policy analysis purposes.

6. Limitations and proposals for future research

The empirical exercise performed in this research presents, as any other study of this nature, important limitations, which should be weighed in terms of the methodology used (see Miller and Blair, 1985, for an exhaustive analysis of this methodology's limitations) and of the hypothesis taken in the process of data treatment. These limitations do not invalidate the results achieved, but should be reflected in their interpretation, namely in processes directed towards helping policy-makers in the definition and adoption of specific policy measures.

It is also relevant to mention that the information generated by the analysis undertaken was vast. However, only some of it is shown in the tables presented. This was a deliberate approach, as there is the need to condense information, so that it can be comprehended and thus allow policy conclusions to be drawn. Nevertheless, it is also worthwhile to note that the full potential of the data set was not exploited; indeed, many areas of further work remain, and there are several extensions to the model that should be explored in later stages of the research.

Indeed, in future work some scenarios should be performed in order to obtain a broad idea of the consequences (in terms of amounts of reductions in energy requirements and CO_2 emissions) of:

- recent national policy measures to promote non-fossil-fuel electricity generation;

[28] Indeed, both the model and the database are formulated in terms of detailed technical parameters, on a multi-sector basis, that can be directly evaluated by technical experts and readily changed in order to explore the consequences of alternative scenarios (see Cruz, 2002).

- switching to a mix of fuel inputs with lower CO_2 emissions (inter-fuel substitution), namely concerning an increasing penetration of natural gas use in industries;

- changes in the technologies used for specific purposes (energy efficiency);

- alterations in the structure of inter-industry relations, as well as in the structure and in the level of the final demand.

Finally, as soon as the information becomes available, particularly concerning National Accounts, it will also be important to perform the analysis for more recent years and to study the reasons behind the changes which might have occurred, namely through techniques of structural decomposition analysis. Also, it can particularly relevant to present contributes that allow us to become aware not only of the reactions of the sectors included in NAPs 2, but also to identify the weak and strong points, the threats and the opportunities, that this process may bring to the Portuguese economy, with the goal of anticipate potential (positive and negative) changes throughout the current (and eventually of a third) trading period.

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Appendix

Table 1.
Primary energy intensities

unit: *toe / million €*

		Corresponding to Direct Production demand		+ Corresponding to Indirect Production demand		= Corresponding to Total Production demand		+ Corresponding to Direct Consumption Demand		= Corresponding to Final Demand			
		C		C (A+A²+...)		C(I-A)⁻¹		P		Total Primary Energy Intensity		Tt. Primary Energy Intens.' Ranking	
		(1) Oil	(2) Natural gas	(3) Oil	(4) Nat. gas	(5) Oil	(6) Natural gas	(7) Oil	(8) Nat. gas	(9) Oil	(10) Natural gas	Oil	Natural gas
01	Agriculture, hunting and related service activities	43.7	0.0	64.0	9.6	107.7	9.6			107.7	9.6	18	27
02	Forestry, logging and related service activities	10.7	0.0	43.0	0.7	53.7	0.7			53.7	0.7	39	62
05	Fishing, fish farming and related service activities	174.1		41.4	4.0	215.5	4.0			215.5	4.0	11	53
13	Mining of metal ores	39.7	0.2	171.1	18.9	210.7	19.2			210.7	19.2	12	13
14	Other mining and quarrying	71.0	0.4	178.7	16.1	249.6	16.5			249.6	16.5	10	15
15	Manufacture of food products and beverages	21.3	0.4	73.5	8.5	94.8	8.9			94.8	8.9	21	29
16	Manufacture of tobacco products	0.4	0.0	47.9	3.9	48.3	3.9			48.3	3.9	43	54
17	Manufacture of textiles	24.6	3.0	62.8	12.9	87.4	15.9			87.4	15.9	25	17
18	Manufacture of wearing apparel; dressing and	2.1	0.1	49.6	7.2	51.6	7.4			51.6	7.4	41	34
19	Tanning and dressing of leather; manufacture of	1.2	0.1	37.2	5.9	38.4	6.0			38.4	6.0	47	42
20	Manufacture of wood and of products of wood and	5.4	0.1	87.0	5.5	92.4	5.6			92.4	5.6	24	45
21	Manufacture of pulp, paper and paper products	13.0	0.9	174.6	41.1	187.6	42.0			187.6	42.0	13	7
22	Publishing, printing and reproduction of recorded	0.6	0.1	51.0	8.6	51.6	8.6			51.6	8.6	42	30
23	Manufacture of coke, refined petroleum products	600.9		89.0	15.4	689.9	15.4	2,323.4		3,013.3	15.4	1	18
24	Manufacture of chemicals and chemical products	39.1	13.2	56.0	8.0	95.1	21.2			95.1	21.2	20	11
25	Manufacture of rubber and plastic products	5.4	0.0	79.0	13.1	84.4	13.1			84.4	13.1	27	21
26	Manufacture of other non-metallic mineral	200.6	86.2	122.2	38.6	322.8	124.8			322.8	124.8	7	5
27	Manufacture of basic metals	14.4	13.6	79.5	23.2	93.9	36.8			93.9	36.8	22	8
28	Manufacture of fabricated metal products, except	5.9	2.1	54.5	10.7	60.3	12.8			60.3	12.8	35	23
29	Manufacture of machinery and equipment n.e.c.	26.3	6.0	49.9	8.8	76.2	14.8			76.2	14.8	29	19
30	Manufacture of office machinery and computers	0.0	0.0	8.5	1.5	8.5	1.5			8.5	1.5	62	61
31	Manufacture of electrical machinery and	0.6	0.1	52.6	6.7	53.3	6.7			53.3	6.7	40	36
32	Manufacture of radio, television and	0.1	0.0	39.7	5.0	39.8	5.0			39.8	5.0	46	48
33	Manufacture of medical, precision and optical	0.3	0.0	38.1	6.4	38.4	6.5			38.4	6.5	48	39
34	Manufacture of motor vehicles, trailers and	0.2	0.0	29.1	6.6	29.3	6.6			29.3	6.6	51	37
35	Manufacture of other transport equipment	0.5	0.0	28.0	7.4	28.5	7.5			28.5	7.5	52	33
36	Manufacture of furniture; manufacturing n.e.c.	10.7	0.2	58.4	7.9	69.1	8.1			69.1	8.1	32	31
37	Recycling	3.9	0.4	83.0	16.0	86.9	16.4			86.9	16.4	26	16
40101A	Production of electricity from fossil fuels	1,940.2	909.5	54.4	3.0	1,994.6	912.5			1,994.6	912.5	2	2
40101B	Production of electricity from renewable sources			14.9	2.1	14.9	2.1			14.9	2.1	61	60
40102	Distribution and trade of Electricity			782.9	357.7	782.9	357.7			782.9	357.7	5	4
40201	Manufacture of gas		1,244.1	118.8	7.1	118.8	1,251.2			118.8	1,251.2	17	1
40202	Distribution and trade of gaseous fuels		24.3	33.2	366.6	33.2	390.9		104.0	33.2	494.9	50	3
41	Collection, purification and distribution of water			63.2	16.6	63.2	16.6			63.2	16.6	34	14
45	Construction	10.4	0.0	82.7	19.4	93.1	19.4			93.1	19.4	23	12
50	Sale, maintenance and repair of motor vehicles	12.2	0.6	53.7	5.0	65.9	5.6			65.9	5.6	33	44
51	Wholesale trade and commission trade, except of	4.1	0.2	102.1	10.8	106.2	11.0			106.2	11.0	19	25
52	Retail trade, except of motor vehicles and	5.1	0.2	77.3	7.6	82.4	7.9			82.4	7.9	28	32
55	Hotels and restaurants	10.6	0.5	64.8	13.8	75.4	14.3			75.4	14.3	31	20
601	Transport via railways	144.9		111.4	6.6	256.3	6.6			256.3	6.6	8	38
602	Other land transport	1,855.3		123.2	7.3	1,978.5	7.3			1,978.5	7.3	3	35
603	Transport via pipelines			76.0	4.5	76.0	4.5			76.0	4.5	30	50
61	Water transport	174.6		78.3	3.0	252.9	3.0			252.9	3.0	9	58
62	Air transport	314.2		71.9	3.3	386.1	3.3			386.1	3.3	6	56
63	Supporting and auxiliary transport activities;	11.3	0.6	140.3	8.5	151.7	9.1			151.7	9.1	15	28
64	Post and telecommunications	2.4	0.1	20.3	4.2	22.7	4.3			22.7	4.3	56	52
65	Financial intermediation, except insurance	0.0	0.0	18.2	4.5	18.2	4.5			18.2	4.5	58	51
66	Insurance and pension funding, except	0.7	0.0	15.2	3.5	16.0	3.5			16.0	3.5	60	55
67	Activities auxiliary to financial intermediation	0.0	0.0	16.2	3.0	16.2	3.0			16.2	3.0	59	57
70	Real estate activities	1.2	0.1	23.4	4.8	24.7	4.8			24.7	4.8	54	49
71	Renting of machinery and equipment without	5.3	0.3	15.4	2.1	20.7	2.4			20.7	2.4	57	59
72	Computer and related activities	1.1	0.1	33.1	5.0	34.2	5.1			34.2	5.1	49	47
73	Research and development	7.1	0.3	52.7	11.2	59.7	11.5			59.7	11.5	36	24
74	Other business activities	2.6	0.1	53.0	10.1	55.5	10.3			55.5	10.3	38	26
75	Public administration and defence; compulsory	10.3	0.5	31.5	5.7	41.8	6.2			41.8	6.2	45	41
80	Education	1.5	0.1	21.9	5.7	23.4	5.8			23.4	5.8	55	43
85	Health and social work	21.5	1.1	34.0	5.2	55.6	6.3			55.6	6.3	37	40
90	Sewage and refuse disposal, sanitation and	20.4	1.0	134.6	24.9	154.9	25.9			154.9	25.9	14	9
91	Activities of membership organizations n.e.c.	12.1	0.6	126.1	25.2	138.2	25.8			138.2	25.8	16	10
92	Recreational, cultural and sporting activities	1.4	0.1	25.8	5.2	27.2	5.2			27.2	5.2	53	46
93	Other service activities	1.1	0.1	43.3	12.9	44.4	13.0			44.4	13.0	44	22
95	Activities of households as employers of domestic											63	63

