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ESTIMATION AND CONTROL OF SPANISH ENERGY- RELATED CO_2 EMISSIONS: AN INPUT – OUTPUT APPROACH

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Estimation and Control of Spanish Energy-Related CO_2 Emissions: An Input-Output Approach

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Abstract

This article uses input-output methods to obtain the energy-related CO_2 intensities for the Spanish economy in 1992. Based on those intensities, it yields a structural decomposition of Spanish energy-related CO_2 emissions and an estimation of the price effects of hypothetical carbon taxes levied on fossil fuel consumption in 1998. Thus the paper responds both to a lack of reliable disaggregated data on Spanish CO_2 emissions and to a growing awareness on the effectiveness of Spanish climate change policies.

Key words: CO_2 emissions; carbon taxation; Spain.

JEL classification: C67, H23, Q48.

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1. Introduction

As pointed out by a growing scientific evidence and consensus, climate change is nowadays a most pressing environmental problem faced by humankind. Climate change phenomena are provoked by the increasing concentrations of greenhouse gases in the atmosphere, with anthropogenic CO_2 production as the main contributor. Hence, the unequivocal need to define and subsequently control human-made CO_2 emissions.

With such objectives in mind, our article provides a new disaggregated measurement of Spanish energy-related CO_2 emissions and an estimation of the price effects of alternative (hypothetical) carbon taxes in Spain. Previous work on these issues includes the decomposition of Spanish CO_2 emissions by Antón and de Bustos (1995), and the calculation of the price effects of the proposed European carbon tax within Spain (Martín and Velázquez, 1992). However those exercises employ 1985 energy and input-output data, largely outdated after the strong changes brought about by the Spanish growth processes of the late 1980s and early 1990s. Moreover, the use of an input-output price model by Martín and Velázquez contrasts with the recent and widespread application of input-output demand models to calculate CO_2 intensities by sector and eventually the price effects of carbon taxes.

This article overcomes the preceding shortcomings, following the same approximation used by Gay and Proops (1993) and Proops, Faber and Wagenhals (1993) to estimate British and German CO_2 emissions, thus allowing for an international comparison of the results. Our price effects are also obtained through input-output methods as in Symons, Proops and Gay (1994) for the United Kingdom, or Cornwell and Creedy (1996) for Australia. In contrast with those exercises, however, we advocate and simulate the use of the actual damage approach as the primary basis for a unilateral carbon tax rate.

The structure of the paper is as follows. Section 2 examines the main reasons for a comprehensive assessment and control of Spanish CO_2 emissions, with an emphasis on the use of environmental taxation. In Section 3 we describe the input-output methods that allow us to calculate the (energy-related) CO_2 intensities for each Spanish economic sector, the foundation to calculate disaggregated emissions by sector and the price effects of taxes on CO_2 emissions. Section 4 deals with the data needed for the empirical implementation of the input-output model. Section 5 yields the main results of the exercise, whose policy implications are discussed in Section 6. Finally, the conclusions of the article are presented in Section 7.

2. Spanish CO_2 Emissions: The Need for Assessment and Control

Despite Spain is not a major CO_2 emitter and is currently subject to rather lax international commitments,[1] there are powerful reasons to think that climate change concerns may play a significant role in future Spanish environmental policies.

First of all, there are strong internal pressures to control the emission of greenhouse gases, as Spain is already largely susceptible to processes of desert advance and water scarcity that are likely to worsen with climate change. There are also external pressures to control Spanish CO_2 emissions, specially due to the exponential growth in recent years which, at the moment of writing, has almost consumed the Kyoto permitted increase in greenhouse gas emissions for the year 2010.[2] Moreover, economic convergence to EU averages and the rising Spanish energy and carbon intensities will probably make untenable the preferential treatment enjoyed by Spain in this matter so far.

Therefore it is clear that some policy instruments to control Spanish CO_2 emissions are necessary at the moment. In particular, we will consider the use of environmental taxes, a well known and efficient 'market' mechanism of environmental policy. Yet before implementing any control instrument on Spanish CO_2 emissions it is desirable to have detailed information on them, as we observe next.

2.1. Towards a Comprehensive Assessment of Spanish CO_2 Emissions

Table 1 presents the main sources of Spanish CO_2 emissions in 1994, the latest available at the moment of writing. Note the importance of energy-related emissions, which explains our focus in the energy segment.

Still, there are significant pieces of information missing in this table. First of all, the degree of aggregation is very high, specially within the energy field. However, it is perhaps more important to know the sectors that are really responsible for CO_2 emissions, rather than those that directly cause such emissions.[3]

[1] Spain signed and ratified the United Nations Framework Convention on Climate Change. As an Annex I party, Spain should return to 1990 levels of anthropogenic greenhouse gas emissions by the year 2000 (Rio target). Moreover, as an Annex B party of the 1997 Kyoto Protocol developing the Convention, Spanish greenhouse gas emissions in 2010 should be below 1990 levels. In both cases, however, Spain was granted a surprising exemption through an EU's overall target which allowed Spanish emissions to grow substantially. This was justified on the strong energy requirements to overcome the relative 'under-development' of the Spanish economy (see Labandeira, 1997).

[2] It is expected that total Spanish greenhouse gas emissions will be allowed to increase by 15% between 1990 and 2010 (see Mas, 1998).

[3] For instance, electricity-related emissions should not be exclusively imputed to the electricity industry as other sectors use electricity to produce their goods and are thus indirectly 'responsible' for some CO_2 emissions (see Sections 3.1 and 5.2).

Table 1 Spanish CO_2 Emissions in 1994

	1000 tonnes	per cent
Energy-Related:	*227,197*	*85.85*
Electricity	76,082	28.75
Transport	59,722	22.57
Industries	50,896	19.23
Households	17,262	6.52
Agriculture	*17,554*	*6.63*
Industrial Processes	*16,370*	*6.18*
Waste	*2,657*	*1.00*
Total	**264,641**	**100.00**

Source: Spanish Ministry of the Environment

A major aim of this paper is to provide a comprehensive, disaggregated and rightly allocated assessment of Spanish energy-related CO_2 emissions. Apart from the intrinsic interest of such information, there are obvious reasons to carry out this objective. Indeed, any strategy to curb climate change effects should have enough data on emissions and sources to choose the adequate instruments in both economic and environmental terms.

2.2. The Carbon Tax: Design and Implementation

As indicated before, carbon taxation is the adopted environmental instrument in our exercise. When dealing with the design of a hypothetical carbon tax we must first refer to the jurisdictional allocation, with 'first-best' carbon taxes being allocated to a worldwide authority because they respond to a global environmental problem. However, the practical impossibility of setting such an institutional arrangement has recommended the assignment of any hypothetical tax intending to control Spanish CO_2 emissions to the Spanish central government.

