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# COMBINING INPUT-OUTPUT ANALYSIS AND MICRO-SIMULATION TO ASSESS THE EFFECTS OF CARBON TAXATION ON SPANISH HOSEHOLDS

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# Combining Input-Output Analysis and Micro-Simulation to Assess the Effects of Carbon Taxation on Spanish Households

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**Abstract**

This paper explores the effects of a tax levied on the Spanish energy-related $CO_2$ emissions. After justifying the relevance of carbon taxation in the Spanish context, we consider the introduction of a product (fossil fuel) tax with a rate obtained through the 'actual damage cost' method. In this sense, our empirical analysis proceeds with two stages. First we employ an input-output demand model to calculate the price changes after carbon taxation. In a second stage, simulation with Spanish household microdata for the year 1994 yields the environmental and economic effects from the Spanish carbon tax. We find a limited short-run reaction to the carbon tax, which hampers its environmental success. The carbon tax burden is however significative, with a proportional distribution across households.

*Key words*: Climate change; demand system; distributional effects; environmental taxation

*JEL classification*: C33; C67; H31; Q28

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# 1 Introduction

The environmental and economic importance of climate change phenomena is well established. Such climatic alterations are provoked by the increasing atmospheric concentrations of greenhouse gases, with anthropogenic $CO_2$ production as the main contributor. Hence, the unequivocal need to control human-made $CO_2$ emissions, the rationale for carbon taxation and our interest in this issue.

The structure of this paper is as follows. We begin by stating the relevance of carbon taxation in the Spanish context as a preamble to the proposed carbon tax design and implementation. With that background, our empirical analysis proceeds with two stages: First, we employ an input-output framework to estimate the impact of a hypothetical tax on energy-related $CO_2$ emissions upon the prices of consumer goods. In a second stage we use micro-simulation to explore the consequences of the tax-induced price changes on total $CO_2$ emissions, on government revenue and on the distribution of carbon tax burdens across households, with a simultaneous study of some *ad hoc* compensatory mechanisms.

# 2 Spanish $CO_2$ emissions and the use of carbon taxation

## 2.1 The need for 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 environmental taxation may play a significant role in future Spanish climate change policies.

[1] Spain signed and ratified the United Nations Framework Convention on Climate Change. As an Annex I party of the Convention, 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. However, in both cases Spain was granted a surprising exemption through EU's overall targets 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-Villot, 1997).

On the one hand there has been a sizeable rise of Spanish $CO_2$ emissions, which is directly related to the economic growth of recent years. Indeed, at the moment of writing, Spain has almost consumed the (conceivable) Kyoto permitted increase in greenhouse gas emissions for the year 2010.[2] On the other hand, the economic convergence to EU figures and the adverse Spanish energy and carbon ratios will probably make untenable the preferential treatment enjoyed by Spain so far.

Table 1 presents the main sources of Spanish $CO_2$ emissions in 1994, the year of the simulation. It is noticeable the importance of energy-related emissions, which obviously make $CO_2$ emissions quite dependent on the economic cycle.

**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

## 2.2 The carbon tax: design and implementation

Carbon taxes not only constitute key tools for climate change policies but are also powerful fiscal instruments. Indeed, this section builds a practical carbon tax from various theoretical contents.

First of all, we must refer to the jurisdictional allocation of the carbon tax. First-best carbon taxes should be 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 the hypothetical tax on Spanish $CO_2$ emissions to the Spanish central government. This would have obvious influences on

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

all tax matters, although we believe that the definition of the carbon tax rate deserves a special attention.

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 the cost-benefit paradigm was not followed, environmental tax rates could be equally defined as the shadow prices from welfare optimization with a binding environmental standard. Those 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 Fankhauser, 1995).

We have decided to use the carbon tax rates obtained by Fankhauser (1994) with an actual damage cost approach. Appendix 1 thoroughly describes Fankhauser's procedure and presents a comparative assessment of his results, which are to be preferred 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.[3] Finally, because a unilateral Spanish carbon tax is not thought to affect the future trajectory of total $CO_2$ emissions, a *sine qua non* condition for a reliable application of the actual damage approach.[4]

Choosing a non-contentious and simple carbon tax base is much easier. On the one hand, 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 renders difficult the direct taxation of emissions. On the other hand, however, the existence of 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,

[3] 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). Although these studies also combined input-output analysis and simulation with micro data, the 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 very limited policy relevance.

[4] In fact, Spain is a minor $CO_2$ emitter that causes slightly less than one per cent of the world's emissions.

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

indicated by Table A2.1 (Appendix 2), 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.

Carbon tax receipts are to be controlled by the Spanish tax administration. Given the expected stability of carbon revenues, we assume that they can be employed either with general fiscal purposes or to compensate some negative distributional effects brought about by the externality correction.

# 3 Calculating the price changes caused by carbon taxation through input-output methodology

We now exclusively deal with the impacts of environmental taxation on consumers' prices. Thus, we employ input-output methodology to assess the price effects of carbon taxes, which is justified on multiple grounds. On the one hand, the generalized dependence of contemporary societies upon $CO_2$ emissions means that it is not possible to approximate the influences of carbon taxes by focusing on a single sector. On the other hand, the comparative significance of 'indirect' emissions from final consumption also requires the use of a comprehensive approach.[6]

The utility of input-output methods to appraise the incidence of energy taxes is well 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 estimate the price effects of carbon taxation in Australia (Cornwell and Creedy, 1995), Britain and Germany (Proops, Faber and Wagenhals, 1993). The preceding studies employed an input-output 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 therefore well suited to assess the effects of a one-stage carbon tax on primary fossil fuels upon the relative prices of outputs,[7] thus complying with the practical guidelines of Section 2.2. Yet

[6] Consumers 'directly' cause $CO_2$ emissions through fossil fuel combustion. In addition, consumers are responsible for some 'indirect' $CO_2$ emissions that were generated to satisfy their demand. Actually, the production of most contemporary goods and services is carbon intensive.

