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The distributive effects of carbon taxation in Italy

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Abstract

This work is aimed to assess the distributive incidence of carbon taxation: the issue has not been widely investigated whereas more attention has been focused on the efficiency of ecological tax reforms. Despite of their central role for the achievement of the Kyoto targets and the elaboration of post Kyoto strategies, the analysis of the introduction of energy policies in Italy are not very spread. In particular, ex post analysis or ex ante simulation of policies can represent very useful tools in order to make light on distributional effects. Even if in this area evidence remains very limited, concern with the distributional impacts of environmental policy arises from a widespread fear that such measures could be regressive: poorer households pay disproportionately more of the financial costs associated with the introduction of environmental policies (OECD, 2004).

This research is organized in four chapters. The first offers a review of European experiences in energy taxation, with a focus on Nordic countries, and it also describes the Italian market of energy products. The second chapter highlights two main literature fields, represented by optimal taxation and double dividend; other studies concerning energy taxation distributional impacts are also reviewed. In the third chapter the work hypothesis and the demand system approach are described, whereas in the fourth chapter the estimation and its results are described and discussed.

According to Kyoto Protocol domestic policies to reduce carbon emissions can include carbon/energy taxes, emissions trading, command-and-control regulations and other policies. Market methods are usually preferred in terms of efficiency, and carbon taxes are thought to be the easiest to implement and monitor; furthermore, carbon taxes can act as a continuous incentive to search for cleaner technologies. Until now, only a few European countries have implemented energy or carbon taxes: Nordic countries have been the first-comers and this seems to suggest a tight link between institutional environment and the potential for policy adoption.

The consequences of environmental policies in terms of distributive impacts and competitiveness represent fundamental factors in determining their political acceptability. Carbon taxation may well be regressive but this depends on the hypothesis on price translation, the concept of income adopted, how tax revenue is used and how different households respond to price changes.

In my analysis I assume that the carbon tax is fully shifted forward to consumers; for energy goods, which are traded on international competitive markets, and for which the distribution market can be defined oligopolistic, this is a reasonable assumption. The distribution of the effects of CO_2 abatement policies can be measured along a number of dimensions including household income groups, geographic regions, industries and different generations. The object of my simulation is represented by personal income distribution, then by households; in particular, I examine households own and cross-price elasticities and welfare effects in terms of different incidence measures, namely equivalent and compensating variation. The incidence of an energy tax is connected to consumer behaviour in two ways: direct consumption, represented by the purchase of fossil fuels, and indirect consumption, constituted by the purchase of assets whose production has demanded fossil fuels use. My attention is devoted only to the direct consumption component, focusing on the heterogeneity of behavioral responses among different household types and macro-regions, linked to different consumption habits and substitution possibilities.

Assuming that the problem of deciding how much to consume at any given time has been solved, a demand system for the allocation of family income to an exhaustive set of good and services is estimated. Data from the Italian National Statistical Institute (ISTAT) are

used, in particular a sample extracted from the *Indagine sui Consumi delle Famiglie*. Durable goods are excluded from the sample and six goods enter into the demand system: food, public transport, transport fuels, heating fuels, electricity and a residual good, which contains all the other goods.
The carbon tax is modelled making reference to the Financial Law for 1999 and the DPCM 15/1/1999; one year after its adoption, the carbon tax with its gradual excise rate augmentation – aimed to reach an objective level in 2005 – has been eliminated for fear of its inflation consequences and adversely distributed impacts.
After having analyzed the different functional forms, the Almost Ideal Demand System (AIDS) and the Quadratic Almost Demand System (QAIDS) have been identified as the preferred empirical models, thanks to their theoretical characteristics that is being based on a representative consumer but allowing flexibility in the consideration of demographic characteristics.
The estimation of the AIDS (Deaton and Muellbauer, 1980) and QAIDS (Banks et al., 1997) has provided the parameters of the cost function that represent the inputs for computing price and income elasticities and enable to compute True Cost of Living indices and welfare measures. For the first time True Cost of Living indices are derived for the quadratic model: on this basis, both the compensating and equivalent variations are computed and compared. I show how the output of demand system estimation can be used to simulate different taxation scenarios, modelled by referring to the Financial Law for 1999, and to estimate the revenue raised by carbon taxation.
The welfare effects linked to the carbon tax proposed by the Financial Law for 1999 and also to different taxation scenarios (namely taxation only on heating fuels, fuels, electricity) have been computed. The results show that the carbon tax proposed by Financial Law for 1999 is not regressive, but the simulation of different taxation scenarios allows a regressive component to emerge, related to fuels taxation. The relevance of geographical variables is confirmed by the differentiation in welfare impacts between the North and the South of Italy, which emerges in the taxation scenario where only heating fuels are taxed.
The empirical work has demonstrated the environmental effectiveness of introducing carbon taxation in Italy, given the high price elasticity of energy products; it has also confirmed the key role of public transport, characterized by a high degree of substitutability with private transport. Furthermore, the analysis of elasticities and welfare measures has shown the importance of distinguishing household characteristics and macro-regions when analysing behavioural responses. Finally, the revenue estimation at aggregated level can constitute the starting point for hypothesizing compensation mechanisms directed to particularly affected household profiles or geographical areas.
The originality of my research is linked to the comparison between two functional forms, and the identification of the over-estimation in welfare effects using AIDS. An approach in terms of demand system estimation has many potentialities linked to the utilization of the elasticities for the computation of revenue variation produced by different taxation scenarios. Furthermore, the revenue raised from the households has been compared with the welfare impacts, obtaining the excess burden of taxation.
This research work could be widened by investigating the distributive effects on a more specific sample (i.e. only car owners) or computing the emission reduction associated with the policy simulated; on a larger basis, the demand system could be estimated on individual data, linked with bottom-up or top-down models and employed to provide the informative basis for collective decision making models.

Chapter 1

1.1 Introduction

The distributive incidence of environmental policies has not been widely investigated, whereas more attention has been focused on the efficiency of environmental reforms (Fullerton and Metcalf, 2001; Fischer, 2004; Goulder et al., 1999; Ricther and Schneider, 2003). Even if in this area evidence remains very limited, concern with the distributional impacts of environmental policy arises from a widespread fear that such measures could be regressive: richer households receive disproportionately more of the benefits associated with improved environmental quality whereas, at the same time, poorer households pay disproportionately more of the financial costs associated with the introduction of environmental policies (OECD, 2004). Perhaps the most cogent reason for being concerned with environmental policy and distribution is that understanding distributional impacts can help to shape policy packages that are more likely to be accepted by the public. A transparent framework for analysis can be useful in communicating environmental policy's costs and benefits at any chosen level of detail, and it can ease general understanding of related welfare effects.

The detection of the adverse effects of carbon dioxide emissions at the beginning of the 1990s, resulting mainly from the combustion of fossil fuels, has led to proposals for non-market mechanisms such as regulation, and market mechanisms such as tradable emissions permits and carbon taxes, both aimed at reducing emissions (Hahn, 2000). Market methods are usually preferred in terms of efficiency and the carbon tax is thought to be the easiest to implement and monitor. A carbon tax would affect the price of fossil fuels and thus industrial and consumer prices: in this way the level of final demands is altered, reducing fossil fuel use and aggregate carbon dioxide emissions (Baranzini et al., 2000).

To levy an environmental tax modifies the expenditure choices of economic agents; environmental taxation turns out to be regressive if it concerns goods and services that represent a relatively more large expenditure share of low income households. Households that react more significantly and rapidly to the pressures to reduce the consumption of energy intensive goods will have to bear a smaller impact in terms of costs. In detail, the incidence of an energy tax is connected to consumer behaviour in two ways: it is necessary to consider direct consumption, represented by the purchase of fossil fuels, and indirect consumption, constituted by the purchase of assets whose production has demanded fossil fuels use. Household responsiveness to price changes can be related to disposable income and this can determine tax regressivity. The basis upon which it is often assumed that carbon/energy taxes are regressive is intuitively obvious: lower-income households tend to spend a larger proportion of total household expenditures on fuel for domestic energy services (i.e. heating, hot water, cooking and lighting).

The effects of environmental reforms on different socio-economic groups are not limited to the increases in prices of the goods and services they buy, but come from other sources, among which the reductions in environmental damages they experience. Thus, any analysis of policy costs should be put together with a survey of benefits distribution, because cost regressivity could be compensated by benefit progressivity. Even if it is certainly important to take this point into consideration, one should be cautious about considering environmental risks exposure to make inferences about the distribution of welfare gains, for at least four reasons. First, due to a lack of data, the measures of environmental risk do not adequately account for the degree of exposure and other relevant factors: rather little is known on this topic. One could think, for instance, that long-term benefits related to measures to fight against global warming are more evenly distributed, while the benefits related to human health policies have a more local character and then they are more unevenly distributed. Second, when policies create non-uniform environmental improvements, the existing risk distribution can complicate the detection of distributional benefits linked to the reform. Third, when environmental quality changes, we also need to describe the possible effects on market prices or wages, as these price changes also affect household welfare. Finally, in order to translate physical benefits into welfare gains we need to measure how different households value environmental quality: a factor that could weaken or enhance inequality in environmental benefits distribution is represented by differences in preferences between different income groups. I will not handle the issue of environmental benefits, due both to the mentioned problems and to the lacking of data. My scope will be limited to show if introducing carbon taxation in Italy has a regressive impact just in terms of costs incidence. Because the essential purpose of environmental policy is to change consumption and production patterns, green reforms inevitably entail winners and losers among households and firms (Kriström, 2003): for this reason it is fundamental to scrutinize their effects in a distributional perspective. My decision to examine carbon taxation is due to its peculiarity as an environmental policy instrument, namely potentially embedding adverse distributional effects and, at the same time, raising a double dividend, with the possibility of correcting the regressive impacts produced. Even if my thesis focuses on impacts on household consumption, it is worth mentioning that relaxing the hypothesis of complete translation on end-users prices can contribute to show the overall set of social dilemmas posed by carbon taxation. In fact, since green taxation reforms are likely to affect many industrial sectors, this approach to environmental protection embeds both competitiveness effects and potential adverse distributional effects. Policy makers, in order to identify the better intervention strategy, should evaluate the trade off between the different kind of impacts, taking into account and balancing the interests of all the actors involved.

The distribution of the effects of CO_2 abatement policies can be measured along a number of dimensions including household income groups, geographic regions, generations and industries. An important dimension of environmental taxation is the variation in impacts across industries: carbon taxes can reduce net output prices in the carbon-supplying industries and raise costs in industries that intensively employ fossil fuels as inputs. These price and cost impacts have, in the short term, the potential to seriously harm profits and employment: their distribution crucially influences political feasibility, since the lobbies of fossil fuels' producers have significant weight in the political process.

I will not examine carbon tax implications for firms; on the contrary, the object of simulation will be represented by personal income distribution, then by households. Environmental policy can produce two types of disparities in welfare: the first is due to a change in environmental quality and refers to the externalities whereas the second is linked to the distribution of financial effects (OECD, 2004). My attention will focus on this second type of impact and on an analysis of households elasticities and welfare effects in terms of different incidence measures in particular. Distributional impacts consist of different kinds of financial effects on household groups. They generally include direct compliance costs which can be in the form of energy payments or adaptive expenditures, and indirect compliance costs represented by higher costs for other goods and services due to increased production costs brought about by regulation. The overall distributive incidence of environmental policies also includes even more indirect effects arising through effects on public finance, labour markets, real estate markets: these can either exacerbate or counteract the distributional impacts associated with more direct financial effects. Carbon tax, like any other public policy, will result in costs which vary across socio-economic groups depending on their expenditure patterns, behavioural responses and employment opportunities. While environmental policy could entail unemployment and impose other adjustment costs, these costs are seldom quantified in distributional studies.

The real world consists of heterogeneous households, each with different possibilities to adjust to new policies; the importance of this fact has not been sufficiently appreciated by economists in the shaping of environmental policy. I will look at the welfare losses, in terms of real expenditure, suffered by different households, grouped according to number of members, age and geographical area. Price elasticities will also be calculated as a first approximation of the economic and environmental impact of the tax. I will then calculate tax distributional impacts on households with different income levels using compensating and equivalent variations.

The analysis of environmental taxation distributional impacts could be completed with the examination of tax revenue recycling options, which represent a way to alleviate the potential regressive impacts. One possibility is by means of lump-sum redistribution: the lowest income groups will proportionally receive a higher amount, relative to their income, than highest income households will do. Another possibility to compensate poorer households – and at the same time to reduce other existing distortionary taxes – is represented by using tax revenue to reduce labour taxes, decrease income taxation, or change the social security system. Such measures should be accompanied by a complementary redistribution policy targeted at those social groups that do not benefit directly from tax cuts, such as the pensioners and unemployed.

1.2 Different policy tools implications

This paragraph will offer an overview about the distributional implications associated to different policy tools: in fact, even if my attention is devoted to a specific energy policy, represented by carbon taxation, the differences in distributional impacts with respect to alternative intervention strategies seem worth to be analysed.

The European system of emissions trading fixes a maximum limit to the total emissions, assigning to every plant an emission quota, a part of which should be periodically given back to the competent national authority. There are different ways to satisfy such obligation: giving back the assigned quotas, buying quotas from other plants, obtaining credits from emission reduction projects linked to the Kyoto Protocol. A similar mechanism allows, through a negotiation procedure, to buy or sell own pollution rights, and it changes market signals, in order to modify agents behaviour.

Differently, a command and control approach, like environmental standards, can be preferred both by the public administrators, for reasons linked to reduced informative requirement and to greater certainty of the result, and the industrial sector, because of the possibility of negotiation and subsidies. Such approach generally does not produce a dynamic incentive to innovation or improvement beyond established goals, and risks to determine an inefficient resource use; then, if possible, command and control tools should go with marked based tools.

Since the introduction of carbon taxes alters prices, once fixed the tax rate pollution reduction takes place thank to market action. Consumptions of taxed assets diminish, energetic saving and investments in efficiency and fuel substitution are stimulated. An important feature of this policy tool is diminishing the cost related to target attainment, allowing every firm to choose the more efficient strategy: firms with high marginal reduction costs will pay the tax whereas firms with low marginal reduction costs will reduce polluting emissions.

Different kinds of taxes can be levied on the content in carbon of the energetic products (Baranzini et al., 2000): both energy taxes and carbon taxes are excise taxes, but they have some differences. An energy tax is defined as a fixed absolute amount and is imposed on both fossil fuels and carbon-free energy sources, according to their energy (or heat) contents, with renewable energy usually exempted. By contrast, a carbon tax is levied according to the carbon content of fossil fuels and is thus restricted to carbon-based fuels only. Given that oil and gas have greater heat contents for a given amount of CO_2 emissions as compared with coal, an energy tax lies more heavily on oil and gas than a carbon tax. Moreover, an energy tax burdens nuclear energy, which could provide large-scale generation of electricity without a directly parallel production of CO_2 emissions. If the goal is reducing CO_2 emissions, a carbon tax is clearly more cost effective than an energy tax. Indeed, a carbon tax equals the marginal cost of CO_2 abatement across fuels and therefore it satisfies the condition for minimizing the global cost of reducing CO_2 emissions. Therefore, the implementation of an energy tax will lead to poor CO_2 target achievement or else to unnecessarily high costs as compared with a carbon tax. This can be explained by two factors: price-induced energy conservation and fuel switching. Carbon taxes reduce CO_2 emissions both through their price mechanism effects on energy consumption and fuel choice. By contrast, since energy taxes are imposed on fossil fuels and nuclear energy, the incentive for fuel switching is lower and the reductions in CO_2 emissions will be mainly achieved by price-induced energy conservation. Thus, a higher energy tax is required for achieving the same reduction target as compared with a carbon tax.

Different environmental policies will have various distributional implications, as discussed in the following passages. Although taxation is certainly an efficient tool, its consequences in terms of distributive impacts and of competitiveness represent fundamental factors in determining its political acceptability. All efficient forms of regulation lead to a distribution of costs that is determined by general equilibrium cost incidence, factor endowments and consumption patterns. The distributional effects of tradable permits can be similar to those of taxes since, as noted by Kriström (2003), in a partial equilibrium perspective the use of a tax is comparable to a tradable permits system where permits are auctioned. With environmentally related taxes, distributional effects depend on how revenue is recycled but the rent is generally returned to tax-payers; differently, with permits the distributional implications differ according to the allocation choice, that is to say auctioning versus grandfathering. Auction/tax revenue can be used in a multitude of ways, benefiting many different groups: labour, consumption, payroll or capital gains taxes could be cut, deficit could be reduced. In addition, the revenue-recycling benefits reduce total costs. Grandfathering is usually used to compensate some current owners of specific capital, since it produces a pure wealth effect: only those who directly receive permits gain. The same effect can be achieved with targeted tax breaks: these not only provide direct compensation, but also increase the efficiency of the industry by reducing tax distortions. Furthermore, with grandfathering poorer people are likely to bear a greater burden in terms of costs, because they are workers and consumers more often than shareholders. Conversely, in the case of taxes and auctioned permits cost bearing is widely spread and they are more likely to lead to equitable outcomes than grandfathered permits. With regard to subsidies, the distributional impacts will be linked to the degree of regressivity or progressivity of the tax system used to raise the finance required to finance such programs.

Indirect taxation, and in particular a system of excise duties, has distributive effects which favour lower income classes if some conditions are in force. First, the Engel law must be verified: the necessary goods expenditure share should decrease when income grows and luxury goods expenditure share should increase. Clearly, to identify these goods is often troublesome, especially when households' demographic characteristics change. Second, excises duties should be addressed to those goods which have an income elasticity greater than one. The group of goods should be large enough to include potential substitutes: in this manner, the substitution effect produced by the tax cannot change consumption patterns in a way that affects tax revenue. Then the own-price elasticity should be moderately low; at the same time, even if this one is often a tacit assumption, the supply elasticity should be high in order to translate the tax on consumers. Finally, the expenditure shares on taxed goods should be higher for richer households. With respect to the condition on income elasticities, the hypothesis of a changing expenditure pattern when income changes is added: once identified the goods to be taxed through the study of the elasticities, the consumption pattern must change with income in order to have positive distributive effects.

On the other hand, when these conditions are not verified environmental and energy taxation could have negative distributive impacts that are worth to be examined. I want to specify that the distributive effects are not an objective of the excise duties as fiscal instrument, in the sense that the distributive impact does not represent a criterion adopted to design the excise burden and its structure. Then, the distributive impact should be considered separately from taxation efficiency, such as an effect which the government may take into account in order to compensate some damaged groups.

To summarize, all policy tools have potential but different distributional impacts; in the case of taxes and auctioned permits direct effects on households groups are generally more straightforward; however, even for taxes the analysis is complicated by the inclusion of indirect impacts and behavioural adjustments. The fact that the distributional implications of taxes have been particularly highlighted in literature is probably due to their greater visibility and should not be considered as a proof of their greater regressivity. A review of empirical evidence suggests that environmental policy may well be regressive (Smith, 2000; Symons et al., 1998; Cornwell and Creedy, 1996), but this conclusion depends on the concept of income, how revenue is used and other pertinent dimensions of the analysis, in particular how different households respond to price changes. Paragraph 2.3 focuses on the description of the different choices available to take into consideration these elements.

1.3 The recent energy policy

The international political response to climate change began with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The UNFCCC sets out a framework for action aimed at stabilizing atmospheric concentrations of greenhouse gases to avoid “dangerous anthropogenic interference” with the climate system. It entered into force on 21 March 1994, and now has 192 parties. In December 1997, delegates at The Third Conference of Parties (COP 3) agreed upon the Kyoto Protocol that commits developed countries and countries in transition to a market economy to achieve quantified emission reduction targets. Following COP 3, parties began negotiating many of the rules and operational details concerning how countries will implement and measure their emission reductions.

In November 1998, the COP 4 elaborated the rules and operational details for the Protocol implementation adopting the Buenos Aires Plan of Action; this document set COP 6 as the deadline for finalizing these details and strengthening implementation of the UNFCCC. This Conference started in November 2000 but, since negotiations were not successful, it was suspended until July 2001. Parties reconvened in Bonn and adopted the Bonn Agreements, a decision that provided high-level political direction on the implementation of the Kyoto Protocol.

In November 2001 at COP 7 delegates reached agreement on Marrakesh Accords: they consisted of a package of draft decisions on many of the details of the Kyoto Protocol, including flexible mechanisms, reporting and methodologies, compliance. In COP 8 and COP 9 various technical rules and procedures were elaborated. Always in the context of Marrakesh Accords, COP 10 agreed on two new agenda items focused on adaptation and mitigation, and began informal negotiations on the complex and sensitive issue of how parties might engage on commitments to combat climate change in the post-2012 period.

The meetings in Montreal, held from 28 November to 10 December 2005, formally adopted the Marrakesh Accords and also engaged in negotiations on longer-term international cooperation on climate change. COP 11 agreed to consider long term cooperation also under the UNFCCC and post-2012 arrangements have then been discussed in a series of meetings. The *Ad Hoc* Working Group on Further Commitments for Annex I Parties (AWG) and the workshop "Dialogue on long-term cooperative action to address climate change by enhancing implementation of the Convention" (Convention Dialogue) have convened four times, in Bonn (May 2006 and 2007), in Nairobi for the COP 12 (November 2006), and in Vienna (August 2007). In November 2006, the AWG elaborated a work programme focusing on the following three areas: mitigation potentials and ranges of emission reductions, possible means to achieve mitigation objectives, and consideration of further commitments by Annex I parties.

As he presented the EU executive's work program for 2007, the European commission's president José Manuel Barroso said that energy efficiency and climate change were among the top priorities. In particular, the Commission prioritizes a review of the EU carbon emission trading system and a paper setting out a proposed EU position for a global post-2012 framework. At the end of 2006, there was significant support between EU governments to commit unilaterally to reducing greenhouse gas emissions 30% by 2020.

Referring to the conclusions of the COP12 held in Nairobi, EU leaders had backed a vague goal for all industrialized countries to reduce emissions by 15-30% by 2020. The UK, Germany, Italy and Sweden were among the countries endorsing a 30% target and they also support a follow-up reduction target of 60% by 2050. In a similar context – and from Italy's point of view – to levy a domestic carbon tax is an option worth to be considered. However, Hungary, Slovakia and Poland warned against the EU making a "hasty declaration of commitment" before other developed and developing countries signal their willingness to do likewise. They also said that any future EU target should be differentiated to consider the varying growth potential and emissions of its member states. European ministers underlined their commitment to linking the EU emissions trading system with other national and regional schemes.

At its third session in May 2007, the AWG agreed to develop a timetable to complete its work so as to avoid a gap between the first and second commitment periods. In August 2007 delegates focused on mitigation potentials and possible ranges of emission reductions for Annex I parties: their conclusions recognize that to achieve the lowest stabilization level, Annex I parties as a group would be required to reduce emissions by a range of 25-40% below 1990 levels by 2020. In the United Nations Climate Change Conference in Bali (COP 13), held between 3 and 14 December 2007, delegates deliberated on a wide range of topics and agenda items, with a major focus on finalizing a post-2012 regime by December 2009, after the expiration of Kyoto Protocol's first commitment period (International Institute for Sustainable Development, 2007).

Negotiations were conducted in a number of groups under the aegis of both the Convention and the Protocol. Under the Convention, the discussions focused on how following up the Convention Dialogue, while under the Protocol the AWG discussed its work programme and timetable. Delegates also held consultations on the Russian proposal on voluntary commitments. During the negotiations, several issues proved difficult to resolve, especially during the talks on long-term cooperative action under the Convention: the mitigation strategies for developed and developing countries were particularly contentious. The turning point in the negotiating process has been represented by parties agreement to a proposal by India and other developing countries on mitigation actions by developing country parties in the context of sustainable development, supported by technology and enabled by finance and capacity building. After the EU and all other parties had accepted this proposal, the USA agreed to join the consensus, and the decision on long-term action under the Convention was adopted. This decision established a process and set out guidance and direction for a series of meetings over the next two years under both the Convention and Protocol, with the aim of producing a comprehensive outcome on post-2012 issues at COP 15 set up in Copenhagen (30 November-11 December 2009). As final output of Bali negotiations, the Bali Action Plan was adopted: world governments agreed upon a negotiating framework to decide a new global climate policy by 2009. If successful, the Action Plan would culminate in a new global climate policy in Copenhagen in late 2009. The Bali Action Plan commits all developed countries to measurable and verifiable actions, in order to achieve quantified greenhouse gas emission reduction targets; developing countries have to develop to appropriate mitigation actions. Even if the Action Plan suggests no concrete emission reduction targets because of the insistence of the USA, a footnote makes reference to documents from the intergovernmental panel on climate change (IPCC), according to which reductions of up to 40 per cent by 2020 are needed to head off dangerous climate change. In a separate agreement, parties to the Kyoto protocol agreed to be fully guided by the IPCC recommendations in setting a second round of commitments by 2009. A review of the Protocol, which will focus also on how to enhance carbon markets, was also launched.

The paragraph will at this point be divided in two sub-paragraphs: Paragraph 1.3.1 will offer an overview of the Kyoto Protocol related issues, while Paragraph 1.3.2 will describe the European emission trading scheme (ETS). More than informing on recent developments in the world and European energy policy, the scope of both sub-paragraphs is represented by providing with full information on the high potential of an instrument such as carbon taxation in the current context.

1.3.1 The Kyoto Protocol

A global common good, like greenhouse effect reduction, definitely needs intervention in the transport and energy sectors and therefore involves the entire population. In this context, the Kyoto Protocol, which was opened for signature in March 1998 and came into force in February 2005, plays a central role. The Protocol has been ratified by the European Community on 31st May 2002. Notable exceptions among countries that have made the agreement official include the United States and Australia; other countries, like India and China, which have ratified the Protocol, are not required to reduce carbon emissions under the present agreement. Despite some steps towards cooperation, and the interest of all nations in dealing with the common problem of climate change, there are significant conflicts within the international community over the measures that should be taken. Developing countries fear the imposition of restrictions on their growth in the form of emissions limitations that would curtail their use of own energy and other national resources. Since most net greenhouse gas emissions currently originate – and historically originated – in the industrialized countries, whose patterns of development are at the root of the environmental problems we face today, the developing countries have consistently pressed them to take the lead in reducing emissions.

To a certain extent the Kyoto Protocol has met this requirement. According to the Kyoto Protocol, the overall emissions of greenhouse gases from developed countries should be on average 5% below 1990 levels in the period 2008–2012; in particular, the European Union has agreed to reduce its greenhouse gas emissions by a collective average of 5% below 1990 levels. Quantified emission limitations and reduction commitments for Annex I Parties[1] are established without prescribing the domestic policy tools to use to achieve them. Article 2 of the Kyoto Protocol gives Annex I countries considerable flexibility in the choice of domestic policies to meet their emission commitments. It provides four market-oriented flexibility mechanisms to help to achieve Kyoto targets: pooling of commitments among industrial country Parties to achieve compliance jointly (Article 4.1); transfer among industrial country Parties of joint implementation project-based emissions reduction units (Article 6); the Clean Development Mechanism (Article 12); and emissions trading among industrial country Parties (Article 17). Among them, only the Clean Development Mechanism involves both industrial and developing countries. It enables industrial countries to obtain credits for their Protocol emissions limitation obligations by investments, including investments by private firms, in projects to be realized in developing countries to reduce their greenhouse gas emissions.

Domestic policies can include carbon/energy taxes, domestic emissions trading, command-and-control regulations and other policies. Carbon taxes have long been advocated by economists and international organisations, because they allow to achieve the same emission reduction target at lower costs than conventional command-and-control regulations. Moreover, carbon taxes can act as a constant incentive to search for cleaner technologies whereas with command-and-control regulations there is no incentive for the polluters to go beyond predetermined standards. Until now, only a few European countries have already implemented energy-related taxes or taxes based on the carbon content of

[1] Annex I parties are industrialized countries and countries with economies in transition. Developing countries are referred to as Non-Annex I countries. To date, the Kyoto Protocol has 176 parties, including Annex I parties representing 61.6% of Annex I greenhouse gas emissions in 1990.

energy products: Finland in 1990, Sweden and Norway in 1991, Denmark in 1992, Italy and Germany in 1999 and the United Kingdom in 2001.

Table 1.1 – The commitments of the member countries in accordance with article 4 of the Kyoto Protocol

Member Country Commitment	**(% change in emissions for 2008-2012 compared to the base year)**
Austria	-13
Belgium	-7.5
Denmark	-21
Finland	0
France	0
Germany	-21
Greece	25
Ireland	13
Italy	-6.5
Luxembourg	-28
Netherlands	-6
Portugal	27
Spain	15
Sweden	4
United Kingdom	-12.5

Source: EU burden sharing agreement (Annex II Council Decision 2002/358/EC).

Table 1.2 – The achievement of the Kyoto targets in European countries (emissions in millions tons)

	1990	**1998**	**2000**	**2010**		**Objective 2008-2012**
				IEA 1998	**IEA 2002**	
Austria	57,0	61,0	62,8	66,0	64,8	56,9
Belgium	106,2	122,5	120,3	121,2	114,4	98,2
Denmark	49,7	57,7	50,1	44,8	59,2	39,3
Finland	53,4	59,7	54,8	70,3	49,7	53,4
France	364,0	371,7	373,3	406,6	461,9	364,0
Germany	966,5	857,7	833,0	894,6	838,5	763,5
Greece	69,0	80,9	87,8	135,0	118,2	86,3
Ireland	32,2	38,4	41,2	45,2	44,2	36,4
Italy	396,6	420,1	425,7	484,8	428,9	370,8
Luxembourg	10,5	7,2	8,0	7,8	8,2	7,6
Netherlands	156,5	170,9	177,1	196,1	176,3	147,1
Portugal	39,9	54,6	59,6	66,4	60,1	50,7
Spain	211,5	254,0	284,7	289,3	323,9	243,2
Sweden	48,5	49,6	52,0	61,6	51,1	50,4
United Kingdom	572,3	540,4	531,5	619,5	581,8	500,8
Total UE	3133,8	3146,4	3161,9	3509,2	3381,2	2868,6

Source: AEEG, 2003.

Table 1.1 and Table 1.2 show how, with respect to the Italian trend in the achievement of Kyoto objectives, a measure such as introducing carbon taxation could have helped to reduce the increasing emission trend (for a more detailed analysis of international emission reduction policies see Paragraph 1.6 and Table 1.10 and 1.11). In particular, carbon taxation could have been effective for its inter-sectoral character, given that its effect would have interested a number of different sectors, helping to achieve sector reduction targets fixed by the Second CIPE Deliberation. Its introduction could have been particularly useful considering the assigned maximum emission levels to each sector for the period 2008-2012, calculated as average year emissions and established in conformity with the reference scenario described in the Second CIPE Deliberation (Table 1.3). in fact, carbon taxation would have contributed to the respect of the maximum emissions levels fixed for most of energy uses, namely energy industries (electricity generation), industry, transportation, residential and tertiary sector.

Table 1.3 – Maximum emissions levels (Mt CO_2 eq.)

	1990 emissions	Maximum GHG emission levels 2008-2012
ENERGY USES	**424.9**	**444.5**
- Energy industries:	147.4	144.4
. thermoelectric	124.9	124.1
. refinery (direct consumptions)	18	19.2
. others	4.5	1.1
- Industry	85.5	80.2
- Transportation	103.5	134.7
- Residential and tertiary	70.2	68
- Agriculture	9	9.6
- Others (fugitives, military, distribution)	9.3	7.6
NON ENERGY USES	**96.1**	**95.6**
- Industrial processes (mineral and chemical industry)	35.9	30.4
- Agriculture	43.4	41
- Waste	13.7	7.5
- Others (solvents, fluorinated)	3.1	16.7
TOTAL	**521**	**540.1**

Source: Second CIPE Deliberation.

1.3.2 The emission trading market

EU overall greenhouse gas emissions fell in 2006 (EEA, 2008), but this drop was mainly attributable to lower CO_2 emissions from households and offices due to warmer weather and rising fuel prices, and lower nitrous oxide emissions from some chemical plants. In April 2007, the European Commission reported that carbon dioxide emissions from industrial plants in the EU emission trading scheme had risen in 2006: data from installations responsible for over 90% of emissions showed a slight increase of 1 to 1.5 percent relatively to 2005 emissions. Then, industrial emissions were still below the EU cap set for 2006 in the national allocation plans approved for the first phase of the scheme (2005-2007); also transport emissions were of particular concern since they grew significantly in 2006. The resulting surplus in allowances adds to the growing consensus that governments were overgenerous in distributing carbon permits. In 2007, the final year of the three-year trial phase of EU carbon trading scheme, industries in the EU emission trading scheme emitted 0.8% more carbon dioxide compared with 2006 (European Commission Press Release, 23/05/2008)[2]. Point Carbon indicated an EU over-allocation of around 215 millions tons in the 2005-2007 first phase of the scheme. This brief overview clearly shows the relevance of a more detailed analysis of emission trading market recent trends.

The price of carbon permits for the first phase of the European emission trading scheme fell to a new low of EUR 6.88 at the end of December 2006, probably due to the estimated surplus of 100m phase-one allowances (ENDS, 2006). Prices stayed unexpectedly high over the summer as power generators continued to buy allowances to cover future needs but after, in face of an unusually mild winter, demand in the power sector had fallen away. Meanwhile, the price for phase-two allowances remains significantly higher than phase-one price, reflecting market expectations that supply will be restricted; more precisely it has continued to rise up to EUR 18.73 per ton. This is primarily because of the tough position being taken by the European Commission in its judgment of national allocation plans.

Figure 1.1 - CO_2 price: Spot price (2005-2007) and Futures price (2008-2012)

Source: Powernext (http://www.powernext.fr)

The price of carbon permits slumped further in the first week of 2007, ending at a new record low of EUR 4.88 per ton. It has now fallen by 85% since its positive peak of April 2006. The price of carbon allowances in the first and second phases of the European

[2] Corrected for changes in the number of installations in the ETS, the rise was 0.68 per cent

emission trading scheme (ETS) has fallen to new lows at the end of February 2007: first-phase allowances have collapsed to EUR 0.80 per ton, halving in less than two weeks, while allowances for the 2008-12 second phase are at EUR 12.70 per ton. In May 2007 prices amounted only to 1% of their peak level reached in April 2006.

While an explanation of the first phase price peak could be over-allocation, the reasons behind the fall in the phase two price are less obvious. Point Carbon[3] cited possible reasons running from lower gas prices, reduced demand from utilities and general nervousness in the market. The allowance price nevertheless remains much higher for the second phase because allocation plans for 2008-12 foresee significantly deeper cuts in emissions. Regarding future market developments, an oversupply of carbon credits generated by carbon offset projects in developing countries could lead to a new collapse in carbon prices and hinder efforts to achieve domestic cuts in Europe. In fact, in the second phase of the emission trading market, installations will be able to buy carbon allowances on the international market through the Kyoto Protocol flexible mechanisms. The World Bank (2007) forecasts a shortage of carbon allowances of between 0.9 to 1.5 billion tons during phase two of the ETS. Despite falling prices, activity on the European carbon market is continuing to increase rapidly: the value of the global carbon market tripled in size during 2006 to reach 22 billions of Euro and volumes traded rose from 710 million tons in 2005 to 1.6 billion tons in 2006. At the same time, the International Emission Trading Association (2007) in its first “Greenhouse gas market sentiment survey” shows improving business confidence in carbon trading as an effective long-term tool to reduce emissions. As in previous years, the market was dominated by the European emission trading scheme, which accounted for over 80% of the total value. It transacted 1.1 billion tons of carbon in 2006. The market in the Kyoto Protocol’s flexible mechanisms also doubled in size, trading 450 million tons. In 2006, nearly 90 % of the Kyoto flexible mechanisms market was made up of Clean Development (CDM) projects, among which clean energy projects made up a quarter of total CDM investments in 2006. In 2007, the global carbon market more than doubled in value to 47 billion of Euro, according to the World Bank (2008). Total traded volume increased sharply to 2.9 billion tons and the EU emission trading scheme continues to dominate the market. Trades were worth 32 billion of Euro, nearly double with respect to their 2006 value.

[3] Point Carbon provides carbon price forecasts and analysis of greenhouse gas emissions trading markets.

With regard to the over-allocation problem (if any), different interpretations exist. Over-allocation in phase-one has been widely blamed for volatility and falls in carbon prices, which have dented the scheme's reputation. Buchner and Ellerman (2006) assert that over-allocation may not be as pervasive as many have thought: even a generous approach concludes that 11 member states that distributed nearly three-quarters of all allowances cannot be viewed as having over-allocated. The authors also suggest that emission cuts by companies could have played a part. In particular, according to the authors, more than half of the surplus of allowances recorded in the EU carbon market in 2005 looks to have been caused by companies reducing their emissions rather than by governments having handed out too many allowances. Clearly, the evaluation of phase-one results could not be done without disentangling these factors.

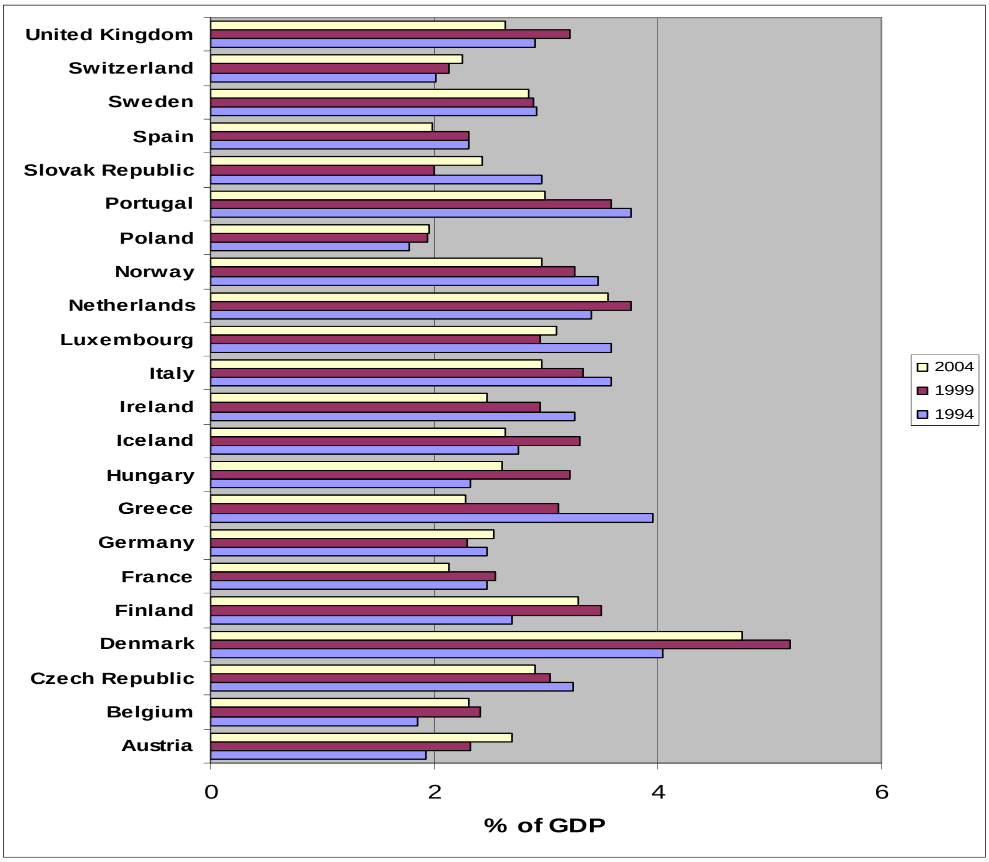
According to a survey of 151 British firms (PricewaterhouseCoopers, 2007), traditional command and control measures and taxes could be more effective at delivering green improvements than instruments such as emissions trading. Even if UK pioneered the emission trading approach in Europe and it is considered one of the best implementers of the ETS, this energy policy tool turns out to be one of the least favoured among the alternative interventions strategies, with less than half of the firms interviewed agreeing on its effectiveness.

1.4 Environmental taxation in Europe

OECD (2006) confirmed that there is a high potential for governments to introduce more environmental taxes. The report recommends reducing exemptions in order to ensure taxes are environmentally effective and economically efficient. Environmental taxes and charges have been widely used in OECD countries during the last decade, but in the last few years have lost some of their allure. In the EU, for example, latest data show that in some countries they are declining as a share of GDP (Figure 1.2) and of overall taxation. The amount of revenue raised could, however, not represent a precise indicator of environmental taxes relevance: this kind of environmental policy can trigger major behavioural changes that discourage polluting activities, then it can raise decreasing amounts of revenue because the tax base diminishes.

The OECD report discusses how key obstacles to environmental taxation use could be overcome. One is the widespread fear that green taxes will hit industrial competitiveness. For this reason many environmental taxes include exemptions or refunds designed to protect certain sectors. Many of these are total or partial exemptions from energy taxes for energy-intensive industries. As a result, the overall burden of environmental taxes falls for the most part on the transport and residential sector, reducing taxes environmental effectiveness and embedding potential regressive effects. In fact, a second key obstacle to environmental taxes is related to their potential to hit poorer households harder, issue that represents the object of my analysis.

Figure 1.2 - Revenue from environmentally related taxes in percent of GDP



Source: European Environment Agency and Oecd (http://www2.oecd.org/ecoinst/queries/index.htm).

Taxation is certainly a powerful and effective instrument that can help to achieve the EU ambitious objectives on energy and climate change at minimum costs. Collective decision-making on tax matters is difficult because it requires unanimous agreement among EU governments and for this reason it can also result in tax rates too low to be effective. Adopting green tax reforms in Europe –introducing a tax shift from labour to the environment – can succeed in realigning some economies that are still characterized by insufficient use of labour resources and excessive environmental pressure. At the end of March 2007 the European Commission has published a green paper which promotes greater use of market-based instruments, such as green taxation, to achieve EU environmental and energy goals. The paper is a joint initiative between the EU environment and tax commissioners Stavros Dimas and László Kovács. Policy areas targeted by the green paper include energy taxation, water pricing, waste management and local air pollution. A key proposal in the green paper is the introduction of an explicit environmental element in the energy tax directive. Reactions to the paper could provide input for fresh EU legislation, in particular for Directive 2003/96/EC revision. Problems implementing the trading scheme (ETS) have bolstered the case for a parallel EU carbon tax. Already the Energy Taxation Directive (2003/96/EC) had foreseen some options according to which energy taxation could be fully or partially replaced by the emission trading market, in order to achieve environmental protection objectives or improvements in energy efficiency. In this context, some overlapping between the European ETS and energy taxation can arise. The solution to avoid this kind of problem has been to establish clearly circumscribed taxation elements, in order to ensure that there is no overlap between the two instruments with regard to purpose and scope. The EU ETS applies to emissions from certain combustion and industrial installations, represented by energy production, production and processing of ferrous materials (iron and steel production), mineralogical industry (from certain capacity threshold upwards) and other activities, such as industrial plants for the production of pulp from timber or other fibrous materials and industrial plants for paper production. Energy taxation, instead, applies to fuel uses of energy[4], leaving the most energy intensive sectors (currently covered by EU ETS) outside its scope. Moreover, energy taxation does not apply to energy products used in energy production or as inputs for electricity generation. Once solved this primary issue, I want to emphasize how carbon taxation can represent a powerful instrument in order to ensure emission trading efficiency. The EU could need a carbon tax alongside its emission trading scheme to deliver the strong price signal required to achieve the 20% greenhouse gas reduction target agreed for 2020[5]. When the scheme was introduced there was a feeling that it was going to be the only EU instrument for reducing carbon dioxide emissions; on the contrary, it now seems that other instruments can be put on its side. In particular, an EU-wide carbon tax could improve the ETS by placing a floor on the price of carbon and it could be applied to sectors, such as transport, which turn out to be difficult to include in the ETS. The European commission floated the idea of an EU-wide carbon tax as long ago as 1991: it was abandoned due to weak political support and has never been seriously revised.

[4] In particular energy taxation does not apply to energy products (and electricity) used as raw materials in industrial processes.

[5] This objective in European energy policy has been adopted by the European Council on 9 March 2007, on the basis of the Commission's Energy Package, e.g. the Communications: “An Energy Policy for Europe” COM(2007)1, “Limiting global climate change to 2 degrees Celsius” COM(2007)2 and “Towards a European Strategic Energy Technology Plan” COM (2006)847.

1.5 A European carbon tax

An important consideration that affects national energy taxation policies is the need to maintain the country's international competitiveness: it is problematic for a single country to change its taxation on environmental grounds if the others do not do the same (Nilsson, 1999; Zhang and Baranzini, 2004). Without international coordination, the result is represented by taxation systems where national authorities have no room for manoeuvre. On an integrated market such as the European one, some degree of harmonization constitutes a precondition for any important change in energy and environmental taxes.

Introducing green taxes on a European scale is fraught with problems, not least because the Amsterdam Treaty[6] requires unanimous support for the implementation of European wide tax legislation. In the past this has proved to be a huge stumbling-block, with the consequence that for a long time none of the European Commission suggestions have past the proposal stage.

In 1991 the Commission first attempted to propose a common climate protection strategy, followed in 1992 by a directive proposal aimed at introducing community-wide carbon and energy taxation (COM/92/226). This intervention was a response to the United Nations Framework Convention on Climate Change; it was supposed to take effect at the beginning of 1993, but neither it nor its amended proposal[7] achieved success. The tax would have been applied *ad quantum* (specific tax) to the final consumption of energy; more specifically, it was structured as follows: half of the tax on crude oil, used as the reference product, was to be collected on the basis of carbon content (in order to reduce air pollution) and half on energy content (in order to improve energy efficiency). The taxes on other energy sources were to be based on unit tax components specified in this way. The rates would have increased over ten years and it would have been calculated in real terms to adjust for inflation. When the tax would have reached its maximum, the tax revenue, recycled through cuts in employers social security contributions, would have represented between 0.8 and 1.3% of GDP, depending on the country.

The potential for using energy/CO_2 taxes to reduce greenhouse gas emissions was again addressed in 1997 (COM/97/30), in reply to the lack of progress in the field of energy taxation. The draft directive rejected the carbon dioxide/energy tax model and called for a

[6] The Treaty of Amsterdam was approved by the European Council on 16-17th June 1997 and signed on 2nd October 1997 by the foreign ministers of the fifteen member countries. It had as main objective to modify certain regulations of the Treaty of the European Union, the constituent treaties of the European Communities (Paris and Rome) and of some acts related to them.

[7] The 1992 proposal was revised in 1995 and structured more flexibly with regard to national implementation, but made the introduction of the tax compulsory by the year 2000 at the latest.

staggered introduction of minimum tax rates on all energy products, the first coming into effect in 1998, the second in 2000 and the third in 2002. The proposed measure aimed at establishing minimum tax rates for coal, natural gas and electricity, as well as increasing minimum rates for petrol, diesel and other fuels. The twin aims of the plan were harmonizing EU energy taxation and encouraging a reduction in fossil fuels burning. Policy guidelines also specified sector and usage specific exemptions, reductions and tax refunds, and the recommendation to use the generated tax revenue to reduce distorting charges on labour. Still, the proposal had to face very hard opposition: after several revisions and amendments, it came into force in 2003. In fact, no consensus could be reached by Ministers during the previous years: the Commission proposal was firmly stuck in the Council and an alternative proposal was needed to reduce emissions whilst avoiding competitiveness issues between EU countries. Also this proposal failed due to fears of upsetting euro-skepticism in several EU countries: a similar approach to emissions reduction could have a negative political impact in many countries if not properly explained or put into context. Opposition is thought to have come from concerns about potential impacts of higher energy taxes on EU industry competitiveness. Clearly, more work was needed to assess how far increases in energy tax rates could be compensated by reductions in labour taxes to achieve fiscal neutrality at member state level. This idea is closely linked to the so-called double dividend literature, which I will review in Paragraph 2.2.

After that, the Commission modified its previous strategy to design a tax which reflect both the carbon content and the energy value of fossil fuels and promoted a different approach. The introduction of an energy tax was justified not only by environmental arguments but by matters of harmonization in the internal market. The plan to harmonize EU energy taxes - widely seen as a key policy in the fight against climate change – could not be finalized in 1999 neither, and the dossier passed on to the Portuguese presidency without any major progress. Both the Finnish and the preceding German EU presidencies strongly supported the plan, but Spain and Ireland blocked any intervention. Neither France, which succeeded Portugal as EU presidency in the second half of 2000, managed to introduce the harmonization measures.

An agreement on EU-wide minimum energy tax levels was then scheduled to be reached by the end of 2002; but conflicting demands from a number of countries caused a series of postponements. Italy emerged as the final hurdle to overcome, as it blocked the agreement on the grounds that it would harm its hauliers competitiveness. The problem seemed to be solved in July 2002 when Italy was praised by the Commission for putting its weight behind a proposed directive to harmonize excise taxes for commercial diesel fuel; even so in March 2003 EU finance ministers failed once again to reach a political agreement on a common energy taxation framework. This time, the delay in agreeing the proposal was caused by Austrian objections to providing exemptions for energy-intensive industries.

In October 2003 the agreement on the text of a directive was finally achieved. A draft opinion on the directive by Finnish Member of European Parliament (MEP) Anneli Korhola had already been voted by the European Parliament's environment committee in March 2003. MEPs passed several amendments widening the scope of the directive to all professional vehicles, moving more quickly towards aligning excise taxes on petrol and diesel, and introducing EU-wide taxation of carbon dioxide emissions. The "Directive restructuring the Community framework for the taxation of energy products and electricity" replaced, in part or in whole, its 1992 predecessor dealing just with mineral oils. Both directives set minimum rates for national taxes on specified products. The Directive 2003/96/EC broadens the scope of EC minimum tax rates beyond mineral oils to cover all energy products, including natural gas and solid fuels (coal, peat, lignite), as well as electricity. It is based on a system of minimum excise rates, specific for every individual fuel and energy type, and not of itself introduces a community energy or carbon tax. The directive had to be transposed by Member States by 2005; even if the agreement provided relief for what were difficult negotiations, it is worth emphasizing that excise taxes fixed by the directive were smaller than the national average, as can be checked from Table 1.4.

Table 1.4 – Excise burden in force and proposed by Directive 2003/96/EC

	(Euro/000 litri)				(Euro/000 Kg)
	Unleaded petrol	**Diesel**	**Diesel (heating)**	**LPG Auto**	**Heavy fuel oil**
Austria	424.7	310.14	106.14	101.02	36.34
Belgium	536.19	321.81	18.49	-	15
Denmark	546.2	369.05	281.82	-	332.82
Finland	597.32	346.81	71.52	-	60.67
France	589.2	416.9	56.6	59.9	18.5
Germany	654.5	470.4	61.35	91.8	25
Greece	296	245	21	99.78	19
Ireland	442.68	368.06	52.12	72.06	18.46
Italy	558.64	403.21	403.21	156.62	31.39
Luxembourg	442.08	252.85	10	54.04	13
Netherlands	664.9	380.4	202.9	54.6	32.11
Portugal	522.6	308.29	89.65	50.8	15
United Kingdom	690.82	690.82	61.89	132	56.15
Spain	395.69	293.86	84.71	32.47	14.43
Sweden	517.49	359.86	359.75	76.92	392.06
Minimum 2004 Level	**359**	**302**	**21**	**68**	**15**

Source: Unione Petrolifera, 2004.

Proposed minimal levels are not always significant: countries in red are those where excise level in 2003 were lower than the minimal 2004 level. At any rate, the compromise-oriented proposal includes a large number of exceptions and country-specific transition periods. By adopting this directive, the European Union equipped itself with a framework for energy taxation before the next phase of the EU enlargement process. This has probably represented an attempt to make concrete steps in implementing the Kyoto Protocol before EU enlargement: the very low minimum rates would probably have some impact in the accession countries. Obviously there is a strong link between national policies and measures (PAM) and EU common and coordinated policies and measures (CCPMs), in this case represented by 2003 directive. Denmark, Finland, France, Germany, Ireland, Netherlands and United Kingdom had already in place policies for the taxation of energy products, Italy and Sweden re-enforced existing national PAM after the adoption of the directive, while Austria and Portugal implemented new national PAM.

Since various policy tools can be employed in order to ensure the respect of Kyoto obligations, my study must broaden out its view to examine different intervention strategies, even if it remains concerned only with the distributive effects of a policy tool such as a carbon tax.

1.6 European experiences in energy taxation

Although the European Union has faced many difficulties related to harmonize energy taxation, this has not precluded unilateral policies to be put into force. When the revenue from taxes on pollution or natural resource depletion is used to lower taxes on valuable economic activities, such as employment or investment, we refer to this as Environmental Tax Reform (ETR). Here I describe in detail the reforms enacted (or tried to be) in some countries. My scope is not offering an exhaustive review but examining the most significant cases in order to carry out my simulation analysis. Several observations can be driven on ETR. First, explicit ETR is a recent political phenomenon: all ETRs were enacted in the past decade[8]. ETR packages have tended to reduce the tax burden placed on labour, primarily by cutting non-wage labour costs in the form of social security contributions paid by employers. ETR packages have very often focused on the energy sector, mainly due to the need for curbing the risk of global climate change, as well as to the high revenue potential of energy taxes compared to other green taxes.

At the annual Nordic Council meeting taking place in Helsinki in 1997 – in the middle of the debate on the proposal of a European carbon tax – members of Parliament from five Nordic countries made a unanimous recommendation to their governments to harmonize energy taxes across the region. Introducing a tax specifically on energy consumption would have enabled progress towards environmental goals without conflicting with EU competition laws, which restricted unilateral taxes on energy production. The Nordic Council (2006) stated that energy and carbon taxes recently introduced in Nordic countries have achieved some remarkable improvements: for example a Danish tax on carbon dioxide has cut emissions by almost a quarter over seven years. The Nordic countries can then be described as forerunners in energy taxation in the European Union. Although some EU Member States, such as Germany and the UK, either introduced new energy/CO_2 taxes or increased existing ones, the energy taxation framework of the Nordic countries still out-performs the situation in other EU Member States, both in terms of the number of energy products being taxed and of tax rates, which are the highest within the EU. For these reasons, I will begin my review of European energy policies from the Nordic countries, the first that have acted in order to reduce carbon dioxide emissions.

Despite of their geographical proximity, a "Nordic model" for CO_2 taxation does not exist: taxes are widely different according to excise rates, taxable basis and exemptions, trying to

[8] Nordic countries' tradition to use fiscal instrument for environmental protection objectives dates back to the seventies but in the last decade it has been intensified with the adoption of fiscally neutral ETR.

adapt to national specific features. Even so, certain characteristic features can be identified: first, ETR are often put into force gradually and excises are modified to account for inflation; second, exemptions for energy-intensive sectors are widely used in order to protect national competitiveness, and often special treatment is reserved to electricity. Regarding the excise rates, sometimes fiscal objectives prevail on environmental ones, so that fuels and gasoline are more heavily taxed (with respect to carbon), having a low price elasticity and allowing for an easy increase in tax revenue. The taxation of transport fuels has a long tradition: for example, in Norway excise taxes on transport fuels were introduced in 1931, and taxes on petrol have existed in Denmark since 1917. Finally, in all these countries energy taxes are the greatest revenue raisers among environmental taxes.

Finland

Finland in 1990 was the first country in Europe to impose a CO_2 tax, levied on fossil fuels depending on their carbon content. The Finnish tax system distinguished between an excise tax (basic duty) and an environmental or CO_2 tax (additional duty), which was calculated according to the carbon content of the energy products and imposed on primary energy inputs (Finnish Economic Council, 2000). This initial CO_2 tax was levied on oil products, other fossil fuels and electricity. The initial rate was low (1.2 EUR/ton CO_2), and it, together with the tax base, has been increased several times since then. In order to create incentives for wider use of natural gas, the CO_2 tax rate for this energy source was reduced by 50% as compared to the general CO_2 tax level and this still applies today. In 1994, the CO_2 tax scheme was changed to a CO_2/energy tax. As a result of this amendment, all primary energy sources were taxed according to both the energy content and the carbon content: 75% of the tax was determined by the carbon content and 25% by the energy content. In 1997 the CO_2 tax became again a 100% carbon tax, but this time applying only to heat generation. The tax reform in 1997 led to some changes in the taxation of energy (Andersen et al., 2001). Firstly, the basic duty was reduced for all energy products and completely abolished for heavy fuel oil and electricity. The additional duty became again completely based on the carbon content of the energy product. Unlike Sweden and Denmark, Finland does not impose any tax on the use of liquefied petroleum gas (LPG). In contrast to the other Scandinavian countries, Finland does not distinguish between tax rates for private users and industrial users.

In 1997 also the tax scheme relating to electricity was thoroughly revised. Before 1997, excise taxes were levied on electricity depending on the production method, and not directly on the consumption of electricity. In accordance with this tax scheme, fossil fuels used for electricity production were levied with the same energy and CO_2 taxes as those levied on industry. In 1997 all production taxes were removed and a consumption tax on electricity was introduced, shifting from an input taxation scheme to an output-based scheme. The 1997 amendment in the tax scheme also included differentiation between the tax rates levied on the consumption of electricity by households/service sector and industry respectively.

The taxation of transport fuels has a long tradition in Finland, as is the case in other Nordic countries. However, environmental issues have not entered into the justification of excise taxies on transport fuels until 1987, when Finnish authorities introduced differentiated tax rates on petrol according to the lead content (Finnish Economic Council, 2000). Even if the tax was introduced in order to establish an economic incentive for choosing more environmental-friendly fuel types, tax rates were not differentiated according to the lead content in the period from 1990–1994. The increase in the tax rates levied on transport fuels has slowed since 2000: the total tax burden levied on transport fuels doubled between 1990 and 2000, but has only increased by around 5% since 2000.

Sweden

The overall principle in Swedish and Danish taxation schemes on fossil fuel is similar. While the energy tax in Denmark is built on three separate taxation schemes, the excise taxes on fossil fuels in Sweden consists of four elements; an energy tax, a CO_2 tax, a sulphur tax and a tax on NO_x emissions. Moreover, taxes on nuclear power and taxes on the consumption of electricity are levied.

Energy policy in Sweden became particularly active in conjunction with the oil crisis in the early '70s, focusing on problems related to the fear of an oil shortage. In the '80s, the motivation for policy intervention switched to environmental concerns; later on, the focus has switched towards the interaction between environmental taxation and public finance, the so-called double-dividend issue (Johansson, 2000).

The energy tax on fossil fuels has been a part of the Swedish tax system since the late '50s, when an energy tax on mineral oil and coal was introduced. The scheme was extended in 1964 by levying an energy tax on LPG; the final step occurred with the inclusion of natural gas into the scheme in 1985. The tax rate was relatively modest when it was first introduced in 1957, and the energy tax has undergone periodic increases ever since, until the energy tax rate peaked in 1990. In 1991 the entire energy taxation scheme was restructured: the energy tax was lowered, offsetting the increase caused by the implementation of the CO_2 tax, leaving the overall tax burden almost unchanged.

The second element of the excise taxes on fossil fuels is the CO_2 tax which was introduced in 1991. The effective CO_2 tax rates on the various fuel types are based on the fossil fuel carbon content. The Swedish excise tax scheme differs significantly from the Danish scheme because in Sweden the CO_2 tax constitutes the most significant part of the excise taxes levied on energy. In 2005, the CO_2 tax constituted more than three-quarters of the total tax on fossil fuel consumption.

An excise tax on electricity consumption in Sweden was introduced already as early as in 1951. During the last 50 years the tax on electricity consumption has been gradually raised, and the taxation scheme has been revised and amended countless times. As in Denmark, the consumption of fossil fuels used for electricity production is not charged with energy or CO_2 taxes. Instead consumers of electricity are charged with an end-user tax. In 1991, the tax on electricity consumption in industrial facilities was completely abandoned and it was not reintroduced before the second half of 2004 as a consequence of the adoption of the EU Energy Taxation Directive. The tax on electricity consumption in Sweden is not levied in a uniform manner; there are some distributional aspects in establishing the tax rates as they are set based on geographical considerations: since 1981 the municipalities in the northern parts of Sweden have been charged with a lower electricity tax. In 1998, the electricity tax scheme was further refined when the tax rates were differentiated according to high and low consumption, leaving large consumers with a higher tax rate than smaller consumers.

The tax on petrol consumption was the first energy tax to be introduced in Sweden in 1924. Taxes on diesel were implemented later in the late '50s and diesel has always been charged with a lower tax rate than petrol. In 1986, the petrol tax was modified by considering the harmful health effect of lead in petrol: two different tax rates for leaded and unleaded petrol have been introduced in order to offer an economic incentive to choose the least harmful type of petrol. When the CO_2 tax scheme entered into force in 1991, transportation fuels were also included in this tax scheme.

The Swedish government increased all energy related taxes considerably during the last five years as compared to other Nordic countries (Ministry of Sustainable Development Sweden, 2005a). The rise in energy tax rates in Denmark, Finland and Norway was almost negligible, at around 5% in nominal terms. Sweden was in strict contrast with this trend, as the non-transport energy tax rates increased between 50 and 60 percent during the same period. Almost the same applies to the electricity tax paid by households, which was raised by around 40%. These nominal increases must be seen in the context of the program of tax shifts over a period of 10 years, which was launched by the Swedish government in 2001.

The primary political objective of this program was to shift the tax burden away from taxes levied on labour and to compensate the loss in revenue by increasing environmental taxes. In particular, the 2004 budget scheme clearly reflects Swedish determination to advance its green policy agenda even as other European countries are downgrading theirs (Ministry of Sustainable Development Sweden, 2005b). Under this budget scheme, energy dominates the environmental tax rises. Sweden's carbon dioxide tax on households and service industries jumped by 18%; electricity and diesel tax paid by the same groups have also risen. Furthermore, the budget scheme abolished Sweden's zero rating on electricity used in industry: starting from 1st July 2004 the tax is charged at the minimum level under the future European energy tax directive. The green tax rises were to be compensated by a cut in state income tax for all employed individuals and a reduction in the payroll tax. Meanwhile, full exemption from excise tax had been given to biofuels and carbon dioxide-neutral fuels have been exempted from both carbon dioxide and energy taxes.

Sweden proposed budget for 2006 goes on with this green tax shift. The output tax on nuclear electricity has been raised by 85% and the tax on electricity used by households and the service sector has also been increased. As part of adaptation to the EU, the reduced tax rates for electricity, gas and heating have been eliminated.

Norway

Energy consumption is charged with many different kinds of taxes in Norway (Andersen et al., 2001). First of all, it is charged with an energy tax already introduced in 1970, which is not levied on coal and coke. This energy tax scheme has undergone several changes since it was first introduced. With the introduction of the CO_2 tax in 1991, the energy tax on mineral oil was lowered in 1992 and abandoned in 1993, as a consequence of the efforts of the Norwegian authorities to put greater focus on CO_2 emissions within the energy tax scheme. As a result of these changes, excise taxes on energy products have been based exclusively on the environmental characteristics of the fossil fuels. The legal foundation concerning the entire energy taxation scheme on fossil fuels was revised and amended in 1998. In 2000, a basic excise or energy tax on fuel oil used for heating purposes was reintroduced, aiming at discouraging increased use of heating oil. This development has also to be seen in the context of the increase in the electricity tax: energy authorities wanted to avoid the tax schemes causing a shift from electricity consumption to oil consumption. The effect of the reintroduction of the basic (or energy) tax on mineral oils was that almost half of the total tax burden on energy consumption in 2005 stemmed from the energy/basic tax.

In 1991 a second kind of taxation on energy consumption was introduced, affecting the use of mineral oils, natural gas and petrol. At the end of 1992 the CO_2 tax scheme was extended and a CO_2 tax was also levied on coal and coke, abandoned in 2003. Norway has adopted a different approach in establishing the CO_2 tax rates, which vary between different energy products, in contrast to the unique Swedish or Danish CO_2 tax rate. The rates have been increased several times since the introduction of the tax; Norway indexes all tax rates, which means that the rates rise in accordance with inflation, guaranteeing that the real value of the tax rates is kept constant (when expressed in the national currency). Such a policy approach is rarely followed by other European countries. Energy related taxes as well as environment related taxes have increased by around 2% annually between 2002 and 2005.

Electricity production in Norway is primarily based on hydropower and it is, therefore, characterized by low emissions of CO_2 and other pollutants. Therefore, it is not surprising that there is no CO_2 tax on electricity consumption in Norway. The Norwegian excise tax on electricity consumption was introduced in 1951 and it has been gradually increased. The revenue from the electricity tax was explicitly earmarked for building hydropower plants or improving them. Some further development occurred in 1993, as Norway introduced a production tax on electricity generated in hydropower plants. During the period 1993–1997 electricity was therefore subject to a production as well as a consumption tax. The production tax was finally removed in 1997.

Two different environmental tax schemes address the transport sector, as is the case in all European countries; energy taxes are levied on transport fuels, while the purchase and ownership of motor vehicles are subject to transport related taxes. Taxes levied on petrol consumption were the first energy taxes to be introduced in Norway in 1931. The revenue generated from the petrol tax has been hypothecated for improvements in road infrastructure. The petrol tax rates have been increased for both fiscal and environmental reasons during the last 80 years. A tax on diesel oil for transportation purposes was introduced in 1970, as a part of the overall taxation scheme on mineral oils. A specific tax on diesel oil for transportation purposes – in addition to the tax implemented in 1970 – was not introduced until 1993.

Aiming at including environmental criteria in the tax computation, transport related fuel taxes have been revised three times. In 1980 and 1986 the tax scheme was changed, focusing before on the octane content and then on the lead content. The second policy approach with a specific environmental purpose was the introduction of the CO_2 tax. While diesel was charged with the tax rate relevant to all mineral oils, petrol was charged with a special and significantly higher CO_2 tax rate. The difference between the CO_2 tax rate on petrol and diesel oil has gradually been decreased after the introduction of the tax in 1991. The third specific environmentally related tax on transportation fuels is a sulphur tax on diesel which was introduced in 2000.

In April 2007 Norwegian prime minister has pledged to make Norway carbon neutral by 2050 (ENDS, 2007). It would be the first time a country set out to reduce its net greenhouse gas emissions to zero. The goal would be reached through a combination of expanding carbon capture and storage and buying emission credits internationally. He declared two further targets: Norway would exceed its Kyoto protocol target by ten percentage points and unilaterally cut emissions by 30% compared to 1990 levels by 2020. Norwegian Kyoto target is restricting emissions rises to 1% above 1990 levels during the second phase (2008-2012) and current emissions are around 10% above.

Denmark

The Danish excise taxes on fossil fuels are divided into three separate tax categories with separate characteristics and distinct historical features (Hoerner and Bosquet, 2001). First, an energy tax is levied on all fossil fuels. The energy tax on fossil fuels was introduced in 1977 as a response to the oil crisis. The tax was supposed to provide consumers with a financial incentive to save energy and, thereby, to reduce the balance of payments deficit resulting from oil products imports. The energy tax, initially levied only on oil products, was extended in 1982 to include coal products. In 1996 the energy tax scheme was expanded further to include natural gas. The tax rates are differentiated across the different energy products according to the energy content of each fuel type, except for natural gas. In fact, the energy tax scheme was partly used as an economic instrument to promote consumption of natural gas: until 2001 it was required by law that its consumer price does not to exceed the price of fuel oil and the energy tax instrument was used to meet this end. In 2001 a political majority decided to abolish this fixed price scheme. The new and more liberal scheme was introduced partly in order to comply with the EU open competition regulation.

The second element of the excise taxes levied on fossil fuels is the CO_2 tax. In 1991, the Danish Parliament passed the CO_2 tax as a reaction to the increased attention on climate change, and this intervention came into force in May 1992. The tax on CO_2 was not intended to increase the overall price on energy, but rather to create economic incentives for less CO_2-intensive energy sources. Later, in order to maintain the overall tax burden and avoid price increases in energy, the energy tax was lowered. During the period from 1992 to 2004 the tax rate was fixed regardless of fuel type. In 2005, a revised CO_2 tax scheme entered into force and the CO_2 tax rate was lowered: to maintain the overall tax burden, the energy tax has been increased correspondingly.

The excise tax on electricity consumption was introduced in 1977 and it is levied on all electricity consumption regardless of its origin. Fossil fuels used in electricity generation are exempted from the energy and CO_2 tax. In 1986 a lower tax on electricity used for space heating was introduced and a two tax-rate scheme exists since this time. The latest revision of the electricity tax scheme came into force during 1999 and it can be seen as an adjustment in response to the liberalisation of the common Nordic electricity market.

Environmental taxes on transportation can be divided into two independent subcategories. Transportation fuels are subject to the energy and the CO_2 tax and, in addition, the acquisition and use of motor vehicles are charged with various vehicle taxes. There is a long-standing tradition in Denmark for levying taxes on fuels for transportation. The first tax on transport fuels was already introduced in 1917 and the rates have been increased since. Up to the late '80s, there were basically two objectives behind the taxes on transportation fuel: they were meant to raise revenue and they were also seen as an instrument to control oil imports. The excise taxes on transportation fuels have, however, also been used as a deliberate means to regulate the environmentally harmful effects arising from transportation fuel consumption. In the late '80s, the harmful effect of lead in petrol was detected and unleaded petrol was given a tax rebate in relation to leaded petrol, thereby giving consumers an economic incentive to choose unleaded petrol. Excise taxes have been used in a similar way to secure the best environmental technology at petrol stations. Also in this sector, the 2005 revision of the CO_2 tax legislation was not intended to increase the overall tax burden on petrol and, therefore, the basic excise charge has been lowered.

Switzerland

Since 2000 the Swiss government has considered the introduction of a new climate levy on fossil fuels used in transport, to bolster the country's measures to meet its Kyoto target (Bernard et al., 2003). In December 2001 Swiss voters rejected a proposal for a potentially massive new energy tax aimed at supporting most or all the country's social security costs. This was the fourth time in little over a year that the public rejected initiatives for higher energy taxes.

Proposed by the Green party in 1996, the initiative "tax energy, not jobs" was aimed at introducing a new tax on all non-renewable energy plus all larger hydroelectricity stations (ENDS, 2001). The Swiss government and parliament, plus business groups, all rejected the proposal. They criticized the lack of a ceiling on the likely size of the proposed energy tax, and the fact that it would affect hydropower, which contributes 60% of Swiss electricity, just when the sector was about to be liberalized. The government still backed the idea of ecological tax reform, and remained committed to considering a tax on carbon dioxide at the beginning of 2004 if current voluntary efforts are not successful. Even if some form of energy tax was anticipated in Switzerland's 1999 CO_2 law, until 2003 there has not been any discussion of specific measures.

With the Kyoto target unlikely to be met through voluntary instruments alone, in 2003 ministers looked at four different tax options. The lowest levy was proposed by the association representing fuel suppliers and was called "centime en faveur du climat" (0.01 eurocent per litre of fuel); it could have been used to fund the purchase of CO_2 certificates abroad and national climate measures. Two options combined this proposal with an energy tax. The final option envisaged imposing an energy tax of EUR 0.30 per litre, and it would not require the purchase of CO_2 certificates.

At the end of March 2005, Switzerland's government approved two fiscal instruments to cut carbon dioxide emissions: a CO_2 tax of EUR 23 per ton to be imposed on most fossil fuels and a separate climate levy of up to 1.6 centimes per litre to be applied to petrol and diesel (ENDS, 2005). The measures were among the four options floated two years before and put out to public consultation. Revenue from the CO_2 tax was to be recycled to the Swiss population through an annual rebate on health insurance bills. Companies would also benefit in proportion to the size of their workforce. Firms could seek to be exempted if they can show that they suffered competitively and they could demonstrate voluntary measures to cut emissions. The levy on transport fuels was introduced for a two-year trial period. If it has not helped to bring down emissions sufficiently by the end of 2007 it can be extended, though possibly only to diesel. Revenue would be independently managed and invested in promoting biofuels, making buildings more energy efficient and financing foreign projects to cut CO2 emissions under the Kyoto protocol JI and CDM flexible mechanisms.

These measures will be completed with a tax on CO_2 emissions from heating fuels, which will enter into force from 2008 after the country's upper parliamentary house, the Council of States, approved the measure at the end of December 2006, ending the legislative process. The variable tax rate will be pegged to carbon emissions: it will initially be set at

EUR 7.5 per ton of CO_2 and it will rise or fall depending on how emission levels move against baselines to be set annually. The law is aimed at achieving a national objective to reduce carbon emissions from fuel combustion by 15% between 1990 and 2010.

Germany

The Dutch system of energy taxation consists of four taxes: the general fuel charge, the regulatory tax on energy, the excise tax and the strategic oil storage tax (Hoerner and Bosquet, 2001). The first two taxes are the most significant ones for my simulation analysis.

The general fuel charge was introduced in 1988 as part of an integral system for financing environmental policy expenditures (then revenue was managed by Ministry of Environment). In 1992, however, the charge was transformed into a tax and became part of general tax revenue; as such, it fell under the administration of the Ministry of Finance. The general fuel tax is collected on all fossil fuels, except for fuels used as raw materials. Tax rates are half based on the energy and half on carbon contents of fuels. Under the general fuel tax, electricity is not taxed, though fuels used to produce electricity are taxable.

The regulatory tax on energy came into force on January 1996. In contrast to the general fuel tax, the regulatory tax on energy was introduced to alter behaviours towards greater energy efficiency, the revenue objective having only secondary importance. Electricity is taxed directly under the regulatory tax system. The regulatory tax on energy focuses on small users of energy for three main reasons. First, as in Denmark, large users are covered by voluntary agreements signed with the authorities, whereby they commit to adopting energy-saving measures. Second, the Dutch government was worried that a unilateral CO_2 tax would harm the export competitiveness of large Dutch energy-intensive companies. Third, large companies are covered by the general fuel tax. Nevertheless, it is estimated that 95% of all Dutch companies, and all individuals, are covered by the tax.

Tax rates for the various fuels are based on their CO_2/energy content. Fuels used to power road vehicles are not subject to the tax as they are covered by excise taxes. Special exemptions are meant to induce energy efficiency; thus heat supplied via district heating and electricity produced with natural gas or renewable energy are exempted from the tax.

On 24 March 1999, the German Bundestag passed the ‘‘Law Introducing the Environmental Fiscal Reform,’’ which entails additional excise taxes on several energy products (Kohlhaas, 2000). The first stage of the environmental fiscal reform entered into force in April 1999: the initial tax rates were raised in four steps until 2003. The revenue from the tax was used to reduce pension insurance contributions: the resulting reduction in non-wage labour costs was expected to lead to employment growth. In addition, funding was provided for a program to promote renewable energy sources. The energy tax concerned fuel oil, gasoline, diesel oil, electricity, and natural gas and was differentiated across these products. Existing taxes on oil products (gasoline, diesel fuel, heating oil, and natural gas) are increased and a new tax on electricity is introduced. The tax was levied on final energy consumption and then, to avoid double taxation, electricity producers receive a rebate for ecological taxes paid on energy sources purchased to produce electricity, because electricity itself is taxed.

Energy products for heating (light fuel oil and natural gas) were taxed almost one order of magnitude less than energy for transport (gasoline, diesel). In addition to this differentiation, there was special treatment according to the sector in which energy was used. In fact, private households, the transport sector and private and public services had to pay the standard tax rate whereas for all other sectors the tax rate on electricity and heating fuels (oil and gas) was reduced. The government in fact considered it necessary taking steps to ensure that the ETR does not impair Germany capacity to compete internationally. Some users were therefore eligible for reduced tax rates, for example the goods and materials sector (i.e., manufacturing industry, energy/water, mining, and construction sectors) as well as the agricultural, forestry and fishery sectors. Moreover, electricity for trains was taxed at only half of the regular tax rate.

Special provisions were also made in order to promote less environmentally harmful sources of energy. In particular, electricity from renewable sources was not subject to the ecological tax if used by the producer itself or if supplied from a network or an electric line exclusively fed by renewable sources. Any power station producing both heat and electricity, namely a cogeneration plant, received a full rebate of all energy taxes.

The revenue from the first step of the ETR has been used to reduce social security contributions. At the same time, the government has increased transfers to the pension program in order to compensate for the reduced revenue from payroll taxes, with the bulk of the funds coming from the ecological tax (Bach et al., 2002). In 2004, five years after the eco-tax program had been launched to curb carbon dioxide emissions, diesel prices had raised by over half and insolvencies among German haulage firms have increased by 71%. Then, Germany Red/Green government considered a dramatic reduction of energy tax exemptions for energy-intensive firms as part of their current review of ecological tax reform program. Opposition against this policy argued that the ecotax program may be unnecessary due to emissions trading. Finance minister first decided that the tax breaks had to be scaled back and then ruled out any additional hikes in the ecotax, saying that, instead, he was looking into extending the scope of carbon emissions trading to include more German firms.

United Kingdom

The United Kingdom's Climate Change Programme was launched in November 2000 by the British government and its aim went beyond the international Kyoto commitment, proposing a reduction by 20% from 1990 levels by 2010.[9] Apart from more conventional measures related to energy efficiency standards, policies included a number of market based instruments. Among them. there was a energy tax – the Climate Change Levy – and a set of negotiated agreements with industry whereby the levy is reduced in return for an agreed package of measures to reduce emissions (OECD, 2005).

The Climate Change Levy was imposed on all non-domestic energy bills, typically raising them by 8% to 10%, with the aim of providing an incentive to increase energy efficiency and reducing carbon emissions. The Climate Change Levy however was offset by corresponding reductions in employers' National Insurance Contributions (NICs) having a net zero effect on the tax burden on UK businesses. Part of the revenue was also used to fund a number of energy efficiency initiatives, including The Carbon Trust. Introduced on April 2001, under the Finance Act 2000, it was forecast to cut annual emissions by 2.5 million tons by 2010, and forms part of the UK's Climate Change Programme. The levy applied to most energy users, with the notable exceptions of those in the domestic and transport sectors. Electricity generated from renewable sources and approved cogeneration schemes was not taxed. Electricity from nuclear was taxed even though it causes no direct carbon emissions. After its introduction, the levy has been frozen at 0.43p/kWh on electricity, 0.15p/kWh on coal and 0.15p/kWh on gas. However, the 2002 Finance Act subsequently increased that rate by 1%, reversing the reduction. In the 2006 budget it was announced that the levy would in future rise annually in line with inflation, starting from April 2007.

The advent of a Labour government in 1997 reaffirmed the commitment to act on climate change and to use market-based instruments where possible. However, concerns that made the design of such measures more complex were added. First, since the previous

[9] When the original programme was published in 2000, it confirmed that UK emissions were already forecast to be around 15% lower by 2010.

government had faced difficulties in extending value added tax to the household sector, the new government did not wish to introduce measures that might have a disproportionate effect on the poor. Then, the question is asking how effective the Climate Change Levy was relatively to how the alternative measure might have been. In fact, imposing a tax also on household consumption probably would have provided a wider price signal, directed to all the concerned economic agents. Coverage was limited because of the exemption of households, who should nonetheless bear some incidence of the tax, and transport which is subject to other tax measures. Moreover, most believe that a "pure" carbon tax would have been better. In contrast, the levy was perversely related to the carbon content of fuels – gas being taxed more heavily than coal in terms of carbon content. The climate change agreements appear to have been very successful with over-compliance with targets, even in the first years of operation. This could reflect the "soft" nature of the targets, with the system being largely "captured" by industry; certainly the levy's design reflects the political economy considerations of government: a pure tax would have come into conflict with government goals concerning household vulnerability, competitiveness concerns and the sensitivity of some sectoral interests.

Portugal

Portugal can be quoted as a good example of the potential positive links between emission trading market and carbon taxation. In October 2003, the Portuguese environment minister thought that the government could introduce taxes on carbon dioxide and methane emissions and use the revenue to offset the anticipated burden of buying greenhouse gas emission credits in the future emissions market (ENDS, 2003a). Portugal was one of the countries furthest from meeting the Kyoto commitments under the EU burden-sharing agreement, and applying emissions taxes to the sectors not covered by the EU directive on emissions trading would have collected revenue for acquiring emission credits in the international Kyoto market. One form of carbon taxation could have been to increase vehicle registration fees, weighting them according to their polluting potential; a restructuring of fuel taxes was also under consideration. One year later, Portugal's 2005 draft budget contained no mention of a road vehicle carbon tax mooted the year before and included in a national climate change plan; on the contrary, it included a new tax exemption for bio-fuels and it maintained the so-called forestry eco-tax on transport fuels (ENDS, 2003b).

1.7 The market of energy products in Italy

In this paragraph the structure of energy products' market will be described: in fact, every analysis of a carbon tax impacts will be not complete without considering the markets of concerned goods and the national and international trends which characterize them.

World electricity demand is slightly increasing and, consequently, also the share of fossil fuels employed by this sector (Table 1.5). For this reason, the energetic sources for electricity production should became more and more differentiated, giving priority to more efficient technologies and less polluting sources.

Table 1.5 - Mondial energy consumption (millions TEP)

	1980	**1990**	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
solid fuels	1,761	2,215	2,237	2,311	2,309	2,402	2,513	2,776	2,916
natural gas	1,247	1,664	1,829	2,100	2,109	2,173	2,225	2.313	2,362
oil	3,015	3,078	3,220	3,502	3,543	3,571	3,650	3,959	4,005
hydro-geo	161	218	253	278	273	278	281	713	318
nuclear	186	525	608	675	688	694	688	304	718
total	***6,370***	***7,700***	***8,147***	***8,866***	***8,922***	***9,118***	***9,357***	***10,065***	***10,319***

Source: ENERDATA, 2006.

In Italy, the electricity balance heavily depends on electricity imported from neighbouring countries (Table 1.6): examining the electricity world market, our country turns out to be the second world importer (IEA, 2006).

Table 1.6 – Italian energy consumption (millions TEP)

	1990	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**% on total 2005**
solid fuels	15	12,6	12,8	13,7	14,2	15,3	17,1	17	8.6
natural gas	39,1	44,8	58,4	58,5	58,1	63,8	66,5	71,2	36
net importations of electricity	7,6	8,2	9,8	10,6	11,1	11,2	10	10,8	5.5
oil	92,5	95,7	92	91,9	92,1	90,8	88	85,2	43.1
renewable sources	8,5	10,4	12,9	14	12,6	12,8	15	13,5	6.8
total	***162,7***	***171,7***	***185,9***	***188,7***	***188,1***	***193,9***	***196,6***	***197,7***	***100***

Source: Unione Petrolifera, 2005.

Because of the scarcity of internal energy sources, the imports of fossil fuels are very high (Table 1.7); they represent 80% of energy sources available, with peak values up to 90%, well above the European and OECD countries average. The percentages shown in Table 1.7 are computed as the ratio between imports and availability net of stocks, and the total is obtained as weighted average, considering the share of different energy sources in the Italian energy mix.

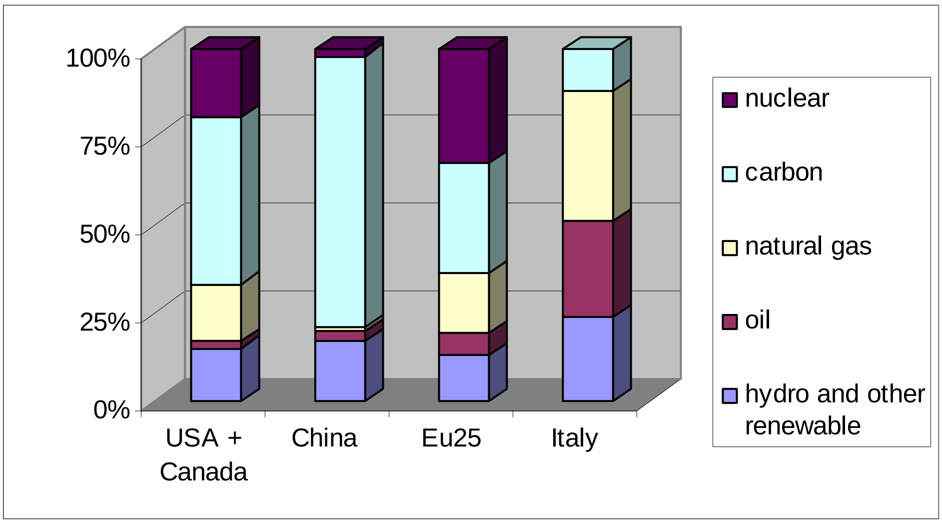
Table 1.7 – Italian energy dependence on importations (%)

	Solid fuels	Natural gas	Oil	Total
1999	86.2	73.9	94.6	82.2
2000	88.1	77.5	95.1	83.7
2001	85.3	78.2	95.5	83.6
2002	84	80.2	94	84.2
2003	82.2	81.7	93.9	84.5
2004	82.6	83.9	93.8	84.3
2005	82.1	85.8	92.9	85.1

Source: ENEA, 2005.

According to IEA (2006), Italy is among the first six countries with respect to the share of oil and gas used in electricity production. In particular, Italy is the fourth world importer country of natural gas and the European country (sixth in the world) for which the dependence on oil in electricity production is the highest. Differently from other countries, that have at their disposal higher quantities of carbon and also use nuclear energy, the Italian energetic system is highly unbalanced towards natural gas and oil (Figure 1.3).

Figure 1.3 – Energy mix: an international comparison



Source: IEA, 2004.

Then, the problem is to find a strategy which combines two objectives, the security of supply and the diversification of energy sources. In particular, the majority of Italian power stations burn natural gas (60.5%), followed by those that burn carbon (16.9%) and oil products (12.9%). These percentages have consistently changed in a few years: in 1996, natural gas, carbon and oil represented respectively 25%, 11% and 59% in the energy mix. The major tendencies have then been represented by an increasing relevance of carbon and by an inversion of oil and natural gas rule. These trends have been determined by costs' assessment, price volatility and oil's provenience from countries with a high level of political instability; furthermore, natural gas has less serious environmental impacts and the Kyoto Protocol structure encourages its utilization.

Table 1.8 – The Italian demand of oil products (millions tons)

	1990	1999	2000	2002	2003	2004	2005	variazione % 2005 vs. 2005
LPG	3,3	4	3,9	3,7	3,7	3,5	3,5	0.0
leaded petrol	13	6,6	4,6					
unleaded petrol	0,7	11,1	12,2	16,1	15,4	14,6	13,5	-7.5
total	***13,7***	***17,7***	***16,8***	***16,1***	***15,4***	***14,6***	***13,5***	***-7.5***
diesel (fuel)	16,3	17,8	18,3	21,5	22,3	24	24,4	1.7
diesel (heating)	6,9	3,8	3,6	2,9	2,8	2,8	2,9	3.6
diesel (other)	3	2,8	2,6	2,3	2,8	2,6	2,6	0.0
total	***26,2***	***24,4***	***24,5***	***26,7***	***27,9***	***29,4***	***29,9***	***5.3***

Source: Unione Petrolifera, 2006.

As to gasoline and diesel, Table 1.8 shows their consumption trend in Italy. A decreasing trend can be observed in gasoline demand, while the demand for diesel is steadily increasing, even if its growth has slowed in recent years. In particular, in 2005, gasoline demand has contracted by 7.5% with respect to its 2004 level, due to the shifting process from gasoline to diesel vehicles. Conversely, the demand for diesel as fuel has increased, even if only by 1.7% (in 2004 the increase equalled 7.6%). Since the demand for diesel as heating fuel is augmented by 3.6%, probably due to climatic effects, the demand for diesel has totally increased by 5.3% with respect to its 2004 level.

In order to better understand market dynamics, in what follows both the supply and the demand side will be examined relatively to the carbon tax's potentially concerned markets. The trends and the main issues highlighted will be useful in order to comment the results obtained from the demand system estimation. Moreover, the following analysis could also help in explaining possible results of differentiated impacts among regions.

Electricity

The Legislative Decree 79/99 (Bersani Decree, approved on 9th May 2001), implementing Directive 96/92/EC based on the Independent System Operator (ISO) model, stated the separation of ownership between the national transmission system management, which is entrusted to a public entity controlled by the Ministry of Finance, and the activities involving the ownership of the grid facilities, which continue to be owned by operators. In this context, three new institutions have been established in the electricity sector, namely Transmission System Operator (TSO), Single Buyer and Market Operator. In particular, the GRTN (Gestore Rete Trasmissione Nazionale) was established at the beginning of 2000 as a state owned company with responsibility for all activities related to transmission

(TSO). The Authority for electricity and gas (AEEG, Autorità per l'Energia Elettrica e il Gas), with the Resolution 48/04 which followed the Bersani Decree, stated the beginning of dispatching, namely the Power Exchange. The electricity market, according to the Decree, should include two types of markets, each type consisting of several markets: markets for energy trading between operators, which include the day-ahead market and the adjustment market (the latter taking place in two sessions), and markets for economic selection of the resources that GRTN requires for its dispatching service. In particular, in the day-ahead market, the schedules for electricity injection (generation) and withdrawal (load) into and from the grid are defined for each hour of the next day, on the basis of the offers/bids submitted by operators. These schedules may be modified by operators through offers/bids submitted into the adjustment market. The first session of this market takes place immediately after the day-ahead market and it allows operators to modify their schedules resulting from the day-ahead market. The second session takes place at the beginning of the day to which injections and withdrawals refer, and it enables operators to modify the injection or withdrawal commitments they made in the previous markets, according to the requirement of potential new developments (e.g. outage of a power plant or of an electricity-consuming unit).

During 2006, GRTN changed its name to GSE (Gestore dei Servizi Elettrici). The new name further stresses the company's public-service mission in the electricity sector. Inefficiencies and difficulties of coordination between the grid operator and the owners of the grid had led the Government to propose that ownership and management be merged once again: this became operational with the creation of TERNA in November 2005. After the Decree of the President of the Council of Ministers of 11 May 2004 stated the transfer of its power dispatching, transmission and grid development assets to TERNA, GSE has become focused on managing and promoting renewable energy in Italy, an activity that it previously carried out only in part.

The prices in the electricity market are set according to a simple and transparent mechanism and, at any time, they reflect the conditions of demand and supply, i.e. the purchase and sale offers/bids submitted by operators. Consequently, the transactions in the electricity market are likely to take place under the best conditions: no customer or producer runs the risk of purchasing or selling electricity at off-market prices, without going through a costly search for the counterparty offering the best conditions. Moreover, the electricity market gives operators more flexibility in making their generation and consumption pledges. In the electricity market, consumers and producers may revise their commitments to withdraw or inject electricity from and into the grid until the previous day, without any penalty, and until a few hours ahead of the real time, in the adjustment market. Potential congestions linked to grid constraints among geographical areas could be managed introducing zonal market articulation, by individuating up to seven market areas. This could embed a differentiation of electric prices in different areas, reflecting the supply and demand peculiarities in each area.

Every operator has to notify to the AEEG the rates to be adopted the next year: the AEEG will check their conformity to the law and decide if they are applicable. For domestic uses, the rates are directly fixed by the AEEG, but electricity sellers can propose supplementary options, which have to be validated by the Authority. During the year, electricity sellers must adjust their rates and prices, by increasing or diminishing them, on the basis of the criteria provided by AEEG. These criteria take into account changes in the variable production cost of electricity, namely the part of production cost linked to fossil fuels' price; clearly this cost strictly depends on the fluctuations of international oil price.

On the demand side, the Italian system of energy prices represent an exception in the European context. In fact, in Italy, the electric sector for residential uses, differently from other countries, has a progressive price structure, which is aimed to promote the containment of consumptions. Final prices for users with low consumption are smaller than the European average; conversely, high consumption users pay a price higher than the European average.

Table 1.9 – Electricity prices for domestic uses (eurocent/kWh, July 2002)

ANNUAL CONSUMPTION	600 kWh		1200 kWh		3500 kWh		7500 kWh	
COUNTRIES	GROSS OF TAXES	NET OF TAXES	GROSS OF TAXES	NET OF TAXES	GROSS OF TAXES	NET OF TAXES	GROSS OF TAXES	NET OF TAXES
Austria	12.7	8.5	13.2	8.9	11.6	7.7	12.9	8.7
Belgium	18.0	14.8	16.8	13.7	13.6	11.1	13.1	10.7
Denmark	32.4	16.9	25.9	11.8	21.8	8.4	20.5	7.4
Finland	17.0	13.3	12.1	9.3	9.4	7.0	8.0	5.8
France	16.3	12.9	14.3	11.3	11.7	9.2	11.3	8.9
Germany	25.2	19.9	20.3	15.7	16.6	12.5	15.1	11.3
Greece	7.9	7.3	7.4	6.8	6.3	5.8	7.1	6.6
Ireland	18.6	16.5	14.7	13.0	9.9	8.8	9.4	8.3
Italy	9.6	7.4	9.9	7.7	19.5	14.2	19.0	13.7
Luxembourg	23.0	21.0	17.3	15.6	13.0	11.5	11.9	10.5
Norway	40.8	31.7	23.8	17.9	12.6	8.9	9.5	6.4
Netherlands	19.4	17.8	17.7	12.6	17.3	9.8	17.0	8.9
Portugal	13.3	12.5	15.1	14.3	12.9	12.2	11.4	10.9
United Kingdom	18.7	17.9	14.9	14.2	10.2	9.7	9.4	8.9
Spain	13.4	11.0	13.4	11.0	10.5	8.6	9.6	7.9
Sweden	24.4	17.5	16.4	11.1	11.2	6.9	10.4	6.3
European weighted average	19.5	15.8	15.9	12.6	13.3	10.1	12.4	9.4
Italy: deviation	-51.1	-53.1	-37.6	-38.5	47.4	39.8	53.7	46.4

Source: AEEG, 2003.

This trend can be checked by examining Table 1.9; the European weighted average is computed by weighting for each country's consumption level and the Italian deviation is computed as the percentage deviation from this weighted average.

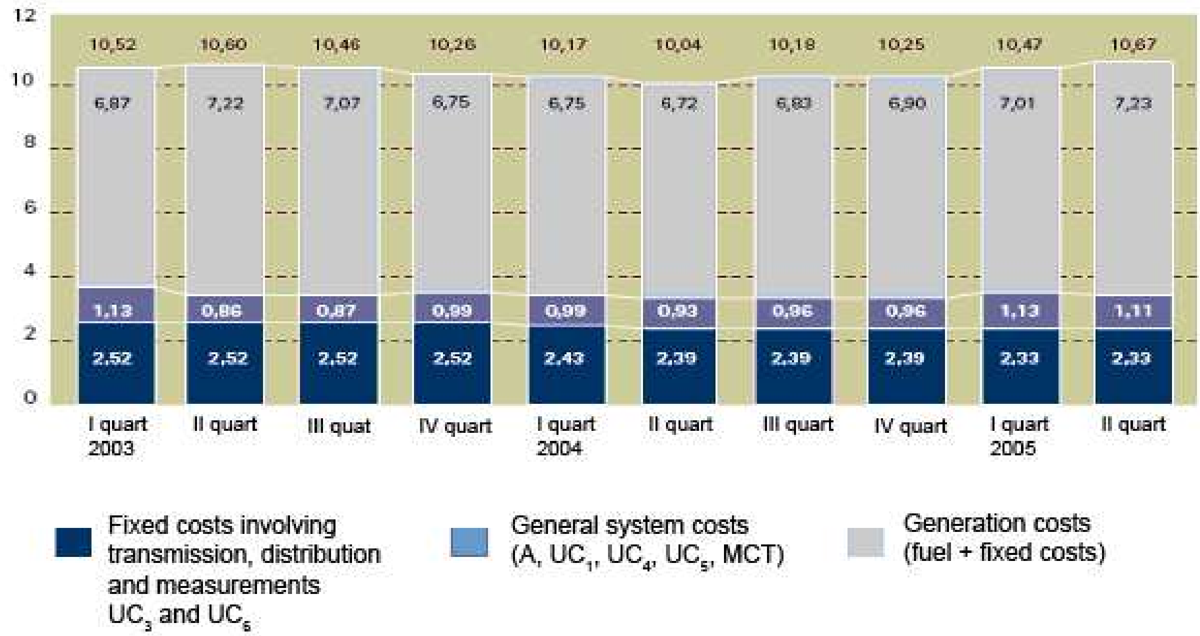
Residential sector represents around the 23% of final electricity consumption and Liguria, Lombardia, Piemonte and Valle d'Aosta are the regions whit higher consumption incidence in this sector; on the contrary, Molise, Puglia and Sardegna have a very low incidence, whit a relevant deviation from the national average. Clearly, climate plays a key role in shaping energetic consumption: all the regions in the North (except for Friuli Venezia Giulia) have consumption values higher than the national average.

The analysis of energy sources highlights relevant differences in the energy production mix at regional level. Solid fuels represent at the national level almost 3% of total consumption, with Puglia, Liguria and Friuli represent relevant exceptions, with respectively 24.4%, 12.6% e 9.8%: these percentages are to be ascribed to thermoelectric production which employs carbon. Examining oil products, which represent the 47% of total energetic consumption, all the regions in the South, Trentino-Alto Adige and Valle d'Aosta have values definitely higher than the national average. The use of natural gas at national level constitutes more than 30% of the final energetic consumption and all the regions in the

North and South – except for Lazio, Liguria, Trentino-Alto Adige and Valle d'Aosta – have higher shares of this energy source in their energy mix. Finally, examining electricity consumption, regional averages are closer to the national average, except for Sardegna, where electricity consumption is higher because of the absence of natural gas, and Liguria and Emilia Romagna, where electricity consumption is lower due to higher utilization of carbon and natural gas (CNEL-ENEA, 2001).

Figure 1.4 shows the trend followed by the tariff component of electricity prices: in the period examined the component related to fuels prices (light blue), has not undergone a substantial augmentation, even if oil price has had a steadily increasing trend. The tendency of Istat price indices for electricity is strictly connected to the tariff trend shown in the graph. The tariff diminished up to the minimum value 10.04 eurocent/kWh in second quarter 2004, when this tendency inverted and it began to increase, due to the increasing trend in international quotations of fuels. The reforms introduced with the Bersani Decree, in particular the Single Buyer procurement strategies, have allowed to weaken the international oil market impacts on the domestic market, reducing the negative effects on the low income customers.

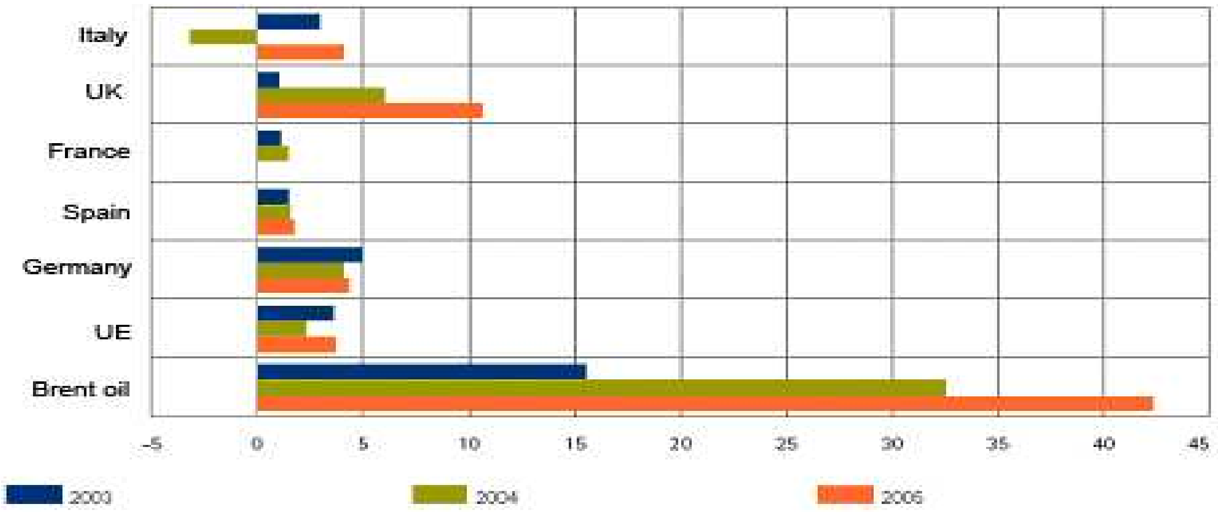
Figure 1.4 – Average electricity tariff net of taxes (burden of different components in % of the total)



Source: AEEG, 2005.

In Figure 1.5 the performance of the price of Italian electricity is compared with the main European countries, using the harmonized consumer price indices collected by Eurostat. Values in the graph are computed as percentage variation with respect to the previous year price. With a change in the price of Brent oil of more than 40% in 2005, the performance of the Italian price is in line with the average European price (3.7%) and it is actually better when compared to Germany (4.3 %) and the United Kingdom (10.6%), the two countries in which the portion of thermoelectric production is very high, as it is in Italy. The increases were considerably more contained only in France and Spain (in France, in particular, there was no change at all): clearly the performance was better because a higher portion of electricity was produced from sources not connected to oil (nuclear sources in the case of France and hydroelectricity in the case of Spain). The fact that in Italy the link with oil price has been not so strong supports the view that imposing a carbon tax on electricity would have been feasible, given that both the overall relevance of its additional price effects and the negative price effects linked to the increasing trend in oil price were likely to be limited.

Figure 1.5 – Electricity prices variation in some European countries



Source: AEEG, 2006

Natural gas

The gas sector is structured in different phases: procurement, transport, storage, primary and secondary distribution. Examining national production, a decreasing trend can be observed; Italy still represents a relevant importer of natural gas: this is bought from Algeria, Russian, Netherlands, Norway and Libya and it represents more than 80% of consumption.

The storage service has the aim of withdrawing the stocks in periods of demand peak and allows the wholesalers to modulate their supply and face importations rigidity and high variability of residential demand, due to seasonal temperature changes.

The retail sector is heavily influenced by the control exercised by Eni, the largest operator in the country. Eni continues to heavily condition the entire gas supply chain, limiting its evolution towards a greater degree of competition. The lack of autonomous procurement on the international gas market forces the authorized retail companies to get gas from the wholesale market, which is fuelled mainly by the amounts made available by the principal retail operator. The Italian gas sector has historically been characterized by the presence of a large number of companies, basically operating on a local level, under legal monopoly conditions for the so-called “civil” supplies (domestic and small industry-trade) hooked up to the city networks. Liberalization and the introduction of third parties’ right to access the grids have changed the reference scenario substantially even if, due to the historic inheritance of a pulverized market and the absence of a competitive process for consumers acquisition, a marked territorial segmentation still remains, especially for the civil sector.

In this context, the analysis of the retail permits trend, issued on national level by the Ministry of Productive Activities, shows a slow decline in the companies present on the market, which did not keep their retail permits. These are mainly represented by small companies, and mostly small_municipalities, that previously managed the integrated service (distribution and sales) directly, and private operators, which sold their activities to other sector operators. On the other hand, the analysis highlights the entry of a lot of new companies. Of these, only a minimal portion (just under 15%) comes from the gas distribution sector: the largest component is indeed constituted by companies specialized in oil product sales (almost 40%). The arrival of electricity operators should also be pointed out (around 15%), as well as that of a few large, foreign energy operators (20%) and energy service supply companies (the remaining 10%). The development of retail gas market shows great differences at the regional level: in the North of the country, new operators are entering the market, while in Central Italy a concentration process prevails. The situation is basically unchanged in the South.

To summarize, the market appears to be characterized, on the one hand, by the predominance of the main operator in all phases of the supply chain (particularly in the procurement phase), and on the other, by a fragmented and basically local offer structure. The market structure is segmented geographically, with operators mainly oriented towards consolidating their positions on the local level, and which in most cases belong to the same industrial group as the distribution network operator, making it even more difficult for new operators to enter the sector. The most important operator sets the market reference price, also exploiting the clear-cut advantages it enjoys in the upstream phase.

In order to complete the overview of the gas retail market, it is interesting to analyse the average prices with whom consumers are charged, broken down by consumption class. Comparing end-user prices in Italy and other European countries for 1999 – the year in which the Italian carbon tax had been introduced and started its gradual excise augmentation – natural gas results more expensive in Italy. The average price net of taxes is 6.7% higher than the European average (weighted with consumption values). The natural gas taxation is structured in a progressive way, and the price tax included is 43% higher than the European average. Examining residential consumption, for small users, Italian prices are lower when compared to other European countries, even if fiscal incidence is very high if compared to other countries, except for Austria and Sweden. Conversely, for higher consumption levels, the price paid is around 70% greater than in other European countries (ENEA, 2000).

Fuels

The fuels distribution market is highly concentrated, among nine operating companies *(*Agip, Ip, Esso, Erg, Shell, Q8, Totalfinaelf, Api and Tamoil), all belonging to oil companies vertically integrated also in the upper phases of refining and logistics. These companies represent the 98% of the market, while the independent plants satisfy the remaining. The Italian distribution system is the_largest in Europe, with more than 22.400 plants (in France they are 13.300 and in Germany 15.000), despite several rationalisation plans had tried to downsize it. Since all imported oil is refined in Italy, oil companies determine the price on the market. Pump prices are almost identical for all the companies, and this can be checked by examining oil products' prices collected and published by the Ministry of Economic Development. Moreover, prices higher than in other European countries (in particular France and Germany) represent a peculiarity of our market: oil companies justify their high prices with the greater distribution costs, to be ascribed both to the geographical conformation of the Italian territory and to the high fragmentation of the distribution system. Every oil company determines consumer price through agreements with the associations of wholesalers, which in turn negotiate the economic aspects with the retailers associated to the company brand. In particular, three different price levels can be distinguished (i) the recommended price, namely the sale price suggested by the oil company; (ii) the cession price, applied to the transaction between the oil company and wholesalers, and obtained by applying a discount to the recommended price (iii) the maximum price, given by the recommended price plus a differential.

The cession price includes also the excise duty paid to the State; the right to levy the excise duty arises when the energy products are introduced in the consumption circuit. Then, the intermediate operators (wholesalers) are those on which the legal incidence falls: this mechanism is easy and works well, because of the limited number of operators involved and the easiness of controls. With respect to excise taxation, several specific conditions can be applied to some regions. The regions with ordinary statute can introduce an additional tax on gasoline consumption, up to 0,026 EUR/litre: until now, only Campania and Molise have adopted this strategy. To the autonomous regions with special statute is often allocated part of the revenue raised with excise taxation: in the case of Sardegna, Trentino Alto Adige and Valle d'Aosta the sum allocated equals 9/10 of the revenue, while in of Friuli-Venezia Giulia the percentage is lower. In the period of my simulation there were still fiscal exemptions for Valle d'Aosta, Gorizia, Trieste and the province of Udine: these exemptions have been removed starting from January 2007. A beneficial treatment is still in place in Lombardia and Piemonte for municipalities next to the frontier with Switzerland: two price's categories are established, in which the gasoline price is discounted according to the distance from the frontier.

The excise rates on gasoline and diesel remain the same even if the oil price undergoes relevant augmentations. The excise incidence on industrial prices is in the range between 156.2% (diesel as fuel) and 197.9% (leaded petrol, abolished in 2002). These values are higher than the excise rates applied to fuels for industrial use, such as heavy fuel oil and light fuel oil, for which the incidence on industrial price respectively equals 21.6% and 72.8%.

In Italy the average consumer price (net of taxes) of unleaded petrol is lower than in Portugal, Sweden, Netherlands and Austria, while it shows a maximum differential with France; on the other hand, in the case of diesel the differential is maximum with respect to the United Kingdom. These differentials are mainly to ascribe to the higher diffusion of self-service in the European supermarkets, which enables to lower the prices and is particularly developed in France and United Kingdom. Confronting Italy with other European countries, the variability of unleaded petrol's price has been higher than in Italy for the 40% in France, 130% in Germany and 95% in the United Kingdom. Relevant values have been assumed also by the variability of diesel's prices, higher than 200% in France, 100% in Germany and 85% in the United Kingdom (ENEA, 2000).

Filling the current price differential with respect to the other European countries (in particular France and Germany) would imply savings for final consumers and would help to make our economic system more competitive, especially relatively to diesel. Actions aimed at rationalizing the distribution system and opening the sector to new companies should be taken, and also interventions which keep under observation – by means of an independent authority – distribution costs, industrial prices and consumer prices, as in the case of electricity and gas. Refining and distribution activities should be separated, by creating independent companies, in order to obtain better levels of transparency and concurrence.

There are big differences in the tax rates of transport fuels between the countries in Table 1.10 and Table 1.11[10]. The highest taxes can be found in the UK, and the gap between unleaded petrol and automotive diesel has not narrowed in many countries. The comparison between the tax rates of unleaded petrol and diesel shows that only

[10] The countries listed in Table 1.10 and 1.11 are those examined in Paragraph 1.6 , chosen for the relevance of their environmental and energy policies.

Switzerland has introduced a higher tax rate for the latter, reflecting its environmental impact. A decreasing trend of tax percentage in prices can be observed and this can be ascribed to the increasing prices for unleaded petrol and for diesel observed in recent years. Italy, in both cases, shows very low tax percentages if compared to other countries, and this highlights a potential for excise augmentations, as planned with the carbon tax introduced in 1999.

Table 1.10 - Percentage of Taxes in Unleaded Petrol Prices

	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Austria	67.7	67.6	60.6	62.6	64.1	63.8	61.5	57.7	55.7	56.7
Denmark	72.4	72.3	66.3	68.4	69.7	69.5	68.5	64.6	62.1	62.4
Finland	78	74.3	67.3	68.4	70	71.7	69.6	66.5	63.7	64.4
France	81.2	78.8	69.8	71.6	73.7	74.3	71.9	67.1	64	64.2
Germany	75.2	73.8	69.3	71.7	73.4	73.7	71.5	67.4	64.6	66.0
Italy	74.7	73	64.8	66.4	68.4	67.8	66.3	62.9	60.5	60.6
Netherlands	74.9	73.3	66.4	68.8	70.9	71	69.2	66	63.8	63.9
Norway	76	74.7	68.7	67.6	70	68.9	66.6	64.5	62.7	63.4
Portugal	72.9	67.7	49.4	46.2	68.9	68.1	66.5	62.8	59.8	62.5
Sweden	75.5	73.1	67	67.6	69.6	70.1	68.1	65.3	63.4	64.3
Switzerland	70.1	69	60.3	62.1	64.3	63.3	59.6	55.2	51.8	52.2
United Kingdom	81.5	81.5	75.5	76.1	77.4	75.5	73.6	69.2	66.6	68.2

Table 1.11 - Percentage of Taxes in Automotive Diesel Prices for Non-Commercial Use

	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Austria	62.6	62.1	53.9	55.5	56.9	56.5	55	50.1	49.9	52.1
Denmark	64.4	63.3	56.2	58.9	60.5	60.5	60.3	55.6	53.4	54.7
Finland	65.7	62.6	53.8	55.2	56.8	57.5	55.7	51	49.3	50.6
France	74.7	72.5	62	63.3	66	65.8	63.5	57.2	55.1	56.5
Germany	68	67.1	61	63.6	66.2	66.8	63.9	57.9	55.9	58.2
Italy	71	69.6	59.5	61	63.8	62.6	59.6	53.8	52.2	53.5
Netherlands	66.9	64.6	56.4	57.7	59.5	59.2	57.3	52.3	50.1	51.9
Norway	68.3	66.8	63.8	58.2	59.1	59.1	58.4	55	52.9	52.9
Portugal	63.8	62.7	52.1	51.3	56.9	56.8	55	50	49.2	52.4
Sweden	62.4	60	54.6	55.2	57.2	59.2	59	55.2	52.9	54.8
Switzerland	69.6	69.3	60.6	61.9	64.3	63.4	60	53.7	50.9	52.2
United Kingdom	81.8	80.9	74.4	74.3	75.6	74.1	72.4	66.7	64.5	66.5

1.8 Emission reduction policies in Italy

The CIPE (Comitato Interministeriale per la Programmazione Economica, Interministerial Committee for Economic Planning) with its 137/98 Deliberation provides a synthesis of the international obligations for Italy in greenhouse gas reduction. In order to highlight the impact of these actions to the consumption of oil products, it is necessary to examine oil demand from the economic sectors involved by the emission reduction policies. For every barrel of oil imported, the percentage destined to the main sectors are represented by:

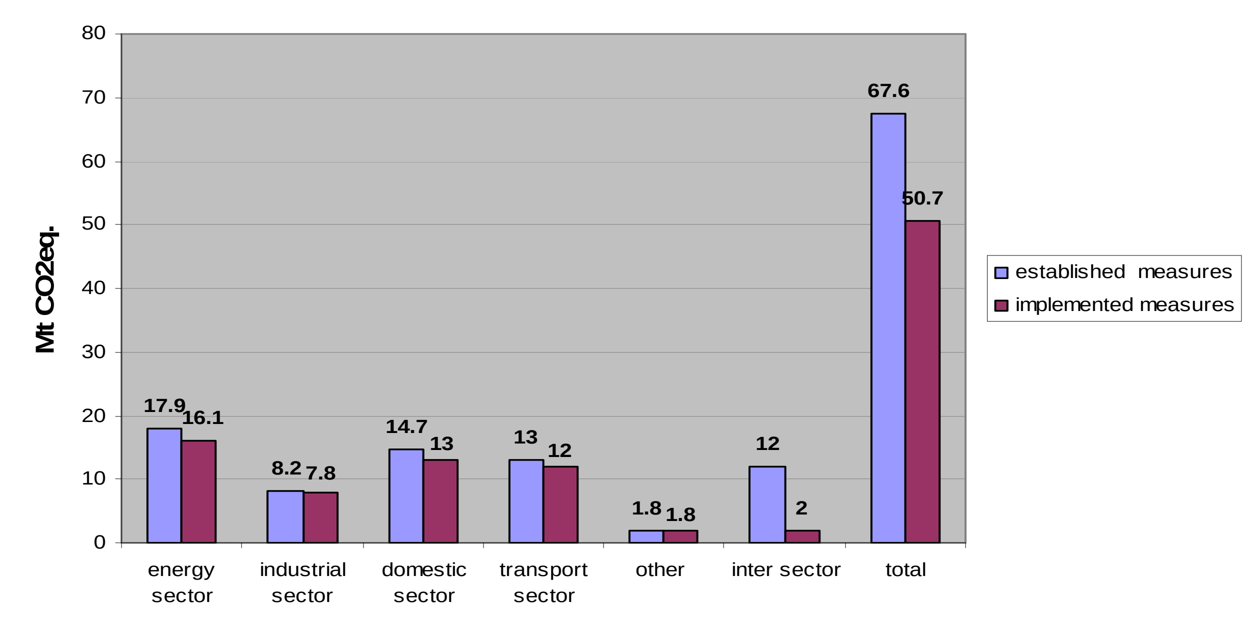
- 20% to the electric generation sector;
- 52% to the transport sector;
- 12% to non energy sectors;
- 16% to the other energy sectors.

This repartition is worth to be mentioned also because – by making evident the dependence on oil – it highlights the sector on which oil price volatility has the stronger impacts.

With the First Deliberation, titled "*Linee guida per le politiche e misure nazionali di riduzione dei gas Serra*", a very important role to achieve the Kyoto reduction target is assigned to the actions in the electric and gas sector: efficiency improvements of the pool of thermoelectric facilities should enable to reach more than 20% of the overall reduction objective for 2008-2012. Renewable energies will contribute with a reduction equal to 18% of the overall objective, and actions related to energy consumption in the industrial, residential and service sector will reduce greenhouse gases emission by 26%. In general, almost 40% of the emission reduction objective has to be achieved with policies related to electricity supply, to be implemented over 15 years. On the demand side, a significant contribution can arise from programs directed to electric consumptions management (or demand side management). All interventions planned should allow to reach at the same time environmental goals and efficiency increases, without altering Italian competitiveness.

In particular, here I will review the impact of policies implemented during the periods covered by the First and the Second CIPE Deliberation (123/02), titled "*Revisione delle linee guida per le politiche e misure nazionali delle emissioni di gas serra*" and enacted the 19th December 2002. The first aspect worth to be considered is that even if the objective fixed by the First Deliberation was represented by an emission reduction of 103.5 Mt CO_2 eq., the emission reduction produced by the measures defined and implemented equals 50.7 Mt CO_2 eq., that corresponds to around 50% of the initial target.

Figure 1.6 – The emission reduction measures in the First CIPE Deliberation (Mt CO2 eq.)

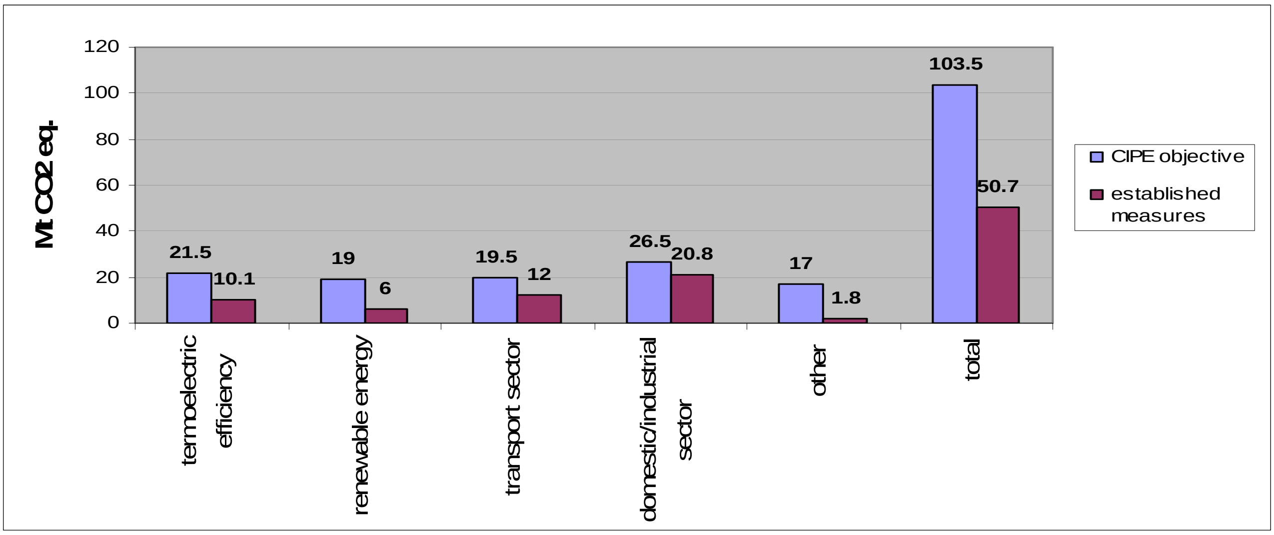


Source: ISSI, 2004.

With reference to Figure 1.6, in achieving the overall emission reduction percentage of 16.1% a key role has been played by a voluntary agreement between Enel and Ministry of Environment, which dates back to 2000 and is aimed at promoting energy efficiency, and by other interventions linked to renewable energy. Regarding the domestic sector (13% emission reduction), the major contribution – equal to 6.3% of the overall emission reduction – has been given in 2001 by the decree passed by the Ministry for Environment and Territory for the energetic efficiency in final uses (24/4/01). In 1998 the Law 10/91, inherent to heating consumptions and energy losses, was also important. Examining transport sector, interventions to reduce green-house gases emissions have assumed different forms: incentives for low emission vehicles, financing of public transport, bio-fuels promotion, modal shift for goods transport. The major contribution to the achievement of 12% emission reduction has been provided by the incentives for purchasing low emission vehicles (6.8%), followed by the financing of public transports (3.2%). The incentives may represent a counterproductive strategy, given that the Italian rate of motorization is among the highest in Europe; differently, investing in public transport, in particular in order to improve their efficiency, should represent the key strategy to reduce emissions in the transport sector. The carbon tax constitutes the only inter-sectoral measure and if it would have been implemented up to 2005, it would have been associated to a emission reduction of 12%. This percentage clearly highlights the strong implications of its abolishment.

In Figure 1.7 the established measures are compared with the CIPE objectives: examining this graph jointly with the previous one shows that even the implementation of all the defined measures would not have been enough for the achievement of the CIPE objectives. In particular, the contribution achieved by the measures in the category “other”, where the carbon tax would have impacted, is very small if compared with the CIPE target.

Figure 1.7 – CIPE objective and established emission reduction measures (Mt CO2 eq.)



Source: ISSI, 2004.

The CIPE, with the 123/02 Deliberation, has revised the guidelines for national emission reduction policies (developed in 137/98 Deliberation) and has approved the “National Plan for greenhouse gases reduction: 2003-2010”, according to the Law 120/02. This law, passed in ratification of the Kyoto Protocol, identifies the following guidelines on policies and measures:

• to increase energy efficiency of the national economic system and to foster the use of renewable sources of energy;

• to increase carbon dioxide removals deriving from land use, to change land-use and forestry, as established under the article 3 of the Kyoto Protocol;

• full implementation of the Joint Implementation and Clean Development Mechanisms established under the Kyoto Protocol, with the aim of reaching the best possible result in terms of generation of emission credits at the lowest incremental cost;

• promotion of innovative technological solutions, such as: research and development aiming at introducing hydrogen as a main fuel in energy systems and in the transport sector; biomass-based combined heat and power plants and solar thermal power plants; wind and photovoltaic power plants and waste and biogas-based power plants.

The objective, established by Law 120/02, is to reduce greenhouse-gas emissions by 6.5% compared with 1990 levels; therefore, the emissions amount assigned to Italy for the period 2008-2012 can not exceed a threshold value, calculated as the average yearly emissions for the period under examination. The Second CIPE deliberation identifies a national emission reduction commitment equal to 487.1 Mt CO_2 eq. and introduces a trend scenario referring to which the distance from the Kyoto objective is computed (CO_2 emissions under the trend scenario amount to 579.7 Mt CO_2 eq., so that the emission reduction needed in order to reach the Kyoto objective equals 92.6 Mt CO_2 eq). The deliberation also defines a reference scenario and a list of established and approved policy measures, even if not yet implemented (to be implemented in the period 2003-2010), thanks to which an emission reduction equal to 51.8 Mt CO_2 eq. will be reached (Table 1.12). Among these measures, around 77% (39.8 Mt CO_2 eq.) concerns national reduction policies, whereas the remaining percentage (12 Mt CO_2 eq.) is covered by flexible mechanisms: this is in accordance with articles 6 and 12 of the Kyoto Protocol, which state that flexible mechanisms must be additional with respect to national policies. Among national measures, 6.5 Mt CO_2 eq. are related to renewable energy production and 6.3 Mt CO_2 eq. to energy saving.

Table 1.12 – Established and approved measures included in the "reference" scenario

	Reduction (Mt CO_2 eq/year)
Electric industry:	**26**
Combined cycle expansion for 3200 MW	8.9
Import expansion capacity for 2300 MW	10.6
Further growth of renewable sources for 2800 MW	6.5
Civil:	**6.3**
Decrees on the efficiency of end uses	6.3
Transportation:	**7.5**
Buses and private vehicles running on fuels with low carbon density(LPG, methane)	1.5
- Optimisation and collectivisation systems for private transportation - Tax reformulation - Activation of computer-telematic systems	2.1
Development of national infrastructures and incentivization of combined road transport and coasting navigation	3.9
Total national measures	**39.8**
Carbon credits from JI and CD mechanisms	**12**
TOTAL MEASURES	**51.8**

Source: Second CIPE Deliberation.

Summing up, the emission reduction to be achieved in order to reach an emissions level in line with the national Kyoto commitment is 40.8 Mt CO2 eq. (obtained as difference between the distance from the this commitment and the total reduction in Table 1.12). To fill this gap a set of options for additional actions is presented (Table 1.13).

Table 1.13 – Options for additional reduction measures

	Potential reduction (Mt CO_2 eq. /year)	
	Min	**Max**
A) OPTIONS FOR THE ADOPTION OF ADDITIONAL NATIONAL REDUCTION MEASURES		
Use of energy sources		
Industrial sector	5.1	8.1
Renewable sources	1.8	3.4
Residential and tertiary sector	3.8	6.5
Agricultural sector	0.28	0.34
Transport sector:		
- technological measures	9.1	12.1
- infra-structural measures	3.4	4.9
- research and development	0.8	2.1
From other sources:		
- industrial sector	6.2	
- agricultural sector	0.6	1.3
- waste	1.4	
B) OPTIONS FOR THE USE OF THE JI AND CDM MECHANISMS		
Carbon removal	5	10
Projects in the energy sector	15.5	38

Source: Second CIPE Deliberation.

The potential of emission reduction associated to these additional measures corresponds to values between 32.5 and 46.4 Mt CO_2 eq., considering the measures in section A), and to values between 20.5 and 48.0 Mt CO_2 eq., relatively to the additional carbon credits attainable through industrial projects and through the Joint Implementaion and Clean Development mechanisms, as specified in section B). In particular, with regard to transport sector, some examples are represented by: (i) technological measures, such as the replacement of circulating vehicles with low-consumption and low-emission vehicles (120 g CO_2/Km) (ii) infra-structural measures, for example given by the reorganization of urban traffic, the adoption of urban mobility plans, the promotion of regional railway networks and connections with exchange park areas (iii) research and development, oriented to pilot projects for the utilization of hydrogen-propelled and cell-combustion systems for_energy production, railcars and car engines. The Clean Development Mechanism and Joint Implementation are instead often aimed at increasing the production of energy from renewable sources and improving the efficiency of electricity generation and industrial activities.

To summarize, the idea was to adopt a mix of different policy measures and the carbon tax played an important role in this approach. It is interesting to notice that the First CIPE Deliberation had identified a distance from the Kyoto objective equal to 103.5 Mt CO_2 eq., whereas with the Second CIPE Deliberation the distance falls to 92.6 Mt CO_2 eq.

1.8.1 The Italian carbon tax

The Italian government unveiled at the end of September 1998 its proposals to raise every year fuel excise for the next five years. More precisely, taxation on the consumption of energy products and related compensation measures have been introduced with the approval of the Budget Law for 1999 (L. 23.12.1998 n. 448, art. 8). The measures was very significant since Italy was the second largest European economy, after Germany, to introduce an environmentally-motivated, energy-based ETR. In addition, Italy represented the first country in southern Europe to introduce CO_2 taxation, a subject already on the agenda of several northern states and also of the European Commission. The new green tax was based on two main components: a reduction in CO_2 emissions through a re-modulation of excise taxes on mineral oils, and the introduction of a consumption tax on coal and natural bitumen used in the combustion plants.

The package affected a range of different fuels: leaded and unleaded petrol, diesel oil (used for both heating and for transports), natural gas (used for both heating and transports), heavy fuel oils and liquefied petroleum gas (LPG)[11]. Excise taxes had to be raised every year from 1999 to meet a target level in 2005. The structure of excise rates was modified in such a way such that each energy product was charged with a specific tax rate that reflected its carbon content. This aimed at satisfying both the need to tax each fossil fuel according to its specific CO_2 emissions and the European requirements on the harmonization process of excise rates on energy products (COM/97/30). Indicating with α_i the excise tax on product *i*, the energy excise rates were structured as follows:

$$\alpha_i = k\beta_m + A_i \tag{1.1}$$

where *k* is the ratio between the Italian excise tax on product *i* before the introduction of the new tax and the minimum excise