Concerning the selected carbon tax rates, it is well known that the shadow prices from the maximization of the net 'social' benefits of emissions could be interpreted as the Pigouvian tax rates. But even if such a cost-benefit paradigm was not followed, the carbon tax rates could be equally defined as the shadow prices from welfare optimization with a binding environmental standard (carbon budget approach).

The previous shadow price approximations contrast with the actual damage cost approach, where the environmental tax rates are determined by computing the reduction in damages from a marginal abatement of emissions (see Section 4.2).

Our carbon tax simulations refer to the year 1998 and were carried out with the tax rate obtained by Fankhauser (1994) through an actual damage cost approach, a representative Pigouvian tax rate and the EU proposals on carbon taxation. However, we use Fankhauser's estimate as our central carbon tax rate on various grounds. First, because some shadow prices are calculated to keep future emissions in the optimal path indicated by a cost-benefit model, thus requiring a complete international coordination that we do not presume for the applied exercise. Second, because the alternative shadow price approach shares the same problem, with the added difficulty of setting the carbon target.[4] Finally, because a unilateral Spanish carbon tax is not thought to affect the future trajectory of total CO_2 emissions (Spain causes slightly less than one per cent of the world's CO_2 emissions), a *sine qua non* condition for a reliable application of the actual damage approach.

Choosing a non-contentious and simple carbon tax base is much easier. Given the major significance of CO_2 emissions from fossil fuel combustion (see Table 1), it seems reasonable to tax energy-related emissions alone. Whereas this clearly leads to a higher administrative feasibility, the presence of a large number of polluters still renders difficult the direct taxation of emissions. However, the existence of a good linkage between fossil fuel consumption and CO_2 emissions sustains the use of product taxation to overcome the previous problem.[5] The product tax rates can be directly calculated from the carbon content of each fossil fuel, indicated by Table 2 (see Section 4.1), and the adopted carbon tax rate. Actually, product carbon taxes only need to be introduced at one stage, thus enhancing the practical feasibility of this approximation.

3. The Input-Output Method

We employ input-output methodology to assess Spanish CO_2 emissions and to examine the price effects of a hypothetical carbon tax. The approach is justified on the generalized dependence of contemporary societies upon CO_2 emissions, which means that it is not possible to estimate the actual emitters and the effects of carbon taxes by considering a single sector. Indeed, the comparative significance of 'indirect' emissions requires the use of such a comprehensive approximation to attribute emissions by sector.

The utility of input-output methods to appraise the incidence of energy taxes is widely known, as they are able to disentangle the complex industrial relationships within any developed economy (see e.g. Common, 1985; Casler and Rafiqui, 1993). In particular, input-output analysis has been recently used to assess CO_2 emissions and to estimate the price effects of carbon taxation in a number of countries (Proops, Faber and Wagenhals, 1993; Symons, Proops and Gay, 1994; Cornwell and Creedy, 1995). The preceding studies employed an input-output

[4] Some recent research on the effects of carbon taxes for the UK and Australia has evidenced the shortcomings of this approach (Symons, Proops and Gay, 1994; Cornwell and Creedy, 1995). The hypothetical carbon tax rates were endogenously determined to meet the Toronto target: a 20 per cent reduction in CO_2 emissions between 1988 and 2005. Such a stringent CO_2 target and the structural rigidities of the input-output approach have led to extremely high carbon taxes, at least when compared to the literature estimates, with limited policy relevance.

[5] This is reinforced by the current absence of feasible CO_2 control technologies.

demand model to calculate the CO_2 intensities for each industrial branch, i.e. the carbon contents of their products, which allows for a straightforward computation of the price changes after carbon taxation. Our exercise for the Spanish economy basically follows the same procedure.

Input-output analyses are thus well suited to assess the effects of a one-stage carbon tax on primary fossil fuels upon the relative prices of outputs.[6] Yet a key assumption of this process is the full shifting of carbon taxation to consumption, with no substitution taking place in production after the carbon tax.[7] Input-output methods are however unique in allowing a highly disaggregated analysis of the economy, even if they should only be taken as a short-term approximation to the impacts of taxes on inputs.

We next present a description of the input-output model used in our exercise. The underlying demand model is rather simple, depicting the relationship between CO_2 emissions and fossil fuel use by industries and final consumers.

The Model

The input-output approximation to production was devised in its modern form by Leontief (1936). Assuming that overall economic activity can be disaggregated into n different producing sectors, input-output analysis decomposes total output of the economy into final and intermediate demands, thus explicitly dealing with inter-industry trading.

The basic equation is

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \tag{3.1}$$

with $\mathbf{x}$ as the n-vector of goods required for total output, $\mathbf{y}$ as the n-vector of goods that satisfies final demand and $\mathbf{Ax}$ as the n-vector of intermediate demand. Actually, $\mathbf{A}$ is the $n \times n$ matrix of technological coefficients, constants that reflect the inputs required (from all sectors) for the production of each particular sector.[8]

Reorganization of expression (3.1) yields

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{3.2}$$

where $\mathbf{I}$ is a unit matrix of order n and $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse, which converts final demand into total output. This is an essential result as final de-

[6] The exercise for Spain involves the application of a product carbon tax on three primary fossil fuels (coal, lignite and natural gas) and on two transformed produces (liquid fossil fuels and manufactured gas). This means that energy losses in the production of liquid fuels and manufactured gas are not taxed and that some sort of double taxation arises (see Martín and Velázquez, 1992), although we feel that the consideration of such matters would not alter significantly the final outcome.

[7] As a consequence, this input-output exercise does not intend to study the industrial reaction to the carbon tax. Note, however, that the full shifting assumption can be partly relieved with the use of sensitivity analysis.

[8] As indicated above, the proportionality between the inputs into a sector and the total output from that sector (no substitution) constitutes a drawback of input-output methodology, being a reasonable assumption only in the short run.

mand, not total output, is the control variable for governments. Moreover, the Leontief inverse indicates the direct (from final demand) and all the indirect (from intermediate demand) requirements for production in the economy.

Since we just contemplate CO_2 emissions from fossil fuel combustion, we now define the use of fuels by industries and consumers as in Gay and Proops (1993). Following the information provided by Spanish input-output tables, we consider 57 producing sectors and five types of fossil fuels: coal, lignite, liquid fuels, natural gas and manufactured gas.