[7] The exercise for Spain involves the application of a product carbon tax on three

a key assumption of this process is the full shifting of carbon taxation to consumption, a very strong and unlikely premise that does not allow for general equilibrium effects such as changes in factor prices and pre-tax prices of goods. Moreover, it is assumed that no substitution takes place in production after the carbon tax, which is obviously related to the incidence presumption.[8] Still, input-output methods are 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.

Appendix 2 presents a comprehensive description of the input-output application to Spain, with the basic model (Section A2.1), data (Section A2.2), $CO_2$ intensities, price changes (Section A2.3) and estimated $CO_2$ emissions (Section A2.4). The underlying demand model is rather simple, depicting the relationship between $CO_2$ emissions and fossil fuel use by industries and final consumers. We found some difficulties for its practical implementation, though, given the absence of reliable and updated data on disaggregated Spanish energy consumption. Therefore, we had to produce our own set of energy data from various and fragmentary sources, which fortunately seems largely consistent with reality.

There are other issues of interest regarding the input-output exercise for Spain. First, our sole concern with the actual emissions from Spanish soil determined the use of the domestic magnitudes in the input-output table.[9] Thus, the modified Leontief inverse had an evident influence on the calculation of $CO_2$ intensities and price changes. Second, the reliability of the application is well established by a consistent estimation of Spanish $CO_2$ emissions from the reported intensities and final demand. As requested for the micro-simulation, the price rises refer to the year 1994, albeit they were calculated from the 1992 $CO_2$ intensities. This is explained by the unavailability of disaggregated energy and conventional input-output data for the Spanish economy after 1992. In any case, given the short-term structural stability, we expect few variations between the 1992 and 1994 $CO_2$ intensities.

Table 2 reports the price increases for the 8-commodity grouping of the demand system estimated in Labandeira-Villot and Labeaga (1998). They

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.

[8] As a consequence, this exercise does not intend to study the industrial reaction to the carbon tax.

[9] In Appendix 2 we consider other alternative treatments of imports and exports.

stem from the carbon tax rates reported by Fankhauser (1994), after reconciling the 57-sector input-output classification with the new eight groups through the PROCOME-CNAE translation (see INE, 1993).[10] For the cases where several 57-sector classifications related to one of the new commodity groups, the new price increase was taken as the weighted average of the related sector price increases, with the weights being the proportional contribution to the new group's final demand.

**Table 2 Price Changes from $CO_2$ Taxes (in %). Spain, 1994**

| | LB | UB | EV |
|---|---|---|---|
| Food and Non-alcoholic Drinks | 0.1065 | 0.7758 | **0.3490** |
| Alcohol | 0.0925 | 0.6742 | **0.3033** |
| Clothing and Footwear | 0.0694 | 0.5057 | **0.2275** |
| Electricity | 1.1734 | 8.5483 | **3.8456** |
| Natural and Manufactured Gas | 0.9784 | 7.1279 | **3.2066** |
| Fuel for Private Transport | 0.8541 | 6.2221 | **2.7991** |
| Public Transport | 0.3658 | 2.6650 | **1.1990** |
| Other Non-Durable Goods | 0.0473 | 0.3445 | **0.1550** |

Note: LB= lower bound; UB=upper bound; EV=expected value
Source: Own calculations from Table A2.5

# 4 The effects of carbon taxes from microdata

This section describes the micro-simulation procedure we employed to assess the effects of the proposed environmental tax. The main results of this micro-simulation are also presented here, with an explicit calculation of the impact of carbon taxation on aggregate government receipts, $CO_2$ emissions, monetarized environmental benefits, and on the distribution of burdens across households.

The micro-simulation procedure uses a demand system that is estimated from the Spanish Family Survey (ECPF) for the years 1985-1994 and a sample of 29,648 households. In order to obtain a realistic picture of the substitution, own price and income effects, we opted for the quadratic extension (QAIDS) to the Almost Ideal Demand System of Deaton and Muellbauer (1980) as proposed by Banks *et al.* (1997). Full details on this demand system estimation can be obtained from Labandeira-Villot and Labeaga (1998).

[10]The reported price changes are implicit *ad valorem* tax rates directly derived from an *ad quantum* environmental tax, as recommended by the 'Polluter Pays Principle' (see Hoornaert, 1992).

We consider an indirect tax reform as the tax-induced change in the relative prices of the commodities that compose the demand system, focusing on the short-run effects from the price changes. As the system expenditure groups are composed of goods bearing different tax rates, we calculate the pre- and post-reform price indices as the sum of the prices of all individual goods weighted by their contribution to the composite category. The pre-reform price for good $i$ is

$$p_i^0 = \left(1 + t_i^0\right)\left(q_i + e_i^0\right) \tag{1}$$

where $t_i^0$, $q_i$ and $e_i^0$ respectively denote the initial value added tax (VAT), the net-of-tax producer price and the excise rates. Although the price changes also apply to goods bearing excise duties, the reform does not affect these duties, i.e. $e_i^0$ equals $e_i^1$. Therefore, the post reform price is given by

$$p_i^1 = \left(1 + t_i^1\right)\left(\frac{p_i^0}{1 + t_i^0}\right) \tag{2}$$

The first step for revenue simulation consists in calculating the new predicted budget shares by using the parameter as obtained in the estimation and the new after-tax prices. When doing this, we must take into account that the model does not predict shares in a perfect manner. Since we are interested in the price and real expenditure effects, it is desirable to separate those components from the overall expenditure in each commodity. We add the share prediction error to the predicted shares as in Baker *et al.* (1990), that is, the part of each share not explained by prices and real expenditure or, equivalently, the component of the share explained by household characteristics, other non-price and non-real expenditure variables and the residual, which may contain household fixed effects.

Once the new shares have been computed, we can calculate the tax changes and the revenue forecasts. In particular, the aggregate tax revenues are obtained from expression

$$\sum_{h=1}^{H} g_h \sum_{i=1}^{N} \left(\frac{t_i^1}{1 + t_i^1} + \frac{e_i^1}{p_i^1}\right) E_{hi}^1 \tag{3}$$

where $g_h$ is the sample weight of each household and $E_{hi}^1$ is the estimated post-reform level of expenditure on good $i$ by household $h$.