Table 2. Primary Energy Requirements corresponding to domestic consumption

(y_{dom} = Final consumption of households + Collective consumption + Gross fixed capital formation + Change in stocks)

unit: 10^3 toe

		Energy Requirements by Direct Production demand: $C\,y_{dom}$		+ Energy Requirements by Indirect Product. demand: $C\,(A+A^2+\ldots)\,y_{dom}$		= Energy Requirements by Total Production demand: $C(I-A)^{-1}\,y_{dom}$		+ Energy Requirements by Direct Consumpt. Demand: PZy_{dom}		= Energy Requirements by Final Demand: Total Primary Energy Requirements		Tt. Prim. Energy Requir.' Ranking		% Distrib. of Energy Req. by Industry	
		(1) Oil	(2) Natural gas	(3) Oil	(4) Natural gas	(5) Oil	(6) Natural gas	(7) Oil	(8) Natural gas	(9) Oil	(10) Natural gas	Oil	Natural gas	Oil	Natural gas
01	Agriculture, hunting and related service activities	59.5	0.0	87.1	13.1	146.7	13.1			146.7	13.1	14	15	1.6	0.9
02	Forestry, logging and related service activities	0.7	0.0	2.6	0.0	3.3	0.0			3.3	0.0	45	56	0.0	0.0
05	Fishing, fish farming and related service activities	50.5		12.0	1.2	62.5	1.2			62.5	1.2	19	39	0.7	0.1
13	Mining of metal ores											57	57		
14	Other mining and quarrying	0.4	0.0	1.0	0.1	1.4	0.1			1.4	0.1	51	52	0.0	0.0
15	Manufacture of food products and beverages	127.5	2.5	440.0	50.8	567.5	53.3			567.5	53.3	6	6	6.0	3.8
16	Manufacture of tobacco products	0.1	0.0	9.3	0.8	9.4	0.8			9.4	0.8	38	41	0.1	0.1
17	Manufacture of textiles	7.9	1.0	20.1	4.1	28.0	5.1			28.0	5.1	27	27	0.3	0.4
18	Manufacture of wearing apparel; dressing and	2.0	0.1	46.8	6.8	48.8	7.0			48.8	7.0	23	22	0.5	0.5
19	Tanning and dressing of leather; manufacture of	0.3	0.0	9.0	1.4	9.2	1.4			9.2	1.4	39	36	0.1	0.1
20	Manufacture of wood and of products of wood and	0.3	0.0	4.5	0.3	4.7	0.3			4.7	0.3	43	47	0.1	0.0
21	Manufacture of pulp, paper and paper products	0.2	0.0	2.4	0.6	2.6	0.6			2.6	0.6	46	44	0.0	0.0
22	Publishing, printing and reproduction of recorded	0.2	0.0	16.2	2.7	16.4	2.7			16.4	2.7	32	33	0.2	0.2
23	Manufacture of coke, refined petroleum products	270.4		40.1	6.9	310.5	6.9	1,043.6		1,354.1	6.9	1	23	14.4	0.5
24	Manufacture of chemicals and chemical products	22.3	7.5	31.9	4.6	54.3	12.1			54.3	12.1	21	16	0.6	0.9
25	Manufacture of rubber and plastic products	1.2	0.0	17.5	2.9	18.7	2.9			18.7	2.9	30	31	0.2	0.2
26	Manufacture of other non-metallic mineral	11.0	4.7	6.7	2.1	17.7	6.8			17.7	6.8	31	24	0.2	0.5
27	Manufacture of basic metals	0.3	0.3	1.6	0.5	1.9	0.8			1.9	0.8	49	42	0.0	0.1
28	Manufacture of fabricated metal products, except	0.2	0.1	2.2	0.4	2.4	0.5			2.4	0.5	47	45	0.0	0.0
29	Manufacture of machinery and equipment n.e.c.	14.7	3.3	27.8	4.9	42.5	8.3			42.5	8.3	24	20	0.5	0.6
30	Manufacture of office machinery and computers	0.0	0.0	1.8	0.3	1.8	0.3			1.8	0.3	50	46	0.0	0.0
31	Manufacture of electrical machinery and	0.0	0.0	0.5	0.1	0.6	0.1			0.6	0.1	56	53	0.0	0.0
32	Manufacture of radio, television and	0.0	0.0	1.4	0.2	1.4	0.2			1.4	0.2	52	49	0.0	0.0
33	Manufacture of medical, precision and optical	0.0	0.0	0.8	0.1	0.8	0.1			0.8	0.1	55	51	0.0	0.0
34	Manufacture of motor vehicles, trailers and	0.0	0.0	6.3	1.4	6.3	1.4			6.3	1.4	42	37	0.1	0.1
35	Manufacture of other transport equipment	0.2	0.0	9.8	2.6	10.0	2.6			10.0	2.6	37	34	0.1	0.2
36	Manufacture of furniture; manufacturing n.e.c.	10.7	0.2	58.3	7.9	69.1	8.1			69.1	8.1	18	21	0.7	0.6
37	Recycling											57	57		
40101A	Production of electricity from fossil fuels											57	57		
40101B	Production of electricity from renewable sources											57	57		
40102	Distribution and trade of Electricity			983.0	449.2	983.0	449.2			983.0	449.2	4	1	10.5	32.2
40201	Manufacture of gas											57	57		
40202	Distribution and trade of gaseous fuels		1.7	2.4	26.2	2.4	27.9		7.4	2.4	35.3	48	10	0.0	2.5
41	Collection, purification and distribution of water			12.7	3.3	12.7	3.3			12.7	3.3	34	30	0.1	0.2
45	Construction	149.7	0.0	1,189.7	278.5	1,339.5	278.5			1,339.5	278.5	2	2	14.2	20.0
50	Sale, maintenance and repair of motor vehicles	53.1	2.6	232.9	21.8	286.0	24.4			286.0	24.4	11	12	3.0	1.7
51	Wholesale trade and commission trade, except of	22.0	1.1	547.8	57.9	569.8	58.9			569.8	58.9	5	4	6.1	4.2
52	Retail trade, except of motor vehicles and	30.9	1.5	469.4	46.4	500.3	47.9			500.3	47.9	7	8	5.3	3.4
55	Hotels and restaurants	63.1	3.1	384.5	81.8	447.5	84.9			447.5	84.9	9	3	4.8	6.1
601	Transport via railways	14.8		11.4	0.7	26.2	0.7			26.2	0.7	28	43	0.3	0.0
602	Other land transport	967.3		64.2	3.8	1,031.5	3.8			1,031.5	3.8	3	28	11.0	0.3
603	Transport via pipelines			1.1	0.1	1.1	0.1			1.1	0.1	53	54	0.0	0.0
61	Water transport	3.0		1.4	0.1	4.4	0.1			4.4	0.1	44	55	0.0	0.0
62	Air transport	20.2		4.6	0.2	24.9	0.2			24.9	0.2	29	48	0.3	0.0
63	Supporting and auxiliary transport activities;	6.7	0.3	82.8	5.0	89.5	5.3			89.5	5.3	16	26	1.0	0.4
64	Post and telecommunications	3.5	0.2	30.1	6.2	33.7	6.4			33.7	6.4	26	25	0.4	0.5
65	Financial intermediation, except insurance	0.0	0.0	11.5	2.8	11.5	2.8			11.5	2.8	35	32	0.1	0.2
66	Insurance and pension funding, except	0.7	0.0	15.2	3.4	15.9	3.5			15.9	3.5	33	29	0.2	0.2
67	Activities auxiliary to financial intermediation	0.0	0.0	0.9	0.2	0.9	0.2			0.9	0.2	54	50	0.0	0.0
70	Real estate activities	8.3	0.4	157.6	32.0	165.9	32.4			165.9	32.4	13	11	1.8	2.3
71	Renting of machinery and equipment without	2.6	0.1	7.5	1.0	10.1	1.2			10.1	1.2	36	40	0.1	0.1
72	Computer and related activities	0.3	0.0	7.7	1.2	8.0	1.2			8.0	1.2	41	38	0.1	0.1
73	Research and development	1.0	0.0	7.5	1.6	8.5	1.6			8.5	1.6	40	35	0.1	0.1
74	Other business activities	4.2	0.2	87.0	16.6	91.2	16.9			91.2	16.9	15	13	1.0	1.2
75	Public administration and defence; compulsory	96.1	4.7	294.2	53.5	390.3	58.2			390.3	58.2	10	5	4.1	4.2
80	Education	11.1	0.5	157.1	41.0	168.2	41.5			168.2	41.5	12	9	1.8	3.0
85	Health and social work	182.1	9.0	287.4	44.1	469.6	53.1			469.6	53.1	8	7	5.0	3.8
90	Sewage and refuse disposal, sanitation and	6.9	0.3	45.9	8.5	52.9	8.8			52.9	8.8	22	19	0.6	0.6
91	Activities of membership organizations n.e.c.	7.3	0.4	76.4	15.2	83.7	15.6			83.7	15.6	17	14	0.9	1.1
92	Recreational, cultural and sporting activities	3.2	0.2	56.9	11.4	60.0	11.6			60.0	11.6	20	17	0.6	0.8
93	Other service activities	0.9	0.0	35.0	10.4	35.8	10.5			35.8	10.5	25	18	0.4	0.8
95	Activities of households as employers of domestic											57	57		
	Total	2,239.5	46.4	6,123.6	1,340.9	8,363.0	1,387.3	1,043.6	7.4	9,406.7	1,394.8			100.0	100.0