Total industrial fuel use is the 5-vector

$$\mathbf{f} = \mathbf{B}'\mathbf{x} \tag{3.3}$$

where $\mathbf{B}'$ represents the transpose of the 57×5 matrix $\mathbf{B}$, containing the coefficients of fuel use per unit total output (kilotonnes/terajoules per million Spanish pesetas).

Total direct fuel use by final consumers is the 5-vector

$$\mathbf{h} = \mathbf{C}'\mathbf{y} \tag{3.4}$$

where $\mathbf{C}'$ is the transpose of $\mathbf{C}$, a 57×5 matrix of coefficients that relate quantities and values of the fuel purchased as part of final demand (kilotonnes/terajoules per million Spanish pesetas).

Total CO_2 emissions from fossil fuel use are given by the scalar

$$\mathbf{g} = \mathbf{e}'(\mathbf{f} + \mathbf{h}) \tag{3.5}$$

where $\mathbf{e}'$ is the transpose of the 5-vector indicating the CO_2 production per unit fuel burnt (kilotonnes of CO_2 per kilotonnes/terajoules of fuel).

From equations (3.2), (3.3), (3.4) and (3.5) we have

$$\mathbf{g} = \mathbf{e}'\mathbf{B}'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} + \mathbf{e}'\mathbf{C}'\mathbf{y} \tag{3.6}$$

i.e., the energy-related CO_2 emissions by an economy can be attributed to total final demand for goods and services (disaggregated national product).

Focusing only on the emissions related to private consumption, $\mathbf{g_p}$, from equation (3.6) and the matrix expansion for $(\mathbf{I} - \mathbf{A})^{-1}$

$$\mathbf{g_p} = \mathbf{e}'\mathbf{C}'\mathbf{y_p} + \mathbf{e}'\mathbf{B}'\left(\mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \ldots\right)\mathbf{y_p} \tag{3.7}$$

with $\mathbf{y_p}$ as the 57-vector representing private consumption. The second term of this expression shows the emissions due to direct fossil fuel demand by consumers, $\mathbf{e}'\mathbf{C}'\mathbf{y_p}$, and the emissions from direct and indirect (first-round, second-round, etc.) fuel use by industries.

Assuming that the carbon tax on fossil fuels is fully shifted forward to consumption (see Section 3), prices are increased in proportion to the carbon content of the produced goods. In fact, the price rises are given by

$$\mathbf{t} = \mu\,\mathbf{u} \tag{3.8}$$

where $\mathbf{u}$ is the 57-vector showing the energy-related CO_2 intensities (kg of CO_2 per Spanish peseta) and μ is the general tax rate on CO_2 emissions. Particularly, $\mathbf{t}$ could be also interpreted as a 57-vector with the derived *ad valorem* tax rates on the produced goods.

Therefore, to estimate the price effects of carbon taxation we need to know the CO_2 intensities for all producing sectors, which can be directly calculated from equation (3.6) with

$$\mathbf{u}' = \mathbf{e}'\left[\mathbf{B}'(\mathbf{I}-\mathbf{A})^{-1} + \mathbf{C}'\right] \tag{3.9}$$

Total CO_2 intensities can be further decomposed into the intensities from fuel use by consumers, $\mathbf{e}'\mathbf{C}'$, from direct fuel use by industries, $\mathbf{e}'\mathbf{B}'$, and from indirect fuel use by industries, $\mathbf{e}'\mathbf{B}'\left(\mathbf{A}+\mathbf{A}^2+\ldots\right)$.

The actual industrial emissions brought about by total final demand can be calculated from

$$\mathbf{g}_{i(ac)} = \mathbf{e}'\mathbf{B}'\,{}^{\wedge}\mathbf{x} \tag{3.10}$$

where ${}^{\wedge}\mathbf{x}$ is the diagonal matrix derived from the $\mathbf{x}$ vector. As indicated before, these emissions are those directly produced from fossil fuel burning by sector.

The imputed industrial emissions by sector brought about by total final demand, not those actually produced in a sector but those for which it is responsible, are given by

$$\mathbf{g}_{i(im)} = \mathbf{e}'\mathbf{B}'(\mathbf{I}-\mathbf{A})^{-1}\,{}^{\wedge}\mathbf{y} \tag{3.11}$$

with ${}^{\wedge}\mathbf{y}$ as the diagonal matrix derived from the $\mathbf{y}$ vector.

4. Data

In this section we present the data used to implement the preceding input-output model. We were unable to obtain fully updated information, which simply did not exist when writing this article, so our emission figures refer to the year 1992. Of course this is an important shortcoming, as the provided emission results are rather old and do not match with the more recent carbon tax simulations. However, we believe that the structural emission differences between 1992 and the present are not that important, as the strong changes seen in the Spanish energy domain during the late 1980s were taken into account.

Section 4.1 deals with the production of matrices and vectors, stressing the difficulties to obtain reliable and updated data on disaggregated Spanish energy consumption. This has led us to produce a set of energy data from various and fragmentary sources, which fortunately seems largely consistent with reality (see Section 5.2). Section 4.2 focuses on the alternative values of the carbon tax rate used in the simulation of the price effects.

4.1. Production of the Matrices and Vectors

The **A** matrix and the **y** and **x** vectors were calculated and obtained from the 1992 Spanish input-output table, the latest available from the Spanish Institute of Statistics (INE) at the moment of writing.[9] In any case, as indicated before, we expect few variations between the 1992 and the current CO_2 intensities. Our interest in the actual emissions of Spanish origin has recommended the use of domestic or internal magnitudes, except in the case of primary use of fossil fuels where imports were also considered (see Section 5.2).

The ratios of CO_2 emissions to fuel use were obtained from OFICO (1995) for lignites, and from Gay and Proops (1993) for the remaining fossil fuels. Table 2 depicts the **e** vector for the Spanish economy.

Table 2 e Vector (5×1)

(1) Coal	$\frac{kt\ CO_2}{kt\ fuel}$	2.250
(2) Lignite	$\frac{kt\ CO_2}{kt\ fuel}$	1.410
(3) Liquid Fuels	$\frac{kt\ CO_2}{kt\ fuel}$	3.200
(4) Natural Gas	$\frac{kt\ CO_2}{tj\ fuel}$	0.055
(5) Manufactured Gas	$\frac{kt\ CO_2}{tj\ fuel}$	0.055

The **B** and **C** matrices could be calculated from the official (extended) energy input-output tables. Unfortunately, the latest and only available energy input-output table refers to the year 1985 (INE, 1991), which we believe largely outdated after the strong changes seen in the Spanish energy field between 1985 and 1992.