We also provide some measures of the welfare effects from the simulated tax reform. Despite its various conceptual drawbacks (see Banks *et al.*, 1996), the change in household welfare is quantified through the equivalent gain, a money metric impact of price changes. An equivalent gain (loss) is actually the amount of money that needs to be substracted from (given to) the household in order to attain the post-reform level of utility while keeping the initial price vector. We follow King (1983) in computing this measure, although adapting it to the QAIDS.[11] In this sense, we calculate the equivalent income as

$$y_e = c(v, \mathbf{p}^r) = c(\mathbf{p}^r, \mathbf{p}, y) \quad (4)$$

which is the household budget that, at the reference price level (initial prices in our case), is equivalent in utility terms to the actual household budget at final prices. Thus, the equivalent gain for household $h$ is

$$EG^h = y_0^h - y_e^h \quad (5)$$

where $c(\cdot)$ is the cost function, $v$ the utility level, $\mathbf{p}^r$ the reference price vector, $\mathbf{p}$ is the vector of final prices, $y_0^h$ is the initial expenditure and $y_e^h$ the equivalent income.

## 4.1 Overall impacts: the 'dividends' from carbon taxation

For welfare and revenue simulation we have used the households that correspond to the second quarter of 1994 in the sample, the latest available from the Spanish Family Survey. Tables 3 and 4 describe the overall impacts of the first simulated reforms which are not revenue-neutral.[12] The first table presents the government receipts, as calculated from equation (3), with a central prediction of a 6.75% increase in VAT revenues relative to the pre-reform situation. The groups contributing most to such a revenue expansion are those with the highest price rises: electricity, gas, fuel for private transport and public transport. This would lead to a sizable revenue boost, with some extra 160,000 million pesetas. Such revenues represent 1.5% of total Spanish receipts in 1994 and could be used in a double dividend fashion (see Labandeira-Villot, 1996).

**Table 3, here (t3.doc)**

[11] In an exercise using the Almost Ideal Model of Deaton and Muellbauer (1980), i.e. without the quadratic terms of total expenditure, we obtained similar results to those reported in this chapter.

[12] There are strong reasons to model the reforms as revenue neutral, as the changes in receipts will be normally fed back to consumers through subsidies and/or changes in the supply of public goods. However, the recent Spanish tax increases have not been handed back to consumers in a straightforward and immediate manner.

Table 4 shows the expected relative demand changes by commodity group after carbon taxation, which were implicit in Table 3. With this information and the $CO_2$ intensities of Table A2.4 we are able to calculate the tax-induced modification in $CO_2$ emissions. The appraisal of environmental benefits is straightforward by applying the $CO_2$ tax rate to abatement. Note the relatively low $CO_2$ abatement achieved by the carbon tax (6,817 kt, only 3% of energy-related emissions), with environmental benefits merely representing 3.5% of total carbon receipts. This obviously reflects the huge dependence of contemporary economies on fossil fuel consumption, which is not surprising as the carbon tax affects all sectors in the economy.

**Table 4, here (t4.doc)**

The effects of a revenue-neutral reform are depicted by Table 5. We start by calculating the extra revenue and dividing it by the corresponding number of households in the population (using the grossing-up factors contained in the sample information). We then substract that average tax payment and recalculate the new tax payments after the household receives this lump-sum. Although we could report payment figures, Table 5 simply focuses on the percentage of winners (and loosers) from the reform. This table indicates that households with retired heads have a lower percentage of winners than those whose head is less than 65.[13] Moreover, the percentage of winners is inversely related to total expenditure rise, a desired feature in any indirect tax reform. Nevertheless, when going from the lower to the upper bounds, there are not important changes in the median of the distribution of tax payments.

**Table 5, here (t5.doc)**

## 4.2 Some distributional effects

We begin by yielding the percentage increase in tax payments (relative to the pre-reform situation) in Table 6. It is noticeable that there are not significant differences in the relative tax-payment increase by demographic breakdown. In this sense we sustain the conclusions of other empirical exercises on this issue, corroborating the proportionality of tax payments from a broad Spanish carbon tax (see Smith, 1995).

[13]Retired heads probably spend more time at home and thus use electricity and/or gas with more intensity.

**Table 6, here (t6.doc)**

At this stage we must note that all the distributional measures of our exercise do not refer to household income but to household expenditure. This is because short-run income may be an unreliable indicator of well-being, as it is clear form the life-cycle and permanent-income theories of consumption. Indeed, household income may easily vary from year to year whereas consumption is thought to be set on the basis of long-run income (Poterba, 1989).

Table 7 reports the welfare effects from the carbon tax by decile of expenditure and using sub-samples corresponding to some socio-economic variables. The column headed 'EL' contains our money metric measure of utility change, while the column 'PET' represents the relative size of the equivalent loss (with respect to pre-reform total expenditure). All figures are equivalent losses because every reform leads to price increases in all the expenditure groups of the demand system.

**Table 7, here (t7.doc)**

There are several issues that emerge from the figures in Table 7. First, the equivalent losses are comparatively substantial in all reforms, which means that price increases are significant and affect Spanish households in a non-negligible way. Second, the variation of EL across total expenditure deciles is inconclusive on the regressivity or progressivity of the reform. Still, it is necessary to remark that the reforms are regressive when looking at sub-samples by head age (see note 13).

# 5 Conclusions

This paper has explored the economic effects of a hypothetical tax levied on Spanish energy-related $CO_2$ emissions. The proposed tax design included the jurisdictional allocation to the Spanish central government, the use of linked product taxation and the adoption of an 'actual damage' carbon tax rate.

Our empirical analysis has proceeded with subsequent stages. First, we employed an input-output demand model to calculate the $CO_2$ intensities for each industrial branch, which allowed for a direct computation of the price changes after carbon taxation. We then simulated the effects of the new tax-induced prices on Spanish household consumption.