Table 3.
CO_2 Intensities

unit: *tonnes of CO_2 / million €*

Code	Sector	Corresponding to Direct Prod. Demand e'C (1)	(1)/(5) %	+ Corresponding to Indirect Prod. Demand e'C(A+A²+…) (2)=(3)-(1)	(2)/(5) %	= Corresponding to Total Prod. Demand e'C (I-A)⁻¹ (3)	+ Corresponding to Direct Cons. Demand e'P (4)	(4)/(5) %	= Corresponding to Final Demand Total CO_2 Intensity (5)=(3)+(4)	Total CO_2 Intensit.' Ranking
01	Agriculture, hunting and related service activities	132.9	38.0	217.0	62.0	349.9			349.9	20
02	Forestry, logging and related service activities	32.4	19.7	132.5	80.3	165.0			165.0	44
05	Fishing, fish farming and related service activities	529.2	79.7	135.2	20.3	664.4			664.4	15
13	Mining of metal ores	121.2	17.7	564.2	82.3	685.4			685.4	13
14	Other mining and quarrying	216.7	27.2	580.7	72.8	797.4			797.4	10
15	Manufacture of food products and beverages	65.7	21.3	243.2	78.7	308.9			308.9	24
16	Manufacture of tobacco products	1.4	0.9	154.7	99.1	156.1			156.1	45
17	Manufacture of textiles	81.8	27.0	221.2	73.0	302.9			302.9	25
18	Manufacture of wearing apparel; dressing and	6.7	3.8	167.6	96.2	174.2			174.2	42
19	Tanning and dressing of leather; manufacture of	3.7	2.8	126.9	97.2	130.6			130.6	49
20	Manufacture of wood and of products of wood and	16.7	5.7	277.1	94.3	293.8			293.8	27
21	Manufacture of pulp, paper and paper products	41.7	6.2	626.6	93.8	668.3			668.3	14
22	Publishing, printing and reproduction of recorded	1.9	1.1	175.0	98.9	176.9			176.9	41
23	Manufacture of coke, refined petroleum products	1,826.5	19.9	306.5	3.3	2,133.1	7,062.2	76.8	9,195.3	1
24	Manufacture of chemicals and chemical products	149.8	44.2	188.9	55.8	338.7			338.7	22
25	Manufacture of rubber and plastic products	16.4	5.7	270.8	94.3	287.2			287.2	28
26	Manufacture of other non-metallic mineral products	811.2	63.7	461.5	36.3	1,272.7			1,272.7	7
27	Manufacture of basic metals	75.4	20.3	295.9	79.7	371.3			371.3	19
28	Manufacture of fabricated metal products, except	22.7	10.7	190.6	89.3	213.4			213.4	36
29	Manufacture of machinery and equipment n.e.c.	94.0	35.3	172.4	64.7	266.4			266.4	30
30	Manufacture of office machinery and computers	0.0	0.1	29.2	99.9	29.2			29.2	62
31	Manufacture of electrical machinery and apparatus	2.0	1.1	175.6	98.9	177.6			177.6	40
32	Manufacture of radio, television and communication	0.4	0.3	132.2	99.7	132.6			132.6	47
33	Manufacture of medical, precision and optical	1.0	0.7	130.7	99.3	131.7			131.7	48
34	Manufacture of motor vehicles, trailers and	0.6	0.6	103.9	99.4	104.5			104.5	51
35	Manufacture of other transport equipment	1.7	1.6	102.5	98.4	104.2			104.2	52
36	Manufacture of furniture; manufacturing n.e.c.	33.2	14.5	195.9	85.5	229.1			229.1	34
37	Recycling	12.6	4.2	289.8	95.8	302.4			302.4	26
40101A	Production of electricity from fossil fuels	8,023.2	97.9	172.3	2.1	8,195.5			8,195.5	2
40101B	Production of electricity from renewable sources			50.1	100.0	50.1			50.1	61
40102	Distribution and trade of Electricity			3,215.8	100.0	3,215.8			3,215.8	6
40201	Manufacture of gas	2,907.6	88.5	377.8	11.5	3,285.4			3,285.4	5
40202	Distribution and trade of gaseous fuels	56.7	4.5	957.6	76.2	1,014.3	243.0	19.3	1,257.3	8
41	Collection, purification and distribution of water			230.9	100.0	230.9			230.9	33
45	Construction	31.6	9.6	296.6	90.4	328.2			328.2	23
50	Sale, maintenance and repair of motor vehicles and	38.6	18.1	174.9	81.9	213.5			213.5	35
51	Wholesale trade and commission trade, except of	12.9	3.7	335.6	96.3	348.5			348.5	21
52	Retail trade, except of motor vehicles and	16.0	6.0	252.8	94.0	268.8			268.8	29
55	Hotels and restaurants	33.5	12.8	229.1	87.2	262.6			262.6	31
601	Transport via railways	440.4	55.4	354.2	44.6	794.6			794.6	11
602	Other land transport	5,639.5	93.5	391.4	6.5	6,030.9			6,030.9	3
603	Transport via pipelines			241.6	100.0	241.6			241.6	32
61	Water transport	530.7	68.4	245.0	31.6	775.6			775.6	12
62	Air transport	955.0	80.9	226.1	19.1	1,181.1			1,181.1	9
63	Supporting and auxiliary transport activities;	35.8	7.4	446.4	92.6	482.2			482.2	17
64	Post and telecommunications	7.6	9.5	71.6	90.5	79.2			79.2	56
65	Financial intermediation, except insurance	0.0	0.0	65.8	100.0	65.8			65.8	58
66	Insurance and pension funding, except compulsory	2.3	4.1	54.4	95.9	56.7			56.7	59
67	Activities auxiliary to financial intermediation	0.1	0.1	56.1	99.9	56.2			56.2	60
70	Real estate activities	3.9	4.5	82.4	95.5	86.3			86.3	54
71	Renting of machinery and equipment without	16.7	24.4	51.8	75.6	68.5			68.5	57
72	Computer and related activities	3.6	3.1	112.3	96.9	115.8			115.8	50
73	Research and development	22.4	10.7	186.2	89.3	208.6			208.6	37
74	Other business activities	8.1	4.2	184.7	95.8	192.8			192.8	38
75	Public administration and defence; compulsory	32.4	22.9	109.1	77.1	141.5			141.5	46
80	Education	4.9	5.7	79.7	94.3	84.6			84.6	55
85	Health and social work	68.0	37.0	115.6	63.0	183.5			183.5	39
90	Sewage and refuse disposal, sanitation and similar	64.2	12.1	467.3	87.9	531.5			531.5	16
91	Activities of membership organizations n.e.c.	38.1	7.9	442.1	92.1	480.2			480.2	18
92	Recreational, cultural and sporting activities	4.5	4.7	90.4	95.3	94.9			94.9	53
93	Other service activities	3.4	2.0	161.9	98.0	165.2			165.2	43
95	Activities of households as employers of domestic		0,0		0,0			0,0		63

Table 4. CO_2 Emissions
corresponding to domestic consumption

(y_{dom} = Final consumption of households + Collective consumption + Gross fixed capital formation + Change in stocks)