Therefore, we decided to produce the **B** and **C** matrices from primary data on fossil fuel use in 1992 and from the conventional input-output table. Often, this constituted a tough and lengthy task due to the fragmentation and/or unavailability of the required data. The basic source of macro data was the Spanish energy balance, the best available energy information used by the Ministry of the Environment to produce its inventories of emissions. The lack of data on direct fossil fuel use by consumers was solved through the use of OECD energy statistics (IEA, 1995). Disaggregated data on industrial consumption of fossil fuels were obtained from the official industrial survey (INE, 1995), although fossil fuel use by the public sector and service sectors had to be disaggregated following the value flows of the conventional input-output table.

Tables 3 and 4 show the produced **B** and **C** matrices. We feel that their validity is demonstrated by the good approximation of the estimated overall level of fossil fuel use, given by expressions (3.3) and (3.4), to the actual figures reported by the Spanish government (see Ministerio de Medio Ambiente, 1996).

[9] This table is obtainable from the INE by request. The latest published version of the Spanish input-output table refers to 1989 (INE, 1993).

(tables 3 and 4, here)

4.2. The Carbon Tax Rate

As indicated in Section 2.2, there are two main theoretical options to determine the carbon tax rate: the actual damage cost method and shadow price approaches. While the former provide the estimated benefits from a marginal abatement of CO_2 emissions (implicitly yielding the social costs of emissions), the latter calculate the tax rate as the carbon price required to keep emissions on the socially optimal path yielded by an intertemporal optimization model. Such an optimization model may take account of both costs and benefits from reducing CO_2 emissions, or simply minimize the costs to attain an exogenous carbon target.[10]

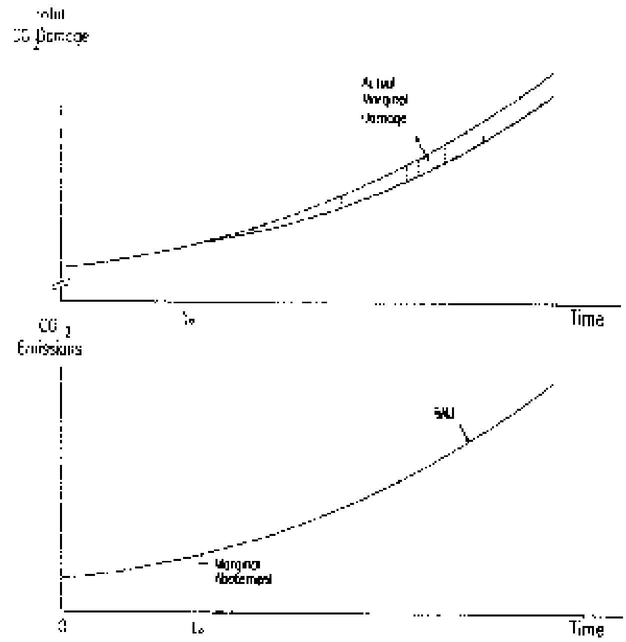

Figure 1: The Actual Marginal Damage Cost of CO_2 Emissions

The superiority of the actual damage approach to establish the unilateral Spanish carbon tax rate was already pointed out. Fankhauser (1994) estimated

[10] The DICE (Nordhaus, 1993) or CETA (Peck and Teisberg, 1992) models are examples of cost-benefit intertemporal optimization, whilst Anderson and Williams (1993) illustrate the carbon budget alternative, where greenhouse damages do not need to be modelled and valued.

the actual marginal damage cost of CO_2 emissions by comparing the present value of the stream of damages associated with the 'business as usual' emissions (as reported by the IPPC) to that brought about by a marginal abatement in the base period. Figure 1 depicts this procedure, which is only acceptable in the case of small scale CO_2 reductions not capable of altering the BAU trajectory of emissions. Otherwise, a new trajectory should be calculated to appraise the marginal change, thus reducing the practical appeal of this approach.

Table 5 summarizes some results of the applied literature on this matter, which we use as an input to carbon tax rate setting. Note that the actual damage estimate is significantly higher than those reported by shadow price studies, not only explained by methodological differences but also by Fankhauser's use of expected values instead of the usual best guesses, as the distribution of global warming damage is skewed to the right.

With this background, the tax rates used for simulation were a representative of the actual damage approach as central estimate (20.3 1990 US$/tonne of carbon), a representative of the lower cost-benefit estimate (6.0 1990 US$/tonne of carbon), and the rate of the European Commission proposed 'ecotax' for 1998 as upper estimate (34.8 1998 US$/tonne of carbon).[11] After transforming the original carbon taxes into a tax on CO_2 emissions and updating the figures to 1998 pesetas, the simulated tax rates (central, lower and upper) are respectively 1014.7, 300 and 1461.4 pesetas per tonne of CO_2.

Table 5 Carbon Tax Rates in Different Studies, 1991-2000

Study	**1990 US$/tonne of carbon**	**Type**
Peck & Teisberg (1992)	10-12	CB
Anderson & Williams (1993)	25 (1990)-120 (2010)	B
Cline (1993)	5.8-124	CB
Maddison (1994)	5.9-6.1	CB-AD
Nordhaus (1994)	best guess=5.3; exp. value=12.0	CB
Fankhauser (1994)	exp. value=20.3	AD

Note: CB=cost benefit; B=carbon budget; AD=actual damage;

How do the previous results compare to implemented tax rates on CO_2 emissions? A number of countries of Northern Europe have recently introduced carbon taxes, with rates generally higher than those contemplated in this exercise. However, these taxes usually involve revenue-neutral reductions in other energy taxes and are seldom levied on energy intensive sectors (see Álvarez, Gago and Labandeira, 1998).

[11] The EU ecotax, without the energy segment, would be levied on the carbon content of fossil fuels at a level equivalent to US$ 4 per barril of oil in 1998 (see Pearson and Smith, 1991).

5. Results

5.1. CO_2 Intensities and Price Effects of Carbon Taxes

The energy-related CO_2 intensities, in Kilograms of CO_2 per peseta, by Spanish input-output sector are the fundamental result of our exercise. They were obtained from the empirical implementation of expression (3.9) and constitute an essential input for the disaggregated estimation of Spanish CO_2 emissions and for the calculation of the price effects from the hypothetical carbon taxes.

Table 6 depicts the total (energy-related) CO_2 intensities by sector and their decomposition in intensities from fuel use by consumers and from direct and indirect fuel use by industries (see Section 3 for more details). As these intensities should only refer to CO_2 emissions of Spanish origin, we had to use a 'modified' Leontief inverse accounting only for domestic intermediate demands and imported fossil fuels.