Given the size and stability of carbon revenues, we were particularly interested in appraising the distributional impacts from the hypothetical carbon tax as its environmental effects were likely to be modest in the short run. In this sense, the use of *ad hoc* welfare measures did not sustain the presumed regressivity of carbon taxation in Spain.

# APPENDIX 1: ADOPTING THE TAX RATE ON $CO_2$ EMISSIONS

## A1.1 Shadow prices vs. actual damages

There are two main theoretical options to determine the carbon tax rate: shadow price approaches and the actual damage cost method. The former calculate the tax rate as the carbon price required to keep emissions on the socially optimal path yielded by an intertemporal optimization model. The underlying 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. 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 so called 'carbon budget' alternative, where greenhouse damages do not need to be modelled and valued.

Section 2.2 has established the superiority of the actual damage approach to calculate the unilateral Spanish carbon tax rate, with Fankhauser's (1994) analysis of greenhouse damage as a key applied contribution. Fankhauser estimated 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 (BAU, as reported by the IPPC) to that brought about by a marginal abatement in the base period. Figure A1.1 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. A new trajectory must be otherwise calculated to appraise the marginal change, thus reducing the practical appeal of this approach.

It is clear that any computation of actual $CO_2$ damage requires the use of a climate module and a damage function. The former converts $CO_2$ emissions in atmospheric concentrations and subsequent warming, which is the input for the damage function.[1] Yet, the broad scientific controversies on climate change phenomena led Fankhauser to use a stochastic greenhouse damage model in which all parameters were defined as random.

[1] Fankhauser's damage function does not contemplate the possibility of a human-induced climate catastrophe. As usual, it is calibrated for a doubling of preindustrial $CO_2$ concentration in the atmosphere due to the wide availability of monetary values for $2\times CO_2$ damage (see e.g. Pearce *et al.*, 1996).

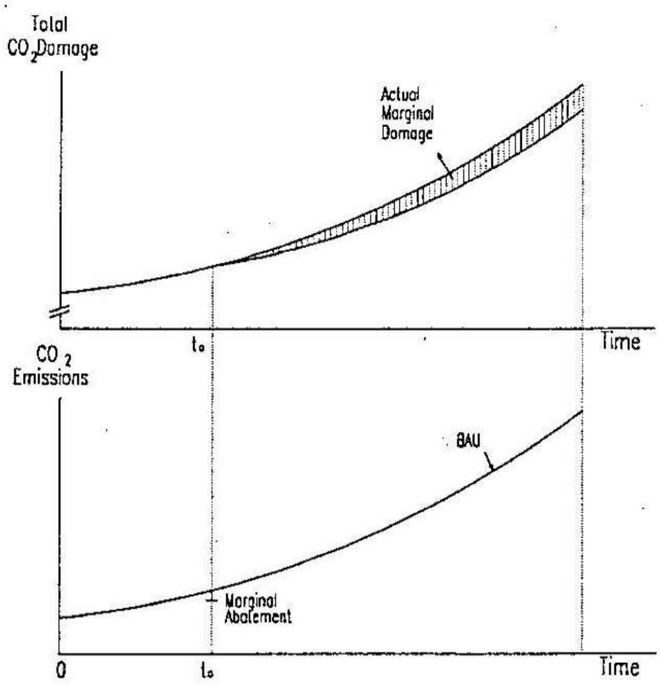


Figure A1.1: The Actual Marginal Damage Cost of $CO_2$ Emissions

## A1.2 A comparative assessment of the adopted carbon tax

The hypothetical Spanish carbon tax rate is directly obtained from Fankhauser's results. As observed in Table A1.1, the adopted tax rate is significantly higher than those reported by the shadow price studies. This is not only explained by methodological differences but also by Fankhauser's use of expected values instead of the usual best guesses.[2] Note that the wide 90% confidence interval reported by Fankhauser reflects the prevailing uncertainty on greenhouse impacts.

How does the adopted Spanish tax rate compare to other implemented or proposed carbon taxes? If Fankhauser's figure for 1991-2000 is compared to the original proposal by the European Commission on carbon taxation for 1994 without taking the general energy segment into account (see Pearson and Smith, 1991), the results are surprisingly approximate. The Spanish tax rate is however much lower than the implemented Swedish carbon tax on industries (+60%) and households (+550%) (see Lövgren, 1994).

[2]The divergence arises because the distribution of global warming damage is skewed to the right.

**Table A1.1 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) | BG=5.3; EV=12.0 | CB |
| Fankhauser (1994) | EV=20.3 (6.2-45.2) | AD |

Note: CB=cost benefit; B=carbon budget; AD=actual damage;
BG=best guess; EV= expected value

# APPENDIX 2: AN INPUT-OUTPUT APPROACH TO ASSESS THE PRICE EFFECTS OF CARBON TAXATION

## A2.1 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

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \tag{A2.1}$$

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 $\mathbf{A}\mathbf{x}$ 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. It is clear that this proportionality between the inputs into a sector and the total output from that sector constitutes a serious drawback of input-output methodology, being a reasonable assumption only in the short run.

Reorganization of expression (A2.1) yields

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{A2.2}$$

where $\mathbf{I}$ is a unit matrix and $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse, which converts final demand into total output. This is an essential result as final demand, 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: first-round, second-round, etc.) 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. 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.

Thus, total industrial fuel use is the 5-vector

$$\mathbf{f} = \mathbf{B}'\mathbf{x} \tag{A2.3}$$

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

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

$$\mathbf{h} = \mathbf{C}'\mathbf{y} \tag{A2.4}$$

where C is a 57×5 matrix of coefficients that relate quantities and values of the fuel purchased as part of final demand (kilotonnes/terajoules per million pesetas).

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

$$\mathbf{g} = \mathbf{e}'(\mathbf{f} + \mathbf{h}) \tag{A2.5}$$

where e is a 5-vector indicating the $CO_2$ production per unit fuel burnt (kilotonnes of $CO_2$ per kilotonnes/terajoules of fuel).