unit: 10^3 *tonnes of* CO_2

		Corresponding to Direct Prod. Demand	+	Corresponding to Indirect Prod. Demand	=	Corresponding to Total Prod. Demand	+ Corresponding to Direct Cons. Demand	=	Corresponding to Final Demand		
		e'C y_{dom}		**e'C $(A+A^2+\ldots)$ y_{dom}**		**$e'C(I-A)^{-1}y_{dom}$**	**e'PZ y_{dom}**		**Total CO_2 emissions**	Total CO_2 Emiss.' Ranking	% Distrib. of CO_2 Emiss. by Industry
		(1)	(1)/(5) %	(2)=(3)-(1)	(2)/(5) %	(3)	(4)	(4)/(5) %	(5)=(3)+(4)		
01	Agriculture, hunting and related service activities	180.9	38.0	295.4	62.0	476.3			476.3	14	1.5
02	Forestry, logging and related service activities	2.0	19.7	8.2	80.3	10.1			10.1	46	0.0
05	Fishing, fish farming and related service activities	153.5	79.7	39.2	20.3	192.7			192.7	21	0.6
13	Mining of metal ores		0,0		0,0			0,0		57	
14	Other mining and quarrying	1.2	27.2	3.3	72.8	4.5			4.5	52	0.0
15	Manufacture of food products and beverages	393.3	21.3	1,456.1	78.7	1,849.4			1,849.4	6	5.8
16	Manufacture of tobacco products	0.3	0.9	30.0	99.1	30.3			30.3	40	0.1
17	Manufacture of textiles	26.2	27.0	70.9	73.0	97.1			97.1	27	0.3
18	Manufacture of wearing apparel; dressing and	6.3	3.8	158.2	96.2	164.5			164.5	23	0.5
19	Tanning and dressing of leather; manufacture of	0.9	2.8	30.6	97.2	31.5			31.5	39	0.1
20	Manufacture of wood and of products of wood and	0.9	5.7	14.2	94.3	15.1			15.1	44	0.0
21	Manufacture of pulp, paper and paper products	0.6	6.2	8.6	93.8	9.2			9.2	47	0.0
22	Publishing, printing and reproduction of recorded	0.6	1.1	55.6	98.9	56.2			56.2	34	0.2
23	Manufacture of coke, refined petroleum products	821.9	19.9	137.9	3.3	959.9	3,172.2	76.8	4,132.1	2	13.0
24	Manufacture of chemicals and chemical products	85.4	44.2	107.8	55.8	193.2			193.2	20	0.6
25	Manufacture of rubber and plastic products	3.6	5.7	59.9	94.3	63.5			63.5	32	0.2
26	Manufacture of other non-metallic mineral products	44.4	63.7	25.3	36.3	69.7			69.7	31	0.2
27	Manufacture of basic metals	1.6	20.3	6.1	79.7	7.6			7.6	49	0.0
28	Manufacture of fabricated metal products, except	0.9	10.7	7.7	89.3	8.6			8.6	48	0.0
29	Manufacture of machinery and equipment n.e.c.	52.4	35.3	96.0	64.7	148.4			148.4	24	0.5
30	Manufacture of office machinery and computers	0.0	0.1	6.3	99.9	6.3			6.3	50	0.0
31	Manufacture of electrical machinery and apparatus	0.0	1.1	1.8	98.9	1.8			1.8	56	0.0
32	Manufacture of radio, television and communication	0.0	0.3	4.6	99.7	4.6			4.6	51	0.0
33	Manufacture of medical, precision and optical	0.0	0.7	2.9	99.3	2.9			2.9	55	0.0
34	Manufacture of motor vehicles, trailers and	0.1	0.6	22.3	99.4	22.4			22.4	43	0.1
35	Manufacture of other transport equipment	0.6	1.6	35.8	98.4	36.4			36.4	37	0.1
36	Manufacture of furniture; manufacturing n.e.c.	33.1	14.5	195.8	85.5	228.9			228.9	18	0.7
37	Recycling		0,0		0,0			0,0		57	
40101A	Production of electricity from fossil fuels		0,0		0,0			0,0		57	
40101B	Production of electricity from renewable sources		0,0		0,0			0,0		57	
40102	Distribution and trade of Electricity			4,037.7	100.0	4,037.7			4,037.7	3	12.7
40201	Manufacture of gas		0,0		0,0			0,0		57	
40202	Distribution and trade of gaseous fuels	4.0	4.5	68.4	76.2	72.4	17.4	19.3	89.8	28	0.3
41	Collection, purification and distribution of water			46.4	100.0	46.4			46.4	35	0.1
45	Construction	455.2	9.6	4,267.2	90.4	4,722.4			4,722.4	1	14.8
50	Sale, maintenance and repair of motor vehicles and	167.5	18.1	758.7	81.9	926.3			926.3	11	2.9
51	Wholesale trade and commission trade, except of	69.4	3.7	1,800.2	96.3	1,869.6			1,869.6	5	5.9
52	Retail trade, except of motor vehicles and	97.3	6.0	1,535.3	94.0	1,632.7			1,632.7	7	5.1
55	Hotels and restaurants	198.9	12.8	1,359.9	87.2	1,558.8			1,558.8	8	4.9
601	Transport via railways	45.0	55.4	36.2	44.6	81.2			81.2	29	0.3
602	Other land transport	2,940.2	93.5	204.1	6.5	3,144.3			3,144.3	4	9.9
603	Transport via pipelines			3.5	100.0	3.5			3.5	53	0.0
61	Water transport	9.2	68.4	4.2	31.6	13.4			13.4	45	0.0
62	Air transport	61.5	80.9	14.6	19.1	76.1			76.1	30	0.2
63	Supporting and auxiliary transport activities;	21.1	7.4	263.5	92.6	284.6			284.6	17	0.9
64	Post and telecommunications	11.2	9.5	106.1	90.5	117.3			117.3	26	0.4
65	Financial intermediation, except insurance	0.0	0.0	41.6	100.0	41.6			41.6	36	0.1
66	Insurance and pension funding, except compulsory	2.3	4.1	54.1	95.9	56.4			56.4	33	0.2
67	Activities auxiliary to financial intermediation	0.0	0.1	3.0	99.9	3.1			3.1	54	0.0
70	Real estate activities	26.2	4.5	553.9	95.5	580.1			580.1	13	1.8
71	Renting of machinery and equipment without	8.2	24.4	25.3	75.6	33.4			33.4	38	0.1
72	Computer and related activities	0.8	3.1	26.3	96.9	27.1			27.1	42	0.1
73	Research and development	3.2	10.7	26.4	89.3	29.6			29.6	41	0.1
74	Other business activities	13.3	4.2	303.2	95.8	316.5			316.5	15	1.0
75	Public administration and defence; compulsory	303.0	22.9	1,019.4	77.1	1,322.4			1,322.4	10	4.2
80	Education	34.9	5.7	573.3	94.3	608.2			608.2	12	1.9
85	Health and social work	574.5	37.0	976.8	63.0	1,551.3			1,551.3	9	4.9
90	Sewage and refuse disposal, sanitation and similar	21.9	12.1	159.4	87.9	181.3			181.3	22	0.6
91	Activities of membership organizations n.e.c.	23.1	7.9	267.7	92.1	290.8			290.8	16	0.9
92	Recreational, cultural and sporting activities	9.9	4.7	199.6	95.3	209.5			209.5	19	0.7
93	Other service activities	2.7	2.0	130.7	98.0	133.4			133.4	25	0.4
95	Activities of households as employers of domestic		0,0		0,0			0,0		57	
	Total	6,915.6	21.7	21,747.1	68.3	28,662.7	3,189.6	10.0	31,852.3		100.0

Table 5. Energy and CO_2 'embodied' in Portuguese iInternational trade

(y_{dom} = FCH + CC + GFCF + CS)
(y_{exp} = Exports of G&S); (y_{imp} = Imports of G&S)

unit for primary energy requirements: 10^3 *toe*
unit for CO_2 emissions: 10^3 *tonnes of* CO_2