(tables 6 and 7, here)

The Spanish CO_2 intensities follow the general trends observed in other European countries (see e.g. Proops, Faber and Wagenhals, 1993). As expected, energy-intensive sectors such as electricity, gas, coal or transport are those with the highest CO_2 intensities. The importance of 'indirect' CO_2 emissions by industries, i.e. those which are not actually produced by consumers, is also evident from the results (see the third and fourth columns). This clearly sustains the use of input-output analysis in our exercise.

Regarding the effects of the simulated carbon taxes on Spanish prices for the year 1998, they were calculated from expression (3.8) and are presented in Table 7. As previously indicated, such price changes refer to final consumption and reflect a full shift forward of the carbon tax burden by firms.

The second, third and fourth columns of Table 7 show the per cent increase in prices from the alternative values of μ, the original carbon taxes levied on emitters used for simulation (see Section 4.2). As the CO_2 intensities lead to the relative differences between sectors, the ranking of price variations (fifth column) does not depend upon the adopted carbon tax rate.

The observed price changes obviously keep the pattern of CO_2 intensities, with energy-intensive sectors suffering the highest effects in both relative (see the ranking) and absolute terms.[12] There are also significant coincidences with previous research on the price effects from the application of the proposed European energy/carbon tax to Spain (Martín and Velázquez, 1992). Nevertheless we found some differences in the 'CO_2 ranking' of energy-intensive and transport sectors, after introducing the implicit tax rate employed by Martín and Velázquez in the model of Section 3. However, these inconsistencies may be partly explained by

[12] We have not reported any price effect on 'non-market' sectors.

their primary taxation of crude oil, their use of an input-output price model or the deep transformations that have occurred in the Spanish energy and economic domains between 1985, the base year for Martín and Velázquez, and 1992.

5.2. Estimating Spanish CO_2 Emissions

The produced vectors and matrices were introduced in expressions (3.6) and (3.7) to estimate total and disaggregated (by sector) Spanish energy-related CO_2 emissions. The results of this assessment for the year 1992 are presented in Table 8. Again, given our sole interest in CO_2 emissions physically produced by Spanish sources, only domestic magnitudes and imports of fossil fuels were contemplated in the modified Leontief inverse. It should be noted, however, that Spanish imports are responsible for some CO_2 emissions generated abroad and, conversely, some emissions produced in Spain should be allocated to other countries' demand for Spanish products.[13]

The first two columns of Table 8 were obtained from equation (3.6), respectively depicting the emissions from direct fossil fuel demand by consumers and from (direct and indirect) industrial fuel use to cover private consumption. The third column shows the actual industrial emissions brought about by total final demand, as calculated from equation (3.10). Finally, the fourth column yields the imputed industrial emissions (by sector) brought about by total final demand, from expression (3.11).

(table 8, here)

Once more, the difference between expressions (3.10) and (3.11) and between their associated columns in Table 8 proves the relevance of input-output analysis. In fact, a simple assignment of CO_2 emissions to actual polluters would not provide the correct information to estimate the price effects of carbon taxation. Instead, CO_2 intensities and the corresponding price changes must be calculated from the imputed emissions by sector.

The distribution of Spanish CO_2 emissions again evidences the relevance of indirect emissions caused by final consumption. They actually account for approximately 50 per cent of total emissions, in contrast with a mere 15 per cent of CO_2 emissions arising directly in final consumption.

Finally, the estimation of emissions serves to test the consistency of the input-output demand model employed for all our preceding calculations. In this sense, the estimated energy-related CO_2 emissions are slightly larger than those provided

[13] Assuming identical **D** matrices for Spain and all the exporting countries, the CO_2 emissions of Spanish responsibility would increase by 12,000 tonnes per year (a five per cent higher than the total figure of Table 8). Surprisingly, if Spanish exports are not considered, Spain would be responsible for less than 210,000 tonnes of CO_2 per year (a 15 per cent lower than the total figure of Table 8).

by the official Spanish inventory (231,261 kt; see Ministerio de Medio Ambiente, 1996). It is our view, however, that the divergence is small and can be attributed to the emission ratios used in the c vector. Previous input-output research on this issue by Antón and de Bustos (1995) has produced even larger CO_2 estimates and some deviation in their relative distribution, probably explained by their departure from the 1985 Spanish energy input-output table.

6. Policy Implications

The preceding empirical results suggest a number of guidelines for future Spanish climate change policies. First of all, it seems necessary to avoid focusing all policy actions on the actual CO_2 emitters. Instead, it is preferable to design a strategy able to modify the behaviour of those responsible for CO_2 emissions. In this sense, it is particularly imperative to improve the energy efficiency of the Spanish economy departing, for instance, from the disaggregated information provided by the energy/economy matrices and the CO_2 intensities presented in this paper.[14]

A policy instrument simply levied on actual energy-related emissions by final consumers exemplifies the above mentioned limitations of a partial climate change strategy. As indicated in Section 5.1, most CO_2 emissions by final consumers are indirect and therefore a comprehensive approach accounting for the energy requirements of final demand is necessary. Otherwise, the environmental effectiveness of the policy instrument will be very limited indeed.

The results of our carbon tax simulations reinforce the well-known theoretical support for this policy instrument. The tax incidence is rather moderate in terms of prices, although concentrated in some key economic sectors. This means a high policy feasibility, as long as the key affected sectors are somehow compensated. In fact, the experiences with carbon taxes in Europe demonstrate that such preferential tax treatments are common.[15] As a whole, the practical feasibility of carbon taxes and their substantial revenues have actually defined the so called green tax reform model (Álvarez, Gago and Labandeira, 1998).

Of course, our input-output exercise has assumed a somewhat unrealistic shift forward of the tax burden to consumption. In a way this is positive because the carbon tax becomes a comprehensive environmental instrument that is paid by the final sources of the problem and that will modify their consuming behaviour. However, from a policy perspective such a concentration of the tax inducements in final consumption is a major shortcoming of our analysis, as the adopted

[14] Compared to most EU countries, Spain shows unfavourable energy intensity ratios as in final energy use/GDP (Labandeira, 1997).

[15] This is mainly related to the adverse effects of unilateral carbon taxes on the markets for energy-intensive products of the country. Given the WTO's legal objections to measures designed to protect internal and external markets against non-taxed foreign products, most countries have opted for wide carbon tax exemptions.

hypotheses disregard the potentially sizable environmental and economic effects of the carbon tax on the intermediate agents. Completing the study of the effects from carbon taxation in the Spanish supply side constitutes an obvious extension of this research.

7. Conclusions

This article responds to the current and pressing need to control Spanish CO_2 emissions in an efficient manner. In this sense, it identifies the actual and imputed sources of CO_2 emissions and it advocates and simulates the use of environmental taxation to curb Spanish greenhouse gas emissions.