From equations (A2.2), (A2.3), (A2.4) and (A2.5) we have

$$\mathbf{g} = \mathbf{e}'\mathbf{B}'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} + \mathbf{e}'\mathbf{C}'\mathbf{y} \tag{A2.6}$$

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 (A2.6) and the matrix expansion for $(\mathbf{I} - \mathbf{A})^{-1}$

$$\mathbf{g_p} = \mathbf{e}'\mathbf{C}'\mathbf{y_p} + \mathbf{e}'\mathbf{B}'\left(\mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \ldots\right)\mathbf{y_p} \tag{A2.7}$$

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.

## A2.2 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).[1] 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 A2.4).

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

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 A2.1 depicts the **e** vector for the Spanish economy.

**Table A2.1 e Vector (5×1)**

| | | |
|---|---|---|
| (1) Coal | $\frac{\text{kt } CO_2}{\text{kt fuel}}$ | 2.250 |
| (2) Lignite | $\frac{\text{kt } CO_2}{\text{kt fuel}}$ | 1.410 |
| (3) Liquid Fuels | $\frac{\text{kt } CO_2}{\text{kt fuel}}$ | 3.200 |
| (4) Natural Gas | $\frac{\text{kt } CO_2}{\text{tj fuel}}$ | 0.055 |
| (5) Manufactured Gas | $\frac{\text{kt } CO_2}{\text{tj fuel}}$ | 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 1995.

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 (Ministerio de Medio Ambiente, 1996). 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 A2.2 and A2.3 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 (A2.4) and (A2.5), to the actual figures reported by the Spanish government.

**Table A2.2, here (matbd.doc)**

**Table A2.3, here (matcd.doc)**

### .2.3 $CO_2$ intensities and price effects

Assuming that the carbon tax on fossil fuels is fully shifted forward to ɔnsumption, prices are increased in proportion to the carbon content of the roduced goods. In fact, the price rises are given by

$$\mathbf{t} = \mu\, \mathbf{u} \tag{A2.8}$$

'here $\mathbf{u}$ is the 57-vector showing the $CO_2$ intensities (kg of $CO_2$ per peseta) nd $\mu$ is the general tax rate on $CO_2$ emissions. Particularly, $\mathbf{t}$ can be inter-reted as a 57-vector with the derived *ad valorem* tax rates on the produced oods.

Therefore, to estimate the price effects of carbon taxation we need to now the $CO_2$ intensities for all producing sectors, which can be directly alculated from equation (A2.6) with

$$\mathbf{u}' = \mathbf{e}' \left[\mathbf{B}' (\mathbf{I} - \mathbf{A})^{-1} + \mathbf{C}'\right] \tag{A2.9}$$

Total $CO_2$ intensities can be further decomposed into the intensities from uel use by consumers, $\mathbf{e}'\mathbf{C}'$, from direct fuel use by industries, $\mathbf{e}'\mathbf{B}'$, and from ndirect fuel use by industries, $\mathbf{e}'\mathbf{B}'\left(\mathbf{A} + \mathbf{A}^2 + \ldots\right)$. Table A2.4 yields the ɔrevious $CO_2$ intensities for the Spanish economy in 1992, showing the im-ɔortance of 'indirect' $CO_2$ emissions by industries and hence the inescapable ıeed of input-output analysis.

With this background, Table A2.5 presents the effects of a simulated :arbon tax on Spanish prices for the year 1994. Given the unavailability of data for 1994 and the insignificant changes expected in the short term, we use the 1992 $CO_2$ intensities. The general tax rate on $CO_2$ emissions is obtained from the results reported by Fankhauser (1994), as shown in Appendix 1. After transforming the original carbon tax into a tax on $CO_2$ emissions and updating the 1990 US$ to 1994 pesetas, the lower, upper and expected values of $\mu$ are respectively 0.2558, 1.8649 and 0.8388 pesetas per kg of $CO_2$.

The observed price changes follow the usual pattern, with energy-intensive sectors suffering the highest effects in both relative (see the ranking) and absolute terms.[2] In this sense, the results follow the general trends observed in other European countries (see Proops, Faber and Wagenhals, 1993).

**Table A2.4, here (tioi.doc)**

[2] Obviously, we have not reported any price effect on 'non-market' sectors.

Table A2.5, here (tiop.doc)

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; 1993). Nevertheless, after introducing the implicit tax rate employed by Martín and Velázquez in the model above (403 pesetas per tonne of $CO_2$), we found some differences in the '$CO_2$ ranking' of energy-intensive and transport sectors. However, these inconsistencies may be partly explained by 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.

## A2.4 Estimating Spanish $CO_2$ emissions

The produced vectors and matrices were introduced in expressions (A2.6) and (A2.7) to estimate total and disaggregated (by sector) Spanish $CO_2$ emissions. The results of this assessment for the year 1992 are presented in Table A2.6. Given our sole interest in $CO_2$ emissions physically produced by Spanish sources, only domestic magnitudes and imports of fossil fuels were contemplated. 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.[3]

The first two columns of Table A2.6 were obtained from equation (A2.6), 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, calculated from

$$\mathbf{g}_{i(ac)} = \mathbf{e}'\mathbf{B}'\,{}^{\wedge}\mathbf{x} \tag{A2.10}$$

where ${}^{\wedge}\mathbf{x}$ is the diagonal matrix derived from the $\mathbf{x}$ vector. Finally, the fourth column yields the imputed industrial emissions (by sector) brought about by total final demand, from

$$\mathbf{g}_{i(im)} = \mathbf{e}'\mathbf{B}'\,(\mathbf{I}-\mathbf{A})^{-1'}\,{}^{\wedge}\mathbf{y} \tag{A2.11}$$

[3]Assuming identical **B** 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 A2.6). 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 A2.6).

**Table A2.6, here (tioe.doc)**

Again, the difference between expressions (A2.10) and (A2.11) and between their associated columns in Table A2.6 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.