		Primary Energy Requirements						CO_2 Emissions						
		Exports		- Imports		= Exports - Imports		Exports			- Imports			= Exp - Imp
		Total Primary Energy 'embodied' in Exports		- Total Primary Energy 'embodied' in imports		= Total Primary Energy Trade Balance		Corresp. to Direct Prod. Demand	+ Corresp. to Ind. Prod. Demand	= Tt. CO_2 emiss. corresp. to Portug. exports	Corresp. to Imports for use in Prod.	+ Corresp. to Imp. for use by final cons.	= Tt. CO_2 emiss. corresp. to Port. Imports	Tt. CO_2 emis. Trade Balance
		$C(I-A)^{-1} y_{exp}$		$C(I-A)^{-1} B(I-A)_{-1} y_{dom} + C(I-A)^{-1}y_{imp}$		$f_{tb}=f_{exp}-f_{imp}$		$e'C\, y_{exp}$	$e'C(A+A^2+\ldots)y_{exp}$	$e'C(I-A)^{-1} y_{exp}$	$e'C(I-A)^{-1}B (I-A)^{-1}y_{dom}$	$e'C(I-A)^{-1} y_{imp}$	$e'C\ldots y_{dom}+ e'C(I-A)^{-1}y_{imp}$	$c_{tb}=c_{exp}-c_{imp}$
		(1) Oil	(2) Natural gas	(3) Oil	(4) Natural gas	(5) Oil	(6) Natural gas	(7)	(8)	(9)=(7)+(8)	(10)	(11)	(12)=(10)+(11)	(13)=(9)-(12)
01	Agriculture, hunting and related service activities	16.2	1.4	61.3	3.2	-45.1	-1.8	20.0	32.6	52.6	90.3	111.8	202.1	-149.5
02	Forestry, logging and related service activities	2.7	0.0	2.2	0.0	0.5	0.0	1.6	6.6	8.3	4.1		4.1	4.2
05	Fishing, fish farming and related service activities	14.7	0.3	32.7	0.4	-18.0	-0.2	36.0	9.2	45.2	19.2	33.1	52.3	-7.1
13	Mining of metal ores	22.9	2.1	20.6	0.1	2.3	1.9	13.2	61.4	74.5				74.5
14	Other mining and quarrying	12.5	0.8	30.4	0.2	-17.9	0.6	10.9	29.1	40.0	0.4	0.9	1.3	38.6
15	Manufacture of food products and beverages	142.1	13.3	193.0	14.2	-51.0	-0.9	98.5	364.5	463.0	397.2	550.5	947.8	-484.7
16	Manufacture of tobacco products	1.5	0.1	33.0	0.3	-31.5	-0.2	0.0	4.8	4.8	12.9	12.7	25.6	-20.7
17	Manufacture of textiles	209.3	38.1	76.4	5.8	133.0	32.4	195.8	529.6	725.5	21.3	118.2	139.5	586.0
18	Manufacture of wearing apparel; dressing and	133.2	19.0	81.4	5.6	51.8	13.5	17.2	432.1	449.3	62.6	246.7	309.3	140.0
19	Tanning and dressing of leather; manufacture of	64.6	10.1	43.5	1.8	21.1	8.3	6.2	213.6	219.9	16.0	92.4	108.4	111.5
20	Manufacture of wood and of products of wood and	99.8	6.0	26.7	0.2	73.1	5.8	18.1	299.4	317.4	3.4	5.4	8.8	308.7
21	Manufacture of pulp, paper and paper products	198.7	44.4	70.6	2.8	128.1	41.6	44.1	663.6	707.7	0.9	18.5	19.4	688.3
22	Publishing, printing and reproduction of recorded	2.5	0.4	56.9	1.8	-54.4	-1.3	0.1	8.6	8.7	21.1	52.2	73.3	-64.6
23	Manufacture of coke, refined petroleum products	292.8	6.5	94.7	1.4	198.0	5.2	775.0	130.1	905.1	29.9	28.1	58.0	847.1
24	Manufacture of chemicals and chemical products	106.1	23.7	169.0	21.2	-62.9	2.4	167.1	210.8	377.9	37.8	341.4	379.3	-1.4
25	Manufacture of rubber and plastic products	49.8	7.7	79.9	3.8	-30.1	3.9	9.7	159.8	169.5	14.7	87.3	102.0	67.5
26	Manufacture of other non-metallic mineral products	286.0	110.6	70.1	10.0	215.9	100.6	718.8	409.0	1,127.8	3.6	26.6	30.2	1,097.6
27	Manufacture of basic metals	46.1	18.1	41.7	0.6	4.3	17.4	37.0	145.2	182.3	1.4		1.4	180.9
28	Manufacture of fabricated metal products, except	39.3	8.3	61.9	1.4	-22.6	6.9	14.8	124.1	138.9	2.7	15.1	17.7	121.2
29	Manufacture of machinery and equipment n.e.c.	93.3	18.1	90.4	6.6	2.9	11.5	115.0	210.9	325.9	36.9	141.6	178.6	147.3
30	Manufacture of office machinery and computers	0.8	0.1	12.5	0.2	-11.7	0.0	0.0	2.8	2.8	14.2	14.0	28.2	-25.3
31	Manufacture of electrical machinery and apparatus	86.0	10.9	46.6	0.8	39.4	10.1	3.2	283.6	286.8	0.7	16.9	17.6	269.2
32	Manufacture of radio, television and communication	58.4	7.3	66.6	3.2	-8.2	4.1	0.5	194.0	194.5	2.3	205.4	207.7	-13.2
33	Manufacture of medical, precision and optical	7.7	1.3	33.6	1.1	-26.0	0.2	0.2	26.1	26.3	1.5	45.5	47.0	-20.7