The paper has provided a new disaggregated estimation of Spanish energy-related CO_2 emissions and of the price effects from alternative hypothetical carbon taxes in Spain. These results were largely derived from the calculation of the 1992 Spanish energy-related CO_2 intensities through an input-output demand model.

The empirical assessment of Spanish CO_2 emissions and of the carbon tax effects calls for the adoption of a comprehensive strategy in Spanish climate change policies. On the one hand it seems necessary to improve the overall efficiency of the Spanish energy system, not merely focusing on the actual CO_2 emitters. On the other hand carbon taxes appear to be a feasible and efficient instrument, both in environmental and economic terms.

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Table 3 B Matrix (57x5); kilotonnes {(1) (2) (3)} and terajoules {(4) (5)} per million 1992 pesetas

INDUSTRY	(1) Coal	(2) Lignite	(3) Liquid Fuels	(4) Natural Gas	(5) Manuf. Gas
1	0.0	0.0	0.000464120	0.00003862	0.0
2	0.000195000	0.0	0.000783000	0.0	0.0
3	0.000010400	0.000178300	0.000542320	0.0	0.0
4	0.0	0.0	0.000056630	0.0	0.0
5	0.0	0.0	0.000078580	0.0	0.0
6	0.0	0.0	0.001293200	0.0	0.0
7	0.0	0.0	0.048210000	0.0	0.0
8	0.000000062	0.0	0.000439460	0.000110000	0.0
9	0.009823400	0.008891000	0.018220000	0.009787700	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.000001114	0.0	0.000157660	0.012278000	0.0
13	0.000003089	0.0	0.000255350	0.006984000	0.0
14	0.006232600	0.0	0.002411700	0.009553100	0.0
15	0.000008434	0.0	0.002719100	0.035204000	0.0
16	0.000370080	0.0	0.003433200	0.065314000	0.0
17	0.000014873	0.0	0.000634580	0.003337200	0.0
18	0.000134780	0.000001858	0.000417430	0.013428000	0.0
19	0.000032340	0.0	0.000092200	0.003206500	0.0
20	0.000001027	0.0	0.000056980	0.000483020	0.0
21	0.000000198	0.0	0.000005339	0.000079890	0.0
22	0.000000052	0.0	0.000039590	0.001158300	0.0
23	0.000001069	0.0	0.000038015	0.003246400	0.0
24	0.000000370	0.0	0.000043097	0.000689790	0.0
25	0.000000343	0.0	0.000073014	0.000131510	0.0
26	0.000002049	0.0	0.000292860	0.000400510	0.0
27	0.000011280	0.0	0.000317100	0.003207100	0.0
28	0.000001789	0.0	0.000208030	0.001907000	0.0
29	0.0	0.0	0.000021489	0.000127830	0.0
30	0.000004076	0.0	0.000132590	0.002660100	0.0
31	0.000000033	0.0	0.000088310	0.000191090	0.0
32	0.000000648	0.0	0.000014696	0.000571750	0.0
33	0.000120390	0.0	0.001000300	0.042281000	0.0
34	0.000000641	0.0	0.000084345	0.001900600	0.0
35	0.000000091	0.0	0.000073740	0.005182800	0.0
36	0.000000192	0.0	0.000018207	0.000459480	0.0
37	0.0	0.0	0.000131650	0.000022470	0.0
38	0.0	0.0	0.000037691	0.000110650	0.000010550
39	0.000000511	0.0	0.000009432	0.000424880	0.000011160
40	0.000006321	0.0	0.000049646	0.000688320	0.000097210
41	0.0	0.0	0.000719140	0.0	0.0
42	0.0	0.0	0.004612700	0.0	0.0
43	0.0	0.0	0.007687900	0.0	0.0
44	0.0	0.0	0.004912700	0.0	0.0
45	0.0	0.0	0.000025400	0.000229800	0.000003042
46	0.000001705	0.0	0.000006121	0.000017510	0.000005966
47	0.000003564	0.0	0.000001188	0.000044900	0.000004050
48	0.0	0.0	0.0	0.0	0.0
49	0.000006890	0.0	0.000037030	0.000106040	0.000031170
50	0.0	0.0	0.000001898	0.0	0.0
51	0.000013774	0.0	0.000033824	0.000270410	0.000028070
52	0.000009246	0.0	0.000015669	0.000262490	0.000012850
53	0.0	0.0	0.000024625	0.000072437	0.000020974
54	0.000002390	0.0	0.000047403	0.000131010	0.000091807
55	0.000003834	0.0	0.000025219	0.000041098	0.000008458
56	0.0	0.0	0.000028739	0.000043128	0.000021285
57	0.000000823	0.0	0.000002533	0.000009542	0.000007074

Table 4 C Matrix (57x5); kilotonnes {(1) (2) (3)} and terajoules {(4) (5)} per million 1992 pesetas

INDUSTRY	(1) Coal	(2) Lignite	(3) Liquid Fuels	(4) Natural Gas	(5) Manuf. Gas
1	0.0	0.0	0.0	0.0	0.0
2	0.035	0.0	0.0	0.0	0.0
3	0.0	0.011	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.009	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.675	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.523
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0
54	0.0	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0

Table 6 Partial and Total CO_2 Intensities, 1992

INDUSTRY	e'C' (kg CO_2 / ptas)	e'B' (kg CO_2 / ptas)	e'B'(I+A+...) (kg CO_2 / ptas)	u (kg CO_2 / ptas)
(1) Agriculture, Forestry & Fishing	0.0	0.0014873	0.0028153	**0.0043026**
(2) Coal Mining	0.078750	0.0006893	0.0032331	**0.0826720**
(3) Lignite Mining	0.015510	0.0017840	0.0031965	**0.0204900**
(4) Coke	0.0	0.0001812	0.0037453	**0.0039265**
(5) Oil	0.0	0.0002514	0.0012496	**0.0015010**
(6) Oil Processing	0.028800	0.0041383	0.0004242	**0.0333630**
(7) Natural Gas	0.037125	0.0026516	0.0004416	**0.0402180**
(8) Water	0.0	0.0014137	0.0052448	**0.0066586**
(9) Electricity	0.0	0.0410070	0.0048287	**0.0458360**
(10) Manufactured Gas	0.028765	0.0	0.0019397	**0.0307050**
(11) Nuclear Fuels	0.0	0.0	0.0025963	**0.0025963**
(12) Iron & Steel	0.0	0.0011823	0.0046635	**0.0058458**
(13) Non-Ferrous Metals	0.0	0.0012082	0.0075275	**0.0087357**
(14) Cement	0.0	0.0222660	0.0054939	**0.0277600**
(15) Glass	0.0	0.0106560	0.0036617	**0.0143180**
(16) Ceramics & Bricks	0.0	0.0154110	0.0047872	**0.0201980**
(17) Other Minerals	0.0	0.0022477	0.0061630	**0.0084107**
(18) Chemicals	0.0	0.0023802	0.0036306	**0.0060108**
(19) Metal Products	0.0	0.0005442	0.0029171	**0.0034612**
(20) Agricultural & Industrial Machines	0.0	0.0002112	0.0019366	**0.0021478**
(21) Office Machines	0.0	0.0000219	0.0009097	**0.0009316**
(22) Electrical Products	0.0	0.0001905	0.0019026	**0.0020931**
(23) Motor Vehicles	0.0	0.0003026	0.0028844	**0.0031870**
(24) Other Vehicles	0.0	0.0001767	0.0017392	**0.0019159**
(25) Meat	0.0	0.0002416	0.0037574	**0.0039990**
(26) Milk	0.0	0.0009638	0.0035873	**0.0045511**
(27) Other Food	0.0	0.0012165	0.0028880	**0.0041045**
(28) Drinks	0.0	0.0007746	0.0028399	**0.0036145**