Moreover, the distribution of Spanish $CO_2$ emissions 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. Therefore, the limitations of any climate change policy entirely focused on the latter are obvious.

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 by the official Spanish official inventory (231,261 kt; see Ministry of the Environment, 1996). It is our view, however, that the divergence is small and can be attributed to the emission ratios used in the **e** 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.

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Table 3 Overall Impacts of the Reforms. Million 1994 pesetas

| Category | Pre-Reform | LB | EV | UB |
|---|---|---|---|---|
| **Food & Non-alc. Drinks** | 342,753.4 | 347,409.1<br>(1.41) | 362,006.5<br>(5.67) | 387,730.0<br>(13.2) |
| **Alcohol** | 72,438.4 | 73,946.3<br>(1.32) | 75,422.1<br>(4.12) | 79,143.3<br>(9.26) |
| **Clothing and footwear** | 376,000.5 | 377,432.1<br>(0.38) | 380,338.1<br>(1.15) | 385,490.8<br>(2.52) |
| **Electricity** | 81,326.4 | 87,499.2<br>(7.59) | 101,596.7<br>(24.9) | 126,190.0<br>(55.2) |
| **Natural & Manuf. Gas** | 8,180.6 | 9,030.1<br>(10.9) | 11,162.2<br>(36.4) | 15,399.1<br>(88.2) |
| **Fuel for Private Transp.** | 464,379.5 | 491,335.4<br>(5.80) | 553,010.7<br>(17.6) | 662,255.9<br>(42.6) |
| **Public transport** | 39,949.0 | 42,618.9<br>(6.68) | 48,630.7<br>(21.7) | 59,425.2<br>(48.7) |
| **Other Non-durables** | 943,071.6 | 948,769.6<br>(0.60) | 952,770.3<br>(1.03) | 959,801.5<br>(1.77) |
| **TOTAL** | 2,327,919.5 | 2,377,489.1<br>(2.13) | 2,484,937.4<br>(6.74) | 2,675,435.9<br>(14.9) |

Notes:
a) Revenue percentage increase in parenthesis.
b) LB: Lower bound for price increase.
c) EV: Expected value of price increase.
d) UB: Upper bound for price increase.

**Table 4 Environmental Effects of the Central Tax Reform**

| Category | Demand[1] | Emissions[2] | Benefits[3] |
|---|---|---|---|
| **Food & Non-alc. Drinks** | -0.78 | -206,000 | 172,792 |
| **Alcohol** | 1.75 | 3,520 | -2,953 |
| **Clothing and Footwear** | -0.58 | -45,750 | 38,376 |
| **Electricity** | -4.25 | -1,215,399 | 1,019,476 |
| **Natural & Manuf. Gas** | 8.92 | 213,130 | -178,774 |
| **Fuel for Private Transp.** | -2.37 | -2,873,969 | 2,410,686 |
| **Public Transport** | -15.66 | -2,671,602 | 2,240,939 |
| **Other Non-durables** | -0.16 | -21,378 | 17,932 |
| **TOTAL** | **n.a** | **6,817,448** | **5,718,474** |

Notes:

1. Percentage change in total demand after the carbon tax.
2. Imputed reduction in $CO_2$ emmissions (tonnes) from demand changes.
3. Environmental benefits from $CO_2$ abatement after the carbon tax (1994 thousand pesetas).

**Table 5 Winners in Revenue-neutral Reforms**

| Group of Households | Reform | | |
|---|---|---|---|
| | LB | EV | UB |
| All | 62.49 | 61.85 | 61.39 |
| Age < 65 | 61.24 | 60.00 | 59.40 |
| Age ≥ 65 | 69.60 | 70.30 | 72.66 |
| No Children | 68.42 | 70.15 | 71.14 |
| 1 Child | 61.05 | 59.65 | 58.37 |
| ≥ 2 Children | 59.46 | 57.68 | 56.71 |
| Decile 1 | 100.0 | 100.0 | 100.0 |
| Decile 2 | 95.96 | 97.57 | 97.57 |
| Decile 3 | 84.37 | 91.37 | 92.45 |
| Decile 4 | 75.13 | 82.97 | 82.70 |
| Decile 5 | 66.85 | 74.93 | 75.74 |
| Decile 6 | 55.53 | 54.72 | 56.33 |
| Decile 7 | 44.32 | 41.62 | 41.89 |
| Decile 8 | 43.67 | 40.16 | 37.20 |
| Decile 9 | 34.23 | 25.61 | 22.38 |
| Decile 10 | 24.86 | 9.46 | 7.57 |

Notes:

a) All figures represent percentage of winners of the corresponding sample.
b) LB: Lower bound for price increase.
c) EV: Expected value of price increase.
d) UP: Upper bound for price increase.

**Table 6 Quarterly Increase in Tax Payments by Breakdown of Variables**

| Group of Households | Reform | | |
|---|---|---|---|
| | LB | EV | UB |
| All households | 1.98 | 6.48 | 14.47 |
| Age < 65 | 1.97 | 6.48 | 14.48 |
| Age ≥ 65 | 2.08 | 6.51 | 14.38 |
| No Children | 2.07 | 6.54 | 14.48 |
| 1 Child | 2.06 | 6.64 | 14.76 |
| ≥ 2 Children | 1.89 | 6.37 | 14.31 |
| Decile 1 | 1.63 | 5.55 | 12.51 |
| Decile 2 | 1.82 | 6.15 | 13.84 |
| Decile 3 | 1.80 | 6.26 | 14.18 |
| Decile 4 | 2.02 | 6.70 | 15.01 |
| Decile 5 | 1.94 | 6.38 | 14.26 |
| Decile 6 | 2.05 | 6.75 | 15.08 |
| Decile 7 | 2.20 | 6.99 | 15.48 |
| Decile 8 | 2.07 | 6.64 | 14.73 |
| Decile 9 | 2.12 | 6.73 | 14.91 |
| Decile 10 | 2.18 | 6.68 | 14.65 |

Notes:

a) All figures represent percentage increases.
b) LB: Lower bound for price increase.
c) EV: Expected value of price increase.
d) UP: Upper bound for price increase.