34	Manufacture of motor vehicles, trailers and	102.9	23.2	132.6	20.2	-29.6	3.0	2.2	365.0	367.2	14.3	1,042.3	1,056.5	-689.3
35	Manufacture of other transport equipment	11.4	3.0	31.9	1.1	-20.5	1.9	0.7	40.8	41.5	23.2	33.5	56.7	-15.2
36	Manufacture of furniture; manufacturing n.e.c.	35.2	4.1	77.8	4.2	-42.6	0.0	16.9	99.8	116.7	66.3	162.5	228.8	-112.0
37	Recycling			25.2	0.3	-25.2	-0.3							
40101A	Production of electricity from fossil fuels	218.2	99.8	42.8	0.1	175.4	99.7	877.7	18.8	896.5				896.5
40101B	Production of electricity from renewable sources	0.4	0.1	40.6	0.1	-40.2	0.0		1.3	1.3				1.3
40102	Distribution and trade of Electricity	1.4	0.7	83.6	1.3	-82.2	-0.7		5.9	5.9	83.3		83.3	-77.4
40201	Manufacture of gas			107.4	0.2	-107.4	-0.2							
40202	Distribution and trade of gaseous fuels	0.0	0.0	34.6	2.4	-34.6	-2.3	0.0	0.1	0.1	4.7		4.7	-4.7
41	Collection, purification and distribution of water	0.0	0.0	17.3	0.2	-17.3	-0.1		0.1	0.1	13.3		13.3	-13.2
45	Construction	0.4	0.1	37.5	0.4	-37.1	-0.3	0.1	1.4	1.5	954.6		954.6	-953.0
50	Sale, maintenance and repair of motor vehicles and	0.1	0.0	19.4	0.1	-19.3	-0.1	0.0	0.2	0.3	287.8		287.8	-287.5
51	Wholesale trade and commission trade, except of	42.7	4.4	25.9	0.2	16.8	4.3	5.2	134.8	140.0	355.9		355.9	-215.9
52	Retail trade, except of motor vehicles and	0.0	0.0	14.4	0.1	-14.4	-0.1	0.0	0.0	0.0	403.0	0.1	403.0	-403.0
55	Hotels and restaurants	12.7	2.4	37.8	0.2	-25.1	2.2	5.6	38.6	44.3	393.8		393.8	-349.5
601	Transport via railways	7.9	0.2	14.7	0.1	-6.8	0.1	13.6	10.9	24.5	6.8	0.1	6.9	17.6
602	Other land transport	1,019.9	3.8	24.7	0.1	995.2	3.7	2,907.2	201.8	3,108.9	34.6	1.5	36.1	3,072.8
603	Transport via pipelines	0.2	0.0	9.9	0.0	-9.8	0.0		0.6	0.6	1.0	0.0	1.0	-0.4
61	Water transport	42.2	0.5	45.1	0.1	-2.9	0.4	88.5	40.8	129.3	1.1		1.1	128.1
62	Air transport	315.4	2.7	108.8	0.3	206.6	2.3	780.2	184.7	965.0	4.3	22.0	26.2	938.7
63	Supporting and auxiliary transport activities;	35.4	2.1	16.6	0.1	18.8	2.0	8.3	104.1	112.5	39.2		39.2	73.3
64	Post and telecommunications	4.2	0.8	8.5	0.1	-4.3	0.7	1.4	13.3	14.7	98.3	5.7	104.0	-89.3
65	Financial intermediation, except insurance	3.0	0.7	6.3	0.1	-3.4	0.7	0.0	10.8	10.8	41.9		41.9	-31.1
66	Insurance and pension funding, except compulsory	1.0	0.2	7.3	0.1	-6.4	0.1	0.1	3.3	3.4	65.9	0.0	66.0	-62.6
67	Activities auxiliary to financial intermediation	1.1	0.2	7.3	0.1	-6.2	0.1	0.0	3.7	3.7	3.6		3.6	0.1
70	Real estate activities	0.0	0.0	7.2	0.1	-7.2	-0.1	0.0	0.1	0.1	446.0		446.0	-445.9
71	Renting of machinery and equipment without	0.5	0.1	6.6	0.1	-6.2	0.0	0.4	1.2	1.5	32.4		32.4	-30.8
72	Computer and related activities	2.6	0.4	13.2	0.1	-10.7	0.2	0.3	8.4	8.7	15.5	3.7	19.2	-10.5
73	Research and development	1.0	0.2	13.6	0.1	-12.6	0.1	0.4	3.1	3.5	9.4		9.4	-5.9
74	Other business activities	30.7	5.7	19.5	0.2	11.2	5.5	4.5	102.0	106.4	108.9		108.9	-2.5
75	Public administration and defence; compulsory			8.6	0.1	-8.6	-0.1				620.2		620.2	-620.2
80	Education			5.8	0.0	-5.8	0.0				477.0		477.0	-477.0
85	Health and social work			22.0	0.2	-22.0	-0.2				560.8		560.8	-560.8
90	Sewage and refuse disposal, sanitation and similar	0.1	0.0	19.1	0.1	-19.0	-0.1	0.0	0.3	0.3	22.6		22.6	-22.3
91	Activities of membership organizations n.e.c.			27.9	0.2	-27.9	-0.2				40.2		40.2	-40.2
92	Recreational, cultural and sporting activities	3.1	0.6	12.1	0.1	-9.0	0.5	0.5	10.2	10.7	146.4		146.4	-135.8
93	Other service activities	0.1	0.0	16.9	0.3	-16.8	-0.2	0.0	0.4	0.4	53.6	3.0	56.6	-56.2
95	Activities of households as employers of domestic										38.1		38.1	-38.1
	Total	3,881.2	505.0	2,707.4	121.0	1,173.8	384.0	7,017.0	5,960.5	12,977.5	6,262.8	3,438.7	9,701.5	3,276.0

