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The Welfare Effects of Carbon Taxation on Italian Households

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Abstract - We simulate the welfare effects of the Carbon-Energy Tax introduced in Italy at the beginning of 1999 which asks for smooth increases, over a number of years, in the prices of most fossil fuels. The welfare effects have been calculated using True Cost of Living index numbers and their parameters have been obtained through estimation of a demand system, using households-data from 1985 to 1996. The welfare loss at the aggregate level turns out to be quite substantial and affects Italian households in a non-negligible way, but the distribution of welfare losses across different levels of total monthly expenditures does not allow sustaining the regressivity of Carbon taxation, as the effect becomes bigger as we move up the income distribution. This evidence might encourage the use of Carbon Taxes as cost-effective instruments of environmental policy, especially after the recent negotiations on Climate Change. However, other important implications of Carbon taxation such as those on competitiveness and the environmental impact are not assessed in this study.

Keywords: Carbon taxes, demand analysis, welfare changes
J.E.L. classification: D11, D12, H31, Q28, Q48.

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1. Introduction

Over the last decade and, particularly, after the Framework Convention on Climate Change of 1992, many OECD countries have considered the introduction of "Green Tax Reforms" aimed at reducing, through higher prices, either the use of scarce resources or emissions of pollutive substances. The rationale is that taxes on environmentally damaging activities, largely considered as cost-effective instruments of environmental policy, could be used in a revenue neutral context (against revenue raising), i.e. introducing environment-related taxes and reducing or removing other existing distortionary taxes (OECD, 2000, p. 5) so that the government budgetary position remains unchanged. A "double dividend" could then be produced: an improvement in environmental quality and a reduction in unemployment[1], although the existence of a double dividend is still controversial. In this context carbon taxes have frequently been advocated, especially as a way to comply with the Kyoto Protocol obligations. However, to date only six countries have implemented taxes based on the carbon content of the energy products: Sweden, Norway, The Netherlands, Denmark, Finland and Italy. Austria and Germany have introduced energy related taxes that do not consider the carbon content of energy products[2]. Other countries like the United Kingdom and Switzerland are currently discussing proposals for implementing carbon or energy taxes (Baranzini et al., 2000, p. 396); whereas the United States, Australia and New Zealand, after having explored the possibility, have abandoned the idea. Finally, the European Union (EU) after a long discussion at the beginning of the nineties on the opportunity of introducing a European Carbon tax[3], has not appeared to attach a priority role to it in the Kyoto Protocol strategies[4]. There thus seems to be a widening gap between the political discourse and the policy practice, as noted by Baranzini et al. (2000, p. 396), who also reported that, while in 1995 environmental taxes in the European Union made up just 1,7% of all EU taxation, taxes on labour in the same year represented 51,4% of all taxation. However, the hypothesis of a European Union Energy Tax has currently received renewed attention[5]. Moreover, the recent decision of the EU to go on with the Kyoto-Protocol obligations, despite its rejection by the United States, gives reasons to think that carbon taxation might play a significant role in the future European Environmental Policy.

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[1] The Double Dividend Hypothesis will not be discussed in this work. For a review of this issue one may consult OECD, 2000.

[2] A "carbon tax" is a charge paid on each fossil fuel, proportional to the quantity of carbon emitted when the fuel is burned. It is not the same as a "CO_2 tax" which is instead specified on the ton of CO_2 emitted. An "energy tax", instead, is to be paid on the quantity of energy consumed and covers nuclear and renewable energy besides fossil fuels' generated energy (in Baranzini et al., 2000, pp. 396-397). A CO_2 tax can be easily translated into a carbon tax by knowing the relationship between the carbon content of fuels and CO_2 emissions.

[3] Commission of the European Community (1991) *A Community Strategy to Limit Carbon Dioxide Emissions and to Improve Energy Efficiency.* Communication from the Commission to the Council. SEC(91)1744 final; Brussels, 14 October 1991.

[4] For a comprehensive survey of the old European Carbon tax proposal and its implications, see C. Carraro and D. Siniscalco (1993).

A fundamental factor determining the acceptability of carbon taxes is the distribution of their costs on households and firms. The distributional impact of a fiscal reform on households can be measured in a number of ways, such as the distribution between households across different income or expenditure groups or between different households' types. Intuitively one might expect carbon taxes to be regressive, i.e. to affect proportionately more low-income households', because they tend to spend a higher share of their income on energy and energy related necessary goods. The existing empirical studies suggest that carbon taxes may be mildly regressive, but this often depends on the modelling framework used. Moreover this regressive effect is much attenuated, or even reversed, in a revenue-neutral context, i.e. when the tax revenues are returned to the households in the form of a cut in other forms of taxation. The following table summarises some of the results of a few country studies on the distributional impact of carbon-energy taxes.