**Table 7 Quarterly Equivalent Loss by Breakdown of Demographic Variables**

| Group of Households | Reform | | | | | |
|---|---|---|---|---|---|---|
| | LB | | EV | | UB | |
| | EL | PET | EL | PET | EL | PET |
| All | 4,962.2 | 0.91 | 15,924.7 | 2.91 | 34,150.1 | 6.23 |
| Age < 65 | 5,004.0 | 0.88 | 16,065.8 | 2.83 | 34,477.4 | 6.07 |
| Age ≥ 65 | 4,725.2 | 1.04 | 15,125.5 | 3.35 | 32,295.5 | 7.15 |
| No Children | 4,269.5 | 0.93 | 13,685.4 | 2.97 | 29,289.1 | 6.36 |
| 1 Child | 4,920.9 | 0.91 | 15,791.3 | 2.92 | 33,861.1 | 6.27 |
| ≥ 2 Children | 5,420.3 | 0.89 | 17,405.5 | 2.86 | 37,364.1 | 6.14 |
| Decile 1 | 1,610.9 | 0.84 | 5,168.8 | 2.70 | 11,081.2 | 5.79 |
| Decile 2 | 2,372.1 | 0.86 | 7,613.8 | 2.76 | 16,332.2 | 5.92 |
| Decile 3 | 2,936.0 | 0.88 | 9,423.7 | 2.81 | 20,214.3 | 6.04 |
| Decile 4 | 3,441.3 | 0.89 | 11,045.7 | 2.85 | 23,694.0 | 6.12 |
| Decile 5 | 3,871.1 | 0.87 | 12,428.3 | 2.81 | 26,670.9 | 6.03 |
| Decile 6 | 4,567.0 | 0.91 | 14,657.1 | 2.93 | 31,434.1 | 6.28 |
| Decile 7 | 5,305.7 | 0.93 | 17,028.6 | 3.00 | 36,522.3 | 6.43 |
| Decile 8 | 6,053.0 | 0.92 | 19,429.3 | 2.95 | 41,679.3 | 6.32 |
| Decile 9 | 7,678.9 | 0.97 | 24,637.6 | 3.11 | 52,813.0 | 6.67 |
| Decile 10 | 11,792.0 | 0.98 | 37,834.3 | 3.14 | 81,101.8 | 6.73 |

Notes:

a) EL: Equivalent loss (1994 pesetas)
b) PET: Percentage of equivalent loss on total expenditure.
c) LB: Lower bound for price increase.
d) EV: Expected value of price increase.
e) UB: Upper bound for price increase.

Table A2.2 B Matrix (57x5); kilotonnes {(1) (2) (3)} and terajoules {(4) (5)} per million 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 A2.3 C Matrix (57x5); kilotonnes {(1) (2) (3)} and terajoules {(4) (5)} per million 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 | 0.675 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.523 |
| 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 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 A2.4 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) |
|---|---|---|---|---|
| **9) Tobacco** | 0.0 | 0.0000758 | 0.0009743 | 0.0010501 |
| **0) Textiles & Clothing** | 0.0 | 0.0005798 | 0.0022496 | 0.0028293 |
| **1) Leather & Footwear** | 0.0 | 0.0002932 | 0.0020863 | 0.0023795 |
| **2) Timber & Furniture** | 0.0 | 0.0000799 | 0.0028580 | 0.0029379 |
| **3) Pulp & Paper** | 0.0 | 0.0057972 | 0.0049131 | 0.0107100 |
| **4) Printing** | 0.0 | 0.0003759 | 0.0030448 | 0.0034207 |
| **5) Rubber & Plastics** | 0.0 | 0.0005212 | 0.0025513 | 0.0030726 |
| **6) Other Manufacturing** | 0.0 | 0.0000839 | 0.0017685 | 0.0018525 |
| **7) Construction** | 0.0 | 0.0004225 | 0.0029503 | 0.0033728 |
| **8) Recovery & Repair** | 0.0 | 0.0001273 | 0.0018029 | 0.0019302 |
| **9) Commerce** | 0.0 | 0.0000553 | 0.0012971 | 0.0013524 |
| **0) Restaurants & Hotels** | 0.0 | 0.0002163 | 0.0025446 | 0.0027609 |
| **1) Railways** | 0.0 | 0.0023012 | 0.0077284 | 0.0103000 |
| **2) Road Transport** | 0.0 | 0.0147600 | 0.0014267 | 0.0161870 |
| **3) Sea Transport** | 0.0 | 0.0246010 | 0.0015466 | 0.0261480 |
| **4) Air Transport** | 0.0 | 0.0157210 | 0.0014385 | 0.0171590 |
| **5) Services for Transport** | 0.0 | 0.0000941 | 0.0011776 | 0.0012717 |
| **6) Communications** | 0.0 | 0.0000247 | 0.0007295 | 0.0007542 |
| **7) Credit & Insurance** | 0.0 | 0.0000145 | 0.0006210 | 0.0006355 |
| **8) Imputed Production to nking Services** | 0.0 | 0.0 | 0.0 | 0.0 |
| **9) Services to Firms** | 0.0 | 0.0001416 | 0.0006274 | 0.0007690 |
| **) Real-Estate Renting** | 0.0 | 0.0000061 | 0.0006784 | 0.0006845 |
| **) Education & Research arket)** | 0.0 | 0.0001556 | 0.0013447 | 0.0015004 |
| **) Health (Market)** | 0.0 | 0.0000861 | 0.0010377 | 0.0011238 |
| **) Other Services (M)** | 0.0 | 0.0000839 | 0.0010381 | 0.0011221 |
| **) Public Services** | 0.0 | 0.0001693 | 0.0014789 | 0.0016482 |
| **) Education & Research n-Market)** | 0.0 | 0.0000921 | 0.0008677 | 0.0009598 |
| **) Health (N-M)** | 0.0 | 0.0000955 | 0.0012732 | 0.0013687 |
| **) Other Services (N-M)** | 0.0 | 0.0000838 | 0.0006251 | 0.0007089 |