Table 6. Portuguese 'responsibility' for CO_2 emissions *versus* CO_2 emissions produced by the Portuguese economy

(y_{dom} = FCH + CC + GFCF + CS)
(y_{exp} = Exports of G&S)
(y_{imp} = Imports of G&S)

unit: 10^3 tonnes of CO_2

		Corresponding to domestic consumption	+	Corresponding to Portuguese imports	=	Portuguese 'responsibility' for CO_2 emissions		Corresponding to domestic consumption	+	Corresponding to Portuguese exports	=	CO_2 emissions produced by the Portug. Economy	
		$e'C(I-A)^{-1}y_{dom}$+ $e'PZy_{dom}$		$e'C(I-A)^{-1}B(I-A)^{-1}y_{dom}$+$e'C(I-A)^{-1}y_{dom}$		$c_{resp}=c_{dom}+c_{imp}$	Portug. 'respons.' for CO_2 Emis.' Rank.	$e'C(I-A)^{-1}y_{dom}$+ $e'PZy_{dom}$		$e'C(I-A)^{-1}y_{exp}$		$c_{emis}=c_{dom}+c_{exp}$	CO_2 emis. by the Portug. economy's Rank.
		(1)	(1)/(3) %	(2)	(2)/(3) %	(3)=(1)+(2)		(4)	(4)/(6) %	(5)	(5)/(6) %	(6)=(4)+(5)	
01	Agriculture, hunting and related service activities	476.3	70.2	202.1	29.8	678.4	15	476.3	90.1	52.6	9.9	528.9	21
02	Forestry, logging and related service activities	10.1	71.3	4.1	28.7	14.2	53	10.1	55.1	8.3	44.9	18.4	55
05	Fishing, fish farming and related service activities	192.7	78.6	52.3	21.4	245.0	24	192.7	81.0	45.2	19.0	237.9	31
13	Mining of metal ores		0,0		0,0		58			74.5	100.0	74.5	44
14	Other mining and quarrying	4.5	77.2	1.3	22.8	5.8	56	4.5	10.1	40.0	89.9	44.4	49
15	Manufacture of food products and beverages	1,849.4	66.1	947.8	33.9	2,797.1	5	1,849.4	80.0	463.0	20.0	2,312.4	5
16	Manufacture of tobacco products	30.3	54.2	25.6	45.8	55.9	42	30.3	86.2	4.8	13.8	35.1	51
17	Manufacture of textiles	97.1	41.0	139.5	59.0	236.6	25	97.1	11.8	725.5	88.2	822.6	15
18	Manufacture of wearing apparel; dressing and	164.5	34.7	309.3	65.3	473.8	17	164.5	26.8	449.3	73.2	613.7	17
19	Tanning and dressing of leather; manufacture of	31.5	22.5	108.4	77.5	139.9	31	31.5	12.5	219.9	87.5	251.3	30
20	Manufacture of wood and of products of wood and	15.1	63.2	8.8	36.8	23.9	50	15.1	4.5	317.4	95.5	332.5	27
21	Manufacture of pulp, paper and paper products	9.2	32.2	19.4	67.8	28.7	48	9.2	1.3	707.7	98.7	716.9	16
22	Publishing, printing and reproduction of recorded	56.2	43.4	73.3	56.6	129.5	32	56.2	86.6	8.7	13.4	64.9	45
23	Manufacture of coke, refined petroleum products	4,132.1	98.6	58.0	1.4	4,190.1	2	4,132.1	82.0	905.1	18.0	5,037.2	2
24	Manufacture of chemicals and chemical products	193.2	33.8	379.3	66.2	572.5	16	193.2	33.8	377.9	66.2	571.1	20
25	Manufacture of rubber and plastic products	63.5	38.4	102.0	61.6	165.5	30	63.5	27.3	169.5	72.7	233.0	32
26	Manufacture of other non-metallic mineral products	69.7	69.8	30.2	30.2	99.9	35	69.7	5.8	1,127.8	94.2	1,197.5	11
27	Manufacture of basic metals	7.6	84.8	1.4	15.2	9.0	54	7.6	4.0	182.3	96.0	189.9	35
28	Manufacture of fabricated metal products, except	8.6	32.7	17.7	67.3	26.3	49	8.6	5.8	138.9	94.2	147.5	37
29	Manufacture of machinery and equipment n.e.c.	148.4	45.4	178.6	54.6	327.0	22	148.4	31.3	325.9	68.7	474.3	22
30	Manufacture of office machinery and computers	6.3	18.2	28.2	81.8	34.4	47	6.3	68.9	2.8	31.1	9.1	56
31	Manufacture of electrical machinery and apparatus	1.8	9.5	17.6	90.5	19.4	51	1.8	0.6	286.8	99.4	288.6	29
32	Manufacture of radio, television and communication	4.6	2.2	207.7	97.8	212.4	27	4.6	2.3	194.5	97.7	199.2	34
33	Manufacture of medical, precision and optical	2.9	5.8	47.0	94.2	49.9	43	2.9	10.0	26.3	90.0	29.2	54
34	Manufacture of motor vehicles, trailers and	22.4	2.1	1,056.5	97.9	1,079.0	13	22.4	5.8	367.2	94.2	389.6	25