Distributional Effects of Carbon-Energy Taxes in some of the previous empirical studies

Country Study	**Type of Taxation**	**Dimension of the Distributional Impact**	**Distributional Effect**
Sweden (Bränlund & Nordström, 1999)	CO_2 tax levied on all fossil fuels	-Income groups; -Number of children per household; -Regions;	Regressive in case of no tax replacement; Not so in a revenue neutral context;
U.K. (Smith, 2000)	Road Fuels Tax	-Income Groups -Regions	Not regressive when all households are considered (the greatest effect is on the middle-income households); Regressive if only car-owning households are considered;
Spain (Labandeira & Labeaga, 1999)	Carbon tax on all fossil fuels	-Expenditure Groups; -Different demographic profiles	Not regressive
Australia (Cornwell & Creedy, 1996)	Carbon tax on fossil fuels used in production and consumption	-Income Groups	Regressive when no technological substitution is allowed; Less so when technological substitution is allowed;
U.K. (Symons, Proops & Gay, 1994)	Carbon tax on fuels	-Expenditure Groups	Regressive in case of no tax replacement; Less so in a revenue neutral context;

The aim of this paper is to carry out a simple exercise to assess the welfare effects of Carbon taxation on Italian households, i.e. to calculate both the dimension (or significance) of the welfare change and its distribution across different types of households and different expenditures levels.

This exercise is limited in many ways: first, only 5 households' profiles are taken into account; secondly the likely changes in prices for products other than fuels are not considered, nor are the welfare effects on firms; thirdly we do not account for a "revenue-neutral" scenario, which might attenuate the welfare changes of the tax reform; finally no competitiveness nor environmental

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[5] The Economist, July 14th 2001, p. 30.

impacts are calculated. Nevertheless, there are no other studies, to our knowledge, that simulate the welfare effects of the Italian Carbon tax. Moreover, a new households data set is used which allows for behavioural responses and for comparisons to be made across different households profiles and across different levels of expenditures. Since carbon taxes, as well as other economic instruments such as exchangeable emissions permits, are likely to become an increasingly interesting policy option in the near future, this exercise could be of help in assessing the implications of such an instrument.

The structure of the article is as follows. In section 2 we illustrate the design and purpose of the Carbon tax introduced in Italy by the Centre-Left government in 1999. Section 3 deals with the theory of True Cost of Living Indices, their use to calculate welfare changes following a fiscal reform and how they can be obtained from a demand system. Section 4 contains the demand system and welfare changes estimation and the simulations' results. Finally, in section 6 we draw some conclusions.

2. Carbon taxation in Italy

With the approval of the Financial Law for 1999, a taxation of CO_2 emissions and related compensation measures has been introduced in Italy (L. 23.12.1998 n. 448, art. 8). The new green tax is in fact a carbon-energy tax and it is based on two main components (OECD, 2000, pp. 23-24): a reduction in CO_2 emissions through a re-modulation of excise duties on mineral oils to be achieved with a smooth transition from 1999 to 2005; the introduction of a consumption tax on coal, petrol coke and natural bitumen used in the combustion plants as defined by the EU Directive 88/609/1998. The following products are involved: leaded and unleaded petrol; Diesel oil (used for both heating and for transports); methane (used for both heating and transports); heavy fuel oils; LPG. This is in line with the national actions defined in 1998 (CIPE resolution of 19.11.1998) to reduce CO_2 emissions in order to comply with the obligations of the Kyoto Protocol.

To modify the preceding structure of excise duties, the target vector of the above energy products tax rates has been identified[6]. This is aimed at satisfying both the necessity to tax each fossil fuel according to its specific CO_2 emissions and the requirements of the EU Directive on the harmonisation process of excise rates on energy products (COM/97/30).

By indicating with α_i the excise duty on product *i*, the new energy excise rates in Italy are structured as follows: $\alpha_i = k\beta_i + A_i$, where k is the ratio between the Italian excise duty and the tax level

[6] To be achieved on January 1st 2005.

proposed by the European Directive[7]; β_i is the minimum excise level on product *i* proposed at the European level and A_i is the environmental component of the tax, proportional to the kg of CO_2 emitted by the fossil fuel *i* under consideration. This procedure has allowed setting out the excise rates for mineral oils to be applied on January 1st 2005. During the years from 1999 to 2004 the rates will be raised smoothly within a range not lower than 10% and not higher than 30% per year of the difference between pre-green reform excise rates and target levels excise rates. In addition to that, a consumption tax of 1.000 Lire per ton has been introduced for coal, petrol-coke and natural bitumen as explained before. In 1999 the increase in the excise rates has been equal to 20% of the increase to be applied as of January 1st 2005. Whereas a further increase was expected in 2000, the first stage of the tax reform has been prolonged for the whole year 2000 and it's still to be modified. This is due to the significant rise in oil prices experienced in 1999 and 2000. However the carbon tax is still expected to be progressively increased to the final target rate.