Table A2.5 Price Effects of $CO_2$ Taxation in the [redacted]

| *INDUSTRY* | Lower Bound (% increase) | Upper Bound (% increase) | Expected Value (% increase) | Ranking |
|---|---|---|---|---|
| (1) Agriculture, Forestry & Fishing | 0.11015 | 0.80244 | 0.36099 | 21 |
| (2) Coal Mining | 2.11641 | 15.41841 | 6.93622 | 1 |
| (3) Lignite Mining | 0.52456 | 3.82147 | 1.71915 | 8 |
| (4) Coke | 0.10052 | 0.73230 | 0.32944 | 24 |
| (5) Oil | 0.03843 | 0.27994 | 0.12594 | 41 |
| (6) Oil Processing | 0.85408 | 6.22211 | 2.79912 | 4 |
| (7) Natural Gas | 1.02959 | 7.50069 | 3.37430 | 3 |
| (8) Water | 0.17046 | 1.24182 | 0.55865 | 17 |
| (9) Electricity | 1.17339 | 8.54836 | 3.84562 | 2 |
| (10) Manufactured Gas | 0.78604 | 5.72643 | 2.57613 | 5 |
| (11) Nuclear Fuels | 0.06647 | 0.48421 | 0.21783 | 34 |
| (12) Iron & Steel | 0.14965 | 1.09024 | 0.49046 | 19 |
| (13) Non-Ferrous Metals | 0.22363 | 1.62921 | 0.73293 | 15 |
| (14) Cement | 0.71066 | 5.17724 | 2.32906 | 6 |
| (15) Glass | 0.36654 | 2.67029 | 1.20127 | 12 |
| (16) Ceramics & Bricks | 0.51708 | 3.76699 | 1.69464 | 9 |
| (17) Other Minerals | 0.21531 | 1.56860 | 0.70566 | 16 |
| (18) Chemicals | 0.15388 | 1.12101 | 0.50431 | 18 |
| (19) Metal Products | 0.08861 | 0.64552 | 0.29040 | 26 |
| (20) Agricultural & Industrial Machines | 0.05498 | 0.40056 | 0.18020 | 36 |
| (21) Office Machines | 0.02385 | 0.17375 | 0.07816 | 48 |
| (22) Electrical Products | 0.05358 | 0.39036 | 0.17561 | 37 |
| (23) Motor Vehicles | 0.08159 | 0.59437 | 0.26739 | 29 |
| (24) Other Vehicles | 0.04905 | 0.35731 | 0.16074 | 39 |
| (25) Meat | 0.10238 | 0.74582 | 0.33552 | 23 |
| (26) Milk | 0.11651 | 0.84878 | 0.38184 | 20 |
| (27) Other Food | 0.10508 | 0.76549 | 0.34437 | 22 |
| (28) Drinks | 0.09253 | 0.67411 | 0.30326 | 25 |

| *INDUSTRY (cont.)* | Lower Bound (% increase) | Upper Bound (% increase) | Expected Value (% increase) | Ranking |
|---|---|---|---|---|
| 29) Tobacco | 0.02688 | 0.19585 | 0.08811 | 47 |
| 30) Textiles & Clothing | 0.07243 | 0.52767 | 0.23738 | 32 |
| 31) Leather & Footwear | 0.06091 | 0.44367 | 0.19964 | 35 |
| 32) Timber & Furniture | 0.07521 | 0.54792 | 0.24649 | 31 |
| 33) Pulp & Paper | 0.27418 | 1.99747 | 0.89859 | 13 |
| 34) Printing | 0.08757 | 0.63796 | 0.28700 | 27 |
| 35) Rubber & Plastics | 0.07866 | 0.57303 | 0.25779 | 30 |
| 36) Other Manufacturing | 0.04742 | 0.34548 | 0.15542 | 40 |
| 37) Construction | 0.08634 | 0.62903 | 0.28298 | 28 |
| 38) Recovery & Repairs | 0.04941 | 0.35998 | 0.16194 | 38 |
| 9) Commerce | 0.03462 | 0.25222 | 0.11346 | 43 |
| 0) Restaurants & Hotels | 0.07068 | 0.51492 | 0.23164 | 33 |
| 1) Railways | 0.25676 | 1.87054 | 0.84149 | 14 |
| 2) Road Transport | 0.41439 | 3.01891 | 1.35811 | 11 |
| 3) Sea Transport | 0.66939 | 4.87660 | 2.19382 | 7 |
| 4) Air Transport | 0.43928 | 3.20020 | 1.43966 | 10 |
| 5) Services for Transport | 0.03255 | 0.23717 | 0.10670 | 44 |
| ) Communications | 0.01931 | 0.14067 | 0.06328 | 50 |
| ) Credit & Insurance | 0.01627 | 0.11853 | 0.05332 | 52 |
| ) Imputed Production to nking Services | 0.0 | 0.0 | 0.0 | 53 |
| ) Services to Firms | 0.01969 | 0.14341 | 0.06452 | 49 |
| ) Real-Estate Renting | 0.01752 | 0.12766 | 0.05743 | 51 |
| ) Education & Research rket) | 0.03841 | 0.27982 | 0.12588 | 42 |
| Health (M) | 0.02877 | 0.20958 | 0.09428 | 45 |
| Other Services (M) | 0.02872 | 0.20927 | 0.09414 | 46 |
| Public Services | - | - | - | - |
| Education & Research (Non-ket) | - | - | - | - |
| Health (N-M) | - | - | - | - |
| Other Services (N-M) | - | - | - | - |

## Table A2.6 $CO_2$ 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 & ndustrial 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** |
| 5) Meat | 0.0 | 417.5 | 446.0 | **5,709.7** |
| 6) Milk | 0.0 | 629.6 | 664.8 | **2,651.7** |
| 7) Other Food | 0.0 | 3,156.1 | 3,872.8 | **6,861.4** |
| 8) 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* | |