35	Manufacture of other transport equipment	36.4	39.1	56.7	60.9	93.0	37	36.4	46.7	41.5	53.3	77.8	43
36	Manufacture of furniture; manufacturing n.e.c.	228.9	50.0	228.8	50.0	457.7	18	228.9	66.2	116.7	33.8	345.7	26
37	Recycling		0,0		0,0		58		0		0		61
40101A	Production of electricity from fossil fuels		0,0		0,0		58			896.5	100.0	896.5	14
40101B	Production of electricity from renewable sources		0,0		0,0		58			1.3	100.0	1.3	60
40102	Distribution and trade of Electricity	4,037.7	98.0	83.3	2.0	4,121.0	3	4,037.7	99.9	5.9	0.1	4,043.7	4
40201	Manufacture of gas		0,0		0,0		58		0		0		61
40202	Distribution and trade of gaseous fuels	89.8	95.0	4.7	5.0	94.5	36	89.8	99.9	0.1	0.1	89.9	42
41	Collection, purification and distribution of water	46.4	77.7	13.3	22.3	59.7	41	46.4	99.8	0.1	0.2	46.5	48
45	Construction	4,722.4	83.2	954.6	16.8	5,677.0	1	4,722.4	100.0	1.5	0.0	4,723.9	3
50	Sale, maintenance and repair of motor vehicles and	926.3	76.3	287.8	23.7	1,214.0	11	926.3	100.0	0.3	0.0	926.5	13
51	Wholesale trade and commission trade, except of	1,869.6	84.0	355.9	16.0	2,225.5	6	1,869.6	93.0	140.0	7.0	2,009.6	6
52	Retail trade, except of motor vehicles and	1,632.7	80.2	403.0	19.8	2,035.7	8	1,632.7	100.0	0.0	0.0	1,632.7	7
55	Hotels and restaurants	1,558.8	79.8	393.8	20.2	1,952.6	9	1,558.8	97.2	44.3	2.8	1,603.1	8
601	Transport via railways	81.2	92.1	6.9	7.9	88.1	38	81.2	76.8	24.5	23.2	105.6	41
602	Other land transport	3,144.3	98.9	36.1	1.1	3,180.4	4	3,144.3	50.3	3,108.9	49.7	6,253.2	1
603	Transport via pipelines	3.5	78.2	1.0	21.8	4.5	57	3.5	85.3	0.6	14.7	4.1	58
61	Water transport	13.4	92.1	1.1	7.9	14.6	52	13.4	9.4	129.3	90.6	142.7	38
62	Air transport	76.1	74.4	26.2	25.6	102.3	34	76.1	7.3	965.0	92.7	1,041.1	12
63	Supporting and auxiliary transport activities;	284.6	87.9	39.2	12.1	323.8	23	284.6	71.7	112.5	28.3	397.1	24
64	Post and telecommunications	117.3	53.0	104.0	47.0	221.3	26	117.3	88.9	14.7	11.1	132.0	40
65	Financial intermediation, except insurance	41.6	49.8	41.9	50.2	83.5	39	41.6	79.4	10.8	20.6	52.4	47
66	Insurance and pension funding, except compulsory	56.4	46.1	66.0	53.9	122.3	33	56.4	94.3	3.4	5.7	59.8	46
67	Activities auxiliary to financial intermediation	3.1	45.9	3.6	54.1	6.7	55	3.1	45.0	3.7	55.0	6.8	57
70	Real estate activities	580.1	56.5	446.0	43.5	1,026.1	14	580.1	100.0	0.1	0.0	580.2	19
71	Renting of machinery and equipment without	33.4	50.8	32.4	49.2	65.8	40	33.4	95.6	1.5	4.4	35.0	52
72	Computer and related activities	27.1	58.5	19.2	41.5	46.3	44	27.1	75.8	8.7	24.2	35.8	50
73	Research and development	29.6	75.9	9.4	24.1	39.0	45	29.6	89.5	3.5	10.5	33.0	53
74	Other business activities	316.5	74.4	108.9	25.6	425.4	19	316.5	74.8	106.4	25.2	423.0	23
75	Public administration and defence; compulsory	1,322.4	68.1	620.2	31.9	1,942.6	10	1,322.4	100.0			1,322.4	10
80	Education	608.2	56.0	477.0	44.0	1,085.2	12	608.2	100.0			608.2	18
85	Health and social work	1,551.3	73.4	560.8	26.6	2,112.1	7	1,551.3	100.0			1,551.3	9
90	Sewage and refuse disposal, sanitation and similar	181.3	88.9	22.6	11.1	204.0	28	181.3	99.8	0.3	0.2	181.7	36
91	Activities of membership organizations n.e.c.	290.8	87.9	40.2	12.1	331.0	21	290.8	100.0			290.8	28
92	Recreational, cultural and sporting activities	209.5	58.9	146.4	41.1	356.0	20	209.5	95.2	10.7	4.8	220.2	33
93	Other service activities	133.4	70.2	56.6	29.8	190.0	29	133.4	99.7	0.4	0.3	133.8	39
95	Activities of households as employers of domestic			38.1	100.0	38.1	46		0		0		61
	Total	31,852.3	76.7	9,701.5	23.3	41,553.8		31,852.3	71.1	12,977.5	28.9	44,829.8	