According to the law, by the end of 2004 the following percentage increases in the consumption price of the taxed mineral oils are planned. Fuels: leaded petrol +2.54%; unleaded petrol + 8,78%; diesel-oil + 13.69%; LPG -23.39%; methane +16.04%. Heating fuels: methane +0.97%; LPG +6.76%; heating diesel oil +13.89%; heavy heating oils +161.2%.

As said before, the green tax reform has been introduced in a revenue-neutral context. The explicit goal of the reform is to exploit a double-dividend: to promote environmental improvement and, at the same time, to reduce the tax wedge in labour costs. In the six years of the reform a revenue of 11.500 billion Lire is projected, coupled with a 12 million tons reduction of $C0_2$, representing 12% of the target reduction (to be achieved by 2010) in CO_2 emissions for Italy set out in the Kyoto Protocol. The revenue for the first year (1999) of the reform's implementation has been equal to 2.180 billion Lire. The largest share (60.5%) of this revenue, 1.319 billion Lire, was used for cutting social security contributions, thus reducing the tax wedge on labour costs by 0,82%[8]. 31.1%, 683 billion Lire, was targeted on compensation measures including a tax credit for lorry hauliers, a reduction in the Diesel-oil duty and reduction in taxation of heating fuels for the poorest and coldest areas of the country. Finally, 8.4% of the revenue, 300 billion Lire, was devoted to interventions improving environmental efficiency of energy use. The difference between the expected Carbon tax revenue and the above expenditures (about 130 billion Lire) was covered

[7] The k coefficient is calculated for each sector by referring to the most used product in that sector: petrol for transports, methane for the civil and industrial sector.

[8] This has been achieved through removal of some social security contribution, through halving the social contributions due by young entrepreneurs in the handcraft and commercial sector and through transfer on the account of the state budget (fiscalizzazione) for three years of the social contributions due by firms for the labour force recruited in the Southern regions by the end of 2001.

through the increase in the excise on unleaded petrol already decided in 1996 and confirmed in the Financial Law for 1999.

3. True Cost-of-Living Indices, the Compensating Variation and the Demand Model

Our aim is to assess the welfare effect of price increases determined by the introduction of the Carbon tax on different households and also to assess its distributive effects, i.e. how households at different levels of income and with different demographic profiles are affected. In order to do that we calculate, first, true cost-of-living index numbers and then the compensating variation. A true cost-of-living index number (TCOL) compares the cost of achieving a given level of economic welfare before a price increase with the cost of achieving the same level of economic welfare after the price increase and measures how much extra income is needed to get back to the original welfare level (Deaton and Muellbauer, 1980a, p. 170). If u^0 is the base level of welfare, the corresponding true index of the cost of living is given by:

$$P(p^1, p^0, u^0) = \frac{c(u^0, p^1)}{c(u^0, p^0)} = \text{TCOL} \qquad (1)$$

where $c(u^0,\boldsymbol{p^1})$ is the minimum cost of reaching utility u^0 at prices $\boldsymbol{p^1}$, whereas $c(u^0,\boldsymbol{p^0})$ is the minimum cost of reaching u^0 at prices $\boldsymbol{p^0}$. Calculation of the true costs-of-living indices involves calculation of the income effect of price changes (if preferences are not assumed to be homothetic) and of the substitution effect. When no substitution is considered, the index in (1) is equal to the Laspeyres index number. If we want to attach a monetary value to the change in welfare resulting from a change in prices we can calculate the compensating variation (CV) defined as the minimum amount by which a consumer would have to be compensated after a price change in order to be as well off as before (Deaton and Muellbauer, 1980a, p. 186). In this case, instead of having ratios as with the true-cost-of-living index number, we have sums of money expressed as the difference in costs of reaching the same utility level at two different price vectors. If we define the compensating variation as: $CV = c(u^0, \boldsymbol{p^1}) - c(u^0, \boldsymbol{p^0})$, this can be easily obtained from the TCOL as:

$$c(u^0, p^0)[TCOL - 1] = c(u^0, p^1) - c(u^0, p^0) = CV \qquad (2)$$

To calculate the TCOL in (1) we need to know the parameters of the cost function $c(u, \boldsymbol{p})$, which can be obtained through the estimation of a complete system of demand equations. This has been specified as an Almost Ideal (AI) demand system (Deaton and Muellbauer, 1980b) starting from a logarithmic cost function implying PIGLOG preferences (Deaton and Muellbauer, 1980a, pp. 154-158), i.e. that allows perfect aggregation over consumers:

$$\ln c(u, p) = \ln a(p)(1-u) + u \ln b(p) \qquad (3)$$

Where $a(\mathbf{p})$ and $b(\mathbf{p})$ are functions of prices and *ln* indicates the natural logarithm. By adopting the flexible functional forms approach (3) can be approximated through a function that, thanks to its large number of parameters, can be considered as a second order approximation of the true cost function.

Thus letting:

$$\ln a(p) = \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j c^*_{ij} \ln p_i \ln p_j \qquad (4)$$

$$\ln b(p) = \ln a(p) + \prod_i p_i^{b_i} \qquad (5)$$

where $i=1,\dots,n$ and $j=1,\dots,n$ are the number of goods considered, substituting (4) and (5) into (3) and differentiating with respect to the prices, p_i, we obtain the Hicksian demand functions as shares and substituting the indirect utility function (obtained by inversion of the cost function) into the Hicksian demand functions we obtain Marshallian demand functions as shares of the form:

$$w_i = \alpha_i + \sum_j c_{ij} \ln p_j + b_i \ln\left(\frac{y}{P}\right) \qquad (6)$$

where y is total expenditure, the P price function is defined as:

$$\ln P = \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j c_{ij} \ln p_i \ln p_j$$

and the parameters c_{ij} are defined as: $c_{ij}=1/2(c^*_{ij} + c^*_{ji})=c_{ji}$.

These demand functions satisfy integrability, i.e. are consistent with utility maximization, when the following restrictions on the parameters are satisfied:

$\sum_i \alpha_i = 1$ $\sum_i b_i = \sum_i c_{ij} = 0$	Adding-up
$\sum_j c_{ij} = 0$	Homogeneity
$c_{ij} = c_{ji}$	Symmetry

Economic theory also requires the matrix of the substitution effects to be negative semidefinite. This last condition will be verified ex post. When using the cost function specified in (3) the TCOL in (1) takes, after normalisation of the prices in the base year, the following form:

$$\ln TCOL = \ln a(p) + \ln y(\prod_i p_i^{b_i} - 1) \qquad (7)$$

where *ln y = u*, the reference level of welfare, at the normalisation point[9]. Thus, different TCOL's can be calculated for different levels of welfare, corresponding to different levels of the total expenditure *y*, to assess the distributive effects of changes in the relative prices, and for different households' types.

4. The consumption set and the data used

To estimate the demand model we have used monthly households data for the period 1985(1) to 1996(12) from the survey *Indagine sui consumi delle famiglie* carried out by ISTAT. The sample used in this work has been obtained from the *non-hierarchical* file, where ISTAT records the micro-data for each of the 12 years under consideration[10]. This file does not include detailed characteristics of any single member of the household surveyed, but one gets information on 17 different demographic profiles based on the number of components of the households and their age. Out of these, we have extracted data for each of the following 5 household types:

N1AD = one adult younger than 65

N2AD = two adults younger than 65

N3AD = three adults

N4AD = four adults

N5AD = five adults.

For these types we have used, for each variable considered, the mean of the number of observations on each type of household per month. Our demand system is composed of expenditures on the following 6 consumption goods (besides the monthly income and total expenditure) that have been obtained as aggregates of detailed current expenditures on 66 goods and services[11].

ALIM = food and beverages

PASTI = outdoors meals and drinks

GAS = domestic fuels (including methane, heating oils and other heating fuels)

BENZI = leaded and unleaded petrol

SETRA = public transports and services

RESTO = all other expenditures

We have also included five dichotomy variables N1-N5 that classify households' types and twelve dichotomy variables M1-M12 associated to the months.

[9] For a detailed treatment of the True Cost of Living Indices and their derivation from a specific cost function, one may consult Patrizii and Rossi (1991), chapter 5.

[10] Details on the sampling procedure used to collect these data can be found in ISTAT, *Indagine sui consumi delle famiglie. Documentazione tecnica e descrizione del file standard non gerarchico. Anni 1987-1994.*

4.1 Prices

Prices vary not only temporally (across months and years), but also longitudinally, i.e. across different types of households, because rather than using a single deflator for each aggregate, we have used different price indices for each of the elementary goods that make up the 6 aggregates. In other words, expenditures at constant prices for each of the 6 aggregates have been obtained as: $Q_{It}{}^{h} = \sum_{i} \frac{p_{i95}}{p_{it}} \left(p_{it} q_{it}^{h} \right)$, where $Q_{It}{}^{h}$ is constant prices expenditure on aggregate good I of household h at time t; i is the number of elementary goods composing aggregate I; p_{i95}/p_{it} is the '95 deflator for good i and $p_{it}q_{it}{}^{h}$ is current expenditure at time t, on good i, of household h. Since different households types spend different amounts on the same good, the implicit prices for each aggregate, obtained dividing current prices expenditures by constant prices expenditures, are different for each households' type. The '95 elementary price indices are the components of the Consumer Price Index (1995=100) published by ISTAT.

If f is the family type, m the month and t the year considered, our final data have been organised as a sample $\Phi(f,m,t)$ by lining up monthly data ($m=1\text{-}12$) for each year ($t=1\text{-}12$), on each family type ($f=1\text{-}5$) in vectors of 720 observations (*12x12x5*). The vectors called V1-V6 (for current price values), Q1-Q6 (for constant, 1995, price values) and P1-P6 for the corresponding implicit prices, plus the dichotomy variables mentioned above, represent the data-set used in this exercise.

5. Estimation and Simulations' Results

5.1 Demand Model Estimation

The AI demand system has been applied to the 6 groups of expenditures to estimate the parameters necessary to calculate the TCOL in (7)[12]. Heterogeneous preferences have been modeled using the *linear demographic translating technique* that implies the introduction, into the demand equations, of two translating intercepts, one for the household type and the other for the months. The values of prices and expenditures have been transformed into logarithms because of the specification of the demand system. All the variables have then been normalised as differences with respect to the sample means. Due to the adding-up restriction we have estimated only five equations, whereas the parameters of the sixth equation can be obtained as a linear combination of

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[11] Aggregation is possible if we assume, as it is usually done, that goods within each group are consistent with the Hicks-Leontief *Composite Commodity Theorem* (Deaton-Muellbauer 1980a, pp. 120-121), which asserts that if a group of prices moves in parallel the corresponding group of commodities can be treated as a single good.

[12] At an earlier stage we have specified the demand system as a Quadratic Almost Ideal Demand System (QUAIDS, Banks, Blundell and Lewbel, 1997), which allows for non-linear income effects of changes in prices. However, a

the coefficients of the first five equations, according to the demand theory restrictions presented at p. 3.

We have thus estimated the system of 5 simultaneous equations in (6) using a non-linear Maximum Likelihood Estimator, implemented by the LSQ command of the TSP 4.4 software. Adding-up, homogeneity and symmetry have been imposed ex-ante. Economic theory also requires the imposition of curvature conditions, i.e. the matrix of the Slutsky substitution effects to be negative semi-definite. Since, in our case, the Slutsky coefficients are a function of the budget's shares, there are no parameter values for which the Slutsky matrix is negative semi-definite on a global basis. However this condition can be imposed, after estimation, at the normalisation point, because at this point the estimated budget shares are only a function of known parameters. This can be done, following Diewert and Wales, imposing the constraint S = -TT', where S is the matrix of the Slutsky substitution effects and T is a lower triangular matrix such that $t_{ij} = 0$ for i<j. At the normalisation point, the elements of the Slutsky matrix are: $s_{ij} = c_{ij} + \alpha_i\alpha_j - \alpha_i\delta_{ij}$, where $\delta=0$ for $i\neq j$ is the Kronecker delta. Substitution of the above constraint leads to $c_{ij} = -(tt')_{ij} - \alpha_i\alpha_j + \alpha_i\delta_{ij}$ which can be estimated.

When the negativity condition is violated it is difficult to achieve convergence maintaining the full rank of the Slutsky matrix. If this is the case, the semi-flexible technique can be used which implies the factorisation of the c_{ij} coefficients with a reduction in the rank of the Slutsky matrix. Here the rank of the S matrix has been reduced from 5 to 3. The Maximum Likelihood estimates of the AID system's parameters to be used later for calculation of the TCOLs are shown in table 1 together with their standard errors, the maximised value of the Maximum Likelihood Function and the value of the coefficient of multiple determination.

5.2 TCOLs calculation

The parameters estimated above have been used to produce the TCOLs in (7). These have been calculated from 1985 (1) till 2000 (12) extending the original prices' data-set from 1997 (1) to 2000 (12). For each households' profile, TCOLs have been calculated for five different welfare levels *lny*[13]. These have been chosen as follows. Indicating with $ln\ \bar{y}$ the mean of the monthly 1995 total expenditure of each family type[14] and with lny_n, $(n=1,...,5)$, the chosen level of welfare, for each of the five households' profiles of our sample we have taken the values:

Likelihood Ratio performed to test the significance of the parameters of the quadratic terms in the equations does not allow rejection of the null hypothesis. The model has therefore been restricted to the AIDS form.

[13] Remember that, at the normalisation point, the welfare level u is equal to the logarithm of total expenditure *y*.

[14] These values have been transformed into adult-equivalent levels of expenditures using equivalence scales taken from Perali (1999). Equivalence scales work like income deflators, as each level of total expenditure is divided by the adult-

$\ln y_1 = \ln(0{,}2\ \bar{y})$; $\ln y_2 = \ln(0{,}5\ \bar{y})$; $\ln y_3 = \ln \bar{y}$; $\ln y_4 = \ln(1{,}7\ \bar{y})$; $\ln y_5 = \ln(3{,}3\ \bar{y})$ indicating very low to very high welfare levels. This specification of different welfare levels for each type of households will be used to assess the distributive effects of this fiscal reform.

In order to simulate the increase in prices due to the introduction of the Carbon tax we have build up two different price indices for the two aggregates under consideration: BENZI, which includes leaded and unleaded petrol and GAS, which includes a number of domestic fuels as specified before. Only the prices of leaded and unleaded petrol, heating oils and methane have been modified to keep track of the tax, although the Law specifies increases in the prices of additional products which have not been taken into account here due to lack of data.

In the base simulation, prices for the products mentioned above have been modified, starting from January 1999 to obtain the base-prices with no Carbon taxation. In order to do that, we have used the structure of monthly prices supplied by Unione Petrolifera, the Italian Oil Firms Union. The consumption price is given by: $p_{it} = ip_{it} + \alpha_{it} + VAT_{it}$ where p_{it} is the industrial price of product *i* at time *t*; α_{it} is the excise duty on product *i* at time *t* and VAT_{it} is the value added tax calculated as a fixed percentage of the sum of the other two components of the price structure[15]. We have thus obtained the base monthly time series of prices to be used in the simulations, which have been normalised with respect to the mean 1995 price. A second time series for the prices under consideration has been obtained as follows. We have simulated the introduction of the Carbon tax for four years, choosing as a reference point January 1997 (although we use the tax system valid from January 1999, as provided by the Law) and have carried out the simulation till December 2000, because for this period data on prices were available. The monthly industrial prices of the above mentioned products have been linearly increased, by 20% per year of the total increase to be achieved at the end of the fourth year, as indicated by the Law. We have thus obtained two time series of monthly prices for each taxed product, normalised with respect to the mean 1995 price. These will be the same up until December 1995 and will start diverging from January 1997. Since we have squeezed the price increases in four rather than six years (as provided by the Law), the simulation is likely to produce welfare changes that are higher than what would result from a linear price increase over six years.

5.3 The Compensating Variation

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equivalent expenditure, thus each level of welfare is independent from the dimension of the household. They allow interpersonal comparisons to be made in terms of welfare levels by turning different households into identical individuals. Equivalence scales calculated by Perali and used in this work are: N1AD=1,62; N2AD=2; N3AD=2,36; N4AD=2,70; N5AD=3,02.

[15] Oil price rises in the year 2000 have boosted the associated VAT revenues anf the Italian government has used this additional revenue to cut the excise on oil products between 30 to 50 Lire per Litre (OECD, 2000, p. 24).

After having obtained TCOLs for the two different scenarios, *a* and *b* (*a* = no Carbon tax scenario; *b* = Carbon tax scenario), we have calculated the monthly Compensating Variation (CV) for each type of household and each welfare level, from 1997 (1) till 2000 (12) as defined in (2). The Compensating Variation is a money metric welfare measure and can be defined as the level of income necessary to compensate the consumer for a price change in order to be as well off as he was before the change in price. The difference in the CV calculated for the two scenarios *a* and *b*, thus indicates the amount of income that, after the introduction of Carbon taxation (scenario *b*), would allow households to enjoy the same level of welfare they would have had without the fiscal reform (scenario *a*). This is given by:

$$CV_{n,b}^{\ \ h,t} - CV_{n,a}^{\ \ h,t} = \left(TCOL_{n,b}^{\ \ h,t} - TCOL_{n,a}^{\ \ h,t}\right) y_n^{h,t} \quad (8)$$

where $CV_{n,b}^{h,t}$ is the *CV* of the household *h*, at time *t*, calculated according to scenario *b*; $CV_{n,a}^{h,t}$ is the *CV* of the household *h*, at time *t*, calculated according to scenario *a* and $y_n^{h,t}$ is the welfare level *n* of household *h* at time *t*. So we get 25 different welfare changes for each month: one for each household type *h* and welfare level *n*.

In order to have an aggregate measure of the monthly welfare change, the number of households in each household and expenditure class has been multiplied by the conversion coefficient (also published by ISTAT) that allows to convert the sample used into the existing population, i.e. into the real number of households in that class of expenditure living in Italy in 1995. Table II shows the annual aggregate welfare losses (expressed in billion Lire '95) calculated for each of the 4 years of the simulation (1997-2000) for each household profile and welfare level. For the poorest group of families, the annual welfare loss goes from 1 billion Lire '95 in 1997 to 10,2 billion Lire '95 in 2000, at the target level of taxation; whereas for the richest group the annual loss amounts to about 40 billion Lire '95 in 1997 and to 413,5 billion Lire '95 in 2000. It might be interesting to make a rough comparison between the expected cumulated revenue from the Green Reform, i.e. about 11.500 billion Lire as explained in paragraph 2, and the cumulated loss of the 5 households types under consideration up to the year 2000. This can also be inferred from table II, where by summing over household types and years, we get 4493 billion Lire '95 amounting to, roughly, 39% of the expected cumulated revenue from the Carbon tax. The aggregate welfare loss seems thus to be significant and to amount to a considerable portion of the expected cumulated revenue from the reform. Among other factors this might be due to the fact that, in our simulation, the smooth increases in carbon taxation up to the target price levels have been squeezed in 4 years rather than 6 as provided by the law. Of course, these results do not take into account any of the expected benefits from the reform that could be relevant as well. Nevertheless, our simple calculation highlights the importance of Green Reforms to take place allowing for some sort of redistribution. The last five rows in table II show the annual aggregate welfare loss per welfare level and the last column in the table indicates the share of the cumulated loss for each household profile and welfare level over the total welfare loss.

Since we are also interested in evaluating the distributive effects of Carbon taxation we have calculated, in table III, the mean monthly welfare loss in the year 2000 (at the target rate of carbon taxation) per household type and welfare level as a percentage of the mean monthly expenditure level. Contrary to what has been found in other similar studies, the tax burden is proportionally distributed across households at different welfare levels. Thus, the presumed regressivity of Carbon taxation is not sustained here. This might be due to the fact that the reform has mainly hit transport fuels, whereas heating fuels' prices have increased relatively less. As Smith (2000) pointed out in her study this effect might also be caused by households in the lowest expenditure levels not owning a car. Indeed, in the British study, when only car-owning households are taken into consideration, the distributional effect is reversed. Figure 1 shows the progressivity of Carbon Taxation in Italy more clearly. Moreover, from figure 1 and table III it can also be observed that the tax burden seems to affect mainly households with one and two adults and decreases for larger families. This could be explained by the fact that the tax burden due to car fuels, for instance, is more distributed as the number of household members increases.

6. Concluding remarks

In this paper we have carried out an exercise to simulate the welfare effects of the Carbon-Energy Tax introduced in Italy at the beginning of 1999 by the Centre-Left coalition which allows for gradual increases in the prices of most fossil fuels over 6 six years. The welfare effects have been calculated using True Cost of Living index numbers. True Cost of Living Indices (TCOLs) measure how much extra income is needed to get back to the original welfare level. Everything else in the comparison is kept constant in order to isolate the effect of the tax increase. The parameters of the True Cost of Living Indices have been obtained through estimation of a demand system using micro-data supplied by the Italian National Statistical Institute from 1985 to 1996. All the welfare changes are positive, thus representing losses rather than gains as consequences of the reform. From table II we can infer that the aggregate welfare loss is quite substantial and affects Italian households in a non-negligible way. However, the variation of welfare losses across different levels of total expenditures does not allow sustaining the presumed regressivity of Carbon taxation, as the cost of living of the lowest income groups is not most adversely affected by the tax increase. In fact the effect becomes bigger as we move up the income distribution and the reform seems to have a greater effect on households with one or two members younger than 65. Other studies have produced similar results (for instance Labandeira and Labeaga, 1999 for Spain, although the methodological framework adopted is different).

Exercises such as these may give useful insights into the policy implications of environmental policy instruments. One of the factors causing great resistance in developed countries to the introduction of carbon taxes is their presumed regressivity. In this paper we show that the distribution of the Italian Carbon tax is not regressive. This evidence thus encourages the use of carbon taxes as cost-effective instruments of environmental policy, although other important factors determining acceptability of carbon taxes, such as their impact on competitiveness and their environmental impact are not assessed in this study. They may be an interesting policy option in the near future, especially after the recent Bonn decision to go ahead with the obligations of the Kyoto Protocol. Nevertheless, welfare losses are substantial in all groups examined. These negative impacts highlight the importance of accurately designing the tax reform in a revenue-neutral context and of redistribution of the generated revenue.

Table I : A.I.D. parameters - Maximum Likelihood Estimation (1985-1996)*

	ALIM -1 (Food and beverages)	PASTI-2 (Outdoors meals and drinks)	GAS-3 (Domestic fuels)	BENZI-4 (Leaded and Unleaded petrol)	SETRA-5 (Public transports and services)	RESTO-6 (All other expenditures)
C_{1j}	0,10302 (0,01786)	-0,14309 (0,10613)	-0,05319 (0,00770)	0,03065 (0,00837)	0,00086 (0,00229)	0,06175 (0,02369)
C_{2j}		-0,08195 (0,01511)	-0,00441 (0,00604)	0,03181 (0,00678)	0,00066 (0,00262)	0,19699 (0,02001)
C_{3j}			0,00057 (0,00503)	0,02735 (0,00376)	0,00270 (0,00136)	0,02696 (0,00861)
C_{4j}				-0,02666 (0,00484)	-0,00242 (0,00099)	-0,06073 (0,01115)
C_{5j}					0,00705 (0,00020)	-0,00886 (0,00497)
C_{6j}						-0,21612 (0,03406)
b_i	-0,16572 (0,00715)	0,03516 (0,00617)	0,03407 (0,00436)	-0,01516 (0,00355)	-0,00200 (0,00106)	0,11365 (0,00777)

Number of observations = 720

Log of Likelihood Function = 13195,3

R^2	**.894**	**.859**	**.704**	**.497**	**.297**

*Standard errors in parenthesis. Standard errors for the c_{ij} and b_6 coefficients have been computed using the Delta Method implemented through the ANALYZ command of TSP 4.4.

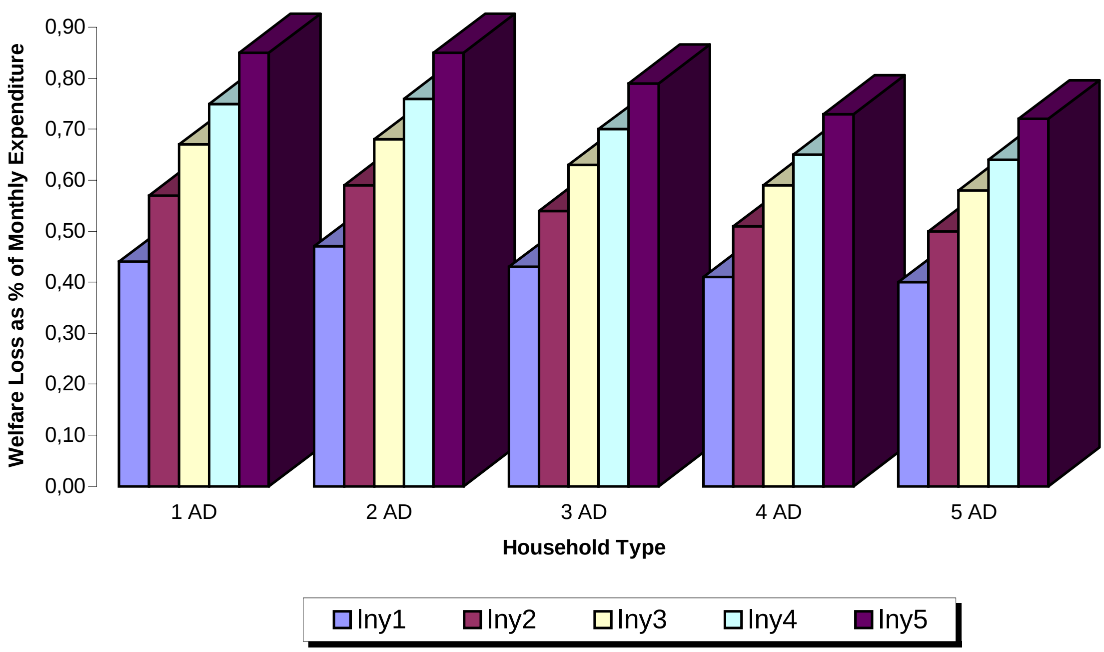
Table II: Aggregate Welfare Losses per Year (Billion Lire 1995)

	Years					
Household type	1997	1998	1999	2000	Sum over the 4 years and percentage values	
1 AD	56,9	115,9	176,6	238,1	**587,6**	13,1
2 AD	106,7	217,1	330,4	444,9	**1099,0**	24,5
3 AD	129,1	262,8	399,6	537,9	**1329,4**	29,6
4 AD	106,7	217,2	329,7	443,4	**1097,1**	24,4
5 AD	37,0	75,3	114,1	153,6	**379,9**	8,5
Sum over all Household types	**436,5**	**888,3**	**1350,4**	**1817,8**	**4493,0**	100,0
Welfare Levels						
lny1	1,0	2,0	3,1	4,1	10,2	0,2
lny2	75,3	152,7	230,5	310,8	769,2	17,1
lny3	141,0	286,7	435,4	586,1	1449,2	32,3
lny4	179,3	365,4	556,8	749,2	1850,8	41,2
lny5	39,9	81,4	124,6	167,6	413,5	9,2

Table III: Monthly Welfare Loss (Year 2000) as a percentage of Mean Expenditure (Lire 1995) per Household Profile and Welfare Levels

Household Type	Welfare Levels				
	Iny1	Iny2	Iny3	Iny4	Iny5
1 AD	0,44	0,57	0,67	0,75	0,85
2 AD	0,47	0,59	0,68	0,76	0,85
3 AD	0,43	0,54	0,63	0,70	0,79
4 AD	0,41	0,51	0,59	0,65	0,73
5 AD	0,40	0,50	0,58	0,64	0,72

Figure 1: Monthly Welfare Loss (Year 2000) as % of Expenditure (Lire 1995) per Household Profile and Welfare Levels



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