INDUSTRY (cont.)	e'C' (kg CO_2 / ptas)	e'B' (kg CO_2 / ptas)	e'B'(I+A+...) (kg CO_2 / ptas)	u (kg CO_2 / ptas)
(29) Tobacco	0.0	0.0000758	0.0009743	**0.0010501**
(30) Textiles & Clothing	0.0	0.0005798	0.0022496	**0.0028293**
(31) Leather & Footwear	0.0	0.0002932	0.0020863	**0.0023795**
(32) Timber & Furniture	0.0	0.0000799	0.0028580	**0.0029379**
(33) Pulp & Paper	0.0	0.0057972	0.0049131	**0.0107100**
(34) Printing	0.0	0.0003759	0.0030448	**0.0034207**
(35) Rubber & Plastics	0.0	0.0005212	0.0025513	**0.0030726**
(36) Other Manufacturing	0.0	0.0000839	0.0017685	**0.0018525**
(37) Construction	0.0	0.0004225	0.0029503	**0.0033728**
(38) Recovery & Repair	0.0	0.0001273	0.0018029	**0.0019302**
(39) Commerce	0.0	0.0000553	0.0012971	**0.0013524**
(40) Restaurants & Hotels	0.0	0.0002163	0.0025446	**0.0027609**
(41) Railways	0.0	0.0023012	0.0077284	**0.0103000**
(42) Road Transport	0.0	0.0147600	0.0014267	**0.0161870**
(43) Sea Transport	0.0	0.0246010	0.0015466	**0.0261480**
(44) Air Transport	0.0	0.0157210	0.0014385	**0.0171590**
(45) Services for Transport	0.0	0.0000941	0.0011776	**0.0012717**
(46) Communications	0.0	0.0000247	0.0007295	**0.0007542**
(47) Credit & Insurance	0.0	0.0000145	0.0006210	**0.0006355**
(48) Imputed Production to Banking Services	0.0	0.0	0.0	**0.0**
(49) Services to Firms	0.0	0.0001416	0.0006274	**0.0007690**
(50) Real-Estate Renting	0.0	0.0000061	0.0006784	**0.0006845**
(51) Education & Research (Market)	0.0	0.0001556	0.0013447	**0.0015004**
(52) Health (Market)	0.0	0.0000861	0.0010377	**0.0011238**
(53) Other Services (M)	0.0	0.0000839	0.0010381	**0.0011221**
(54) Public Services	0.0	0.0001693	0.0014789	**0.0016482**
(55) Education & Research (Non-Market)	0.0	0.0000921	0.0008677	**0.0009598**
(56) Health (N-M)	0.0	0.0000955	0.0012732	**0.0013687**
(57) Other Services (N-M)	0.0	0.0000838	0.0006251	**0.0007089**

Table 7 Price Effects of CO_2 Taxation in the Spanish Economy, 1998

INDUSTRY	Cost-Benefit (% increase)	EU proposals (% increase)	Actual Damage (% increase)	Ranking
(1) Agriculture, Forestry & Fishing	0.12908	0.62861	0.43628	21
(2) Coal Mining	2.48017	12.07844	8.38298	1
(3) Lignite Mining	0.61471	2.99366	2.07773	8
(4) Coke	0.11780	0.57366	0.39825	24
(5) Oil	0.04503	0.21930	0.15220	41
(6) Oil Processing	1.00088	4.87426	3.38296	4
(7) Natural Gas	1.20655	5.87587	4.07812	3
(8) Water	0.19976	0.97281	0.67518	17
(9) Electricity	1.37507	6.69660	4.64774	2
(10) Manufactured Gas	0.92114	4.48596	3.11346	5
(11) Nuclear Fuels	0.07789	0.37932	0.26327	34
(12) Iron & Steel	0.17537	0.85407	0.59276	19
(13) Non-Ferrous Metals	0.26207	1.27629	0.88580	15
(14) Cement	0.83280	4.05574	2.81487	6
(15) Glass	0.42954	2.09185	1.45184	12
(16) Ceramics & Bricks	0.60595	2.95098	2.04811	9
(17) Other Minerals	0.25232	1.22880	0.85284	16
(18) Chemicals	0.18032	0.87818	0.60949	18
(19) Metal Products	0.10384	0.50568	0.35097	26
(20) Agricultural & Industrial Machines	0.06443	0.31379	0.21779	36
(21) Office Machines	0.02795	0.13611	0.09446	48
(22) Electrical Products	0.06279	0.30580	0.21224	37
(23) Motor Vehicles	0.09561	0.46561	0.32316	29
(24) Other Vehicles	0.05748	0.27991	0.19427	39
(25) Meat	0.11997	0.58426	0.40550	23
(26) Milk	0.13653	0.66492	0.46148	20
(27) Other Food	0.12314	0.59967	0.41620	22
(28) Drinks	0.10844	0.52808	0.36651	25

INDUSTRY (cont.)	Cost-Benefit (% increase)	EU proposals (% increase)	Actual Damage (% increase)	Ranking
(29) Tobacco	0.03151	0.15343	0.10648	47
(30) Textiles & Clothing	0.08488	0.41337	0.28689	32
(31) Leather & Footwear	0.07138	0.34764	0.24128	35
(32) Timber & Furniture	0.08814	0.42923	0.29790	31
(33) Pulp & Paper	0.32131	1.56477	1.08602	13
(34) Printing	0.10262	0.49977	0.34686	27
(35) Rubber & Plastics	0.09218	0.44890	0.31156	30
(36) Other Manufacturing	0.05557	0.27064	0.18784	40
(37) Construction	0.10118	0.49277	0.34200	28
(38) Recovery & Repairs	0.05790	0.28200	0.19572	38
(39) Commerce	0.04057	0.19758	0.13713	43
(40) Restaurants & Hotels	0.08282	0.40337	0.27996	33
(41) Railways	0.30089	1.46534	1.01701	14
(42) Road Transport	0.48562	2.36495	1.64138	11
(43) Sea Transport	0.78444	3.82022	2.65141	7
(44) Air Transport	0.51478	2.50697	1.73995	10
(45) Services for Transport	0.03815	0.18579	0.12895	44
(46) Communications	0.02263	0.11020	0.07648	50
(47) Credit & Insurance	0.01901	0.09285	0.06444	52
(48) Imputed Production to Banking Services	0.0	0.0	0.0	53
(49) Services to Firms	0.02301	0.11235	0.07797	49
(50) Real-Estate Renting	0.02054	0.10001	0.06941	51
(51) Education & Research (Market)	0.04501	0.21920	0.15214	42
(52) Health (M)	0.03371	0.16418	0.11395	45
(53) Other Services (M)	0.03366	0.16394	0.11378	46
(54) Public Services	-	-	-	-
(55) Education & Research (Non-Market)	-	-	-	-
(56) Health (N-M)	-	-	-	-
(57) Other Services (N-M)	-	-	-	-

Table 8 CO_2 Emissions from Fossil Fuel Combustion, 1992

INDUSTRY	Direct Emissions from Consumption (1000 tonnes)	Indirect Emissions from Consumption (1000 tonnes)	'Actual' / 'Imputed' Industrial Emissions (1000 tonnes)	
(1) Agriculture, Forestry & Fishing	0.0	5,156.2	6,609.5	**4,760.4**
(2) Coal Mining	2,217.5	109.2	179.4	110.5
(3) Lignite Mining	12.8	87.3	128.7	**4.1**
(4) Coke	0.0	1.6	7.8	**4.3**
(5) Oil	0.0	6.2	9.1	**0.2**
(6) Oil Processing	34,573.6	8,106.5	11,801.1	**6,580.4**
(7) Natural Gas	1,682.5	385.7	565.2	**140.2**
(8) Water	0.0	332.1	416.5	**784.8**
(9) Electricity	0.0	63,852.6	93,939.2	**27,425.3**
(10) Manufactured Gas	346.8	0.0	0.0	**23.4**
(11) Nuclear Fuels	0.0	0.0	0.0	**0.6**
(12) Iron & Steel	0.0	248.6	1,449.2	**1,533.9**
(13) Non-Ferrous Metals	0.0	84.8	456.5	**1,143.7**
(14) Cement	0.0	961.1	6,116.1	**275.0**
(15) Glass	0.0	1,216.2	2,851.1	**776.9**
(16) Ceramics & Bricks	0.0	763.3	5,800.9	**2,592.1**
(17) Other Minerals	0.0	362.5	2,196.6	**670.7**
(18) Chemicals	0.0	3,093.0	5,588.3	**7,184.8**
(19) Metal Products	0.0	294.8	1,041.7	**2,495.6**
(20) Agricultural & Industrial Machines	0.0	47.8	254.0	**1,427.2**
(21) Office Machines	0.0	2.0	10.9	**315.8**
(22) Electrical Products	0.0	60.6	297.3	**2,109.6**
(23) Motor Vehicles	0.0	188.0	861.3	**7,152.4**
(24) Other Vehicles	0.0	20.4	138.7	**919.0**
(25) Meat	0.0	417.5	446.0	**5,709.7**
(26) Milk	0.0	629.6	664.8	**2,651.7**
(27) Other Food	0.0	3,156.1	3,872.8	**6,861.4**
(28) Drinks	0.0	715.4	823.8	**1,478.2**

INDUSTRY (cont.)	Direct Emissions from Consumption (1000 tonnes)	Indirect Emissions from Consumption (1000 tonnes)	'Actual' / 'Imputed' Industrial Emissions (1000 tonnes)	
(29) Tobacco	0.0	38.2	38.5	**532.8**
(30) Textiles & Clothing	0.0	673.6	912.4	**3,355.8**
(31) Leather & Footwear	0.0	119.0	186.7	**1,225.1**
(32) Timber & Furniture	0.0	34.8	74.5	**1,829.9**
(33) Pulp & Paper	0.0	757.9	1,784.6	**955.2**
(34) Printing	0.0	247.6	403.0	**1,191.2**
(35) Rubber & Plastics	0.0	229.3	571.4	**827.7**
(36) Other Manufacturing	0.0	20.4	33.6	**501.1**
(37) Construction	0.0	534.6	3,910.5	**26,183.9**
(38) Recovery & Repairs	0.0	231.6	279.0	**2,798.2**
(39) Commerce	0.0	451.1	524.7	**10,117.0**
(40) Restaurants & Hotels	0.0	1,687.8	1,774.1	**20,815.2**
(41) Railways	0.0	264.5	426.4	**1,151.2**
(42) Road Transport	0.0	21,752.2	36,150.5	**18,107.9**
(43) Sea Transport	0.0	1,034.4	4,600.9	**4,241.7**
(44) Air Transport	0.0	3,578.1	8,634.7	**7,085.9**
(45) Services for Transport	0.0	41.2	74.6	**391.6**
(46) Communications	0.0	21.8	31.2	**302.1**
(47) Credit & Insurance	0.0	10.8	17.6	**328.7**
(48) Imputed Production to Banking Services	0.0	0.0	0.0	**0.0**
(49) Services to Firms	0.0	203.4	588.0	**1,153.7**
(50) Real-Estate Renting	0.0	24.3	26.3	**2,330.5**
(51) Education & Research (Market)	0.0	79.8	91.1	**704.8**
(52) Health (Market)	0.0	74.0	94.5	**949.3**
(53) Other Services (M)	0.0	153.7	182.8	**1,992.2**
(54) Public Services	0.0	0.0	980.5	**9,544.4**
(55) Education & Research (Non-Market)	0.0	6.7	177.4	**1,849.6**
(56) Health (N-M)	0.0	0.0	233.8	**3,351.3**
(57) Other Services (N-M)	0.0	51.0	51.0	**430.9**
TOTAL **248214.1 kt**	**38,833.2**	**122,620.9**	**209,380.8**	
per cent *100.0*	*15.65*	*49.40*	*84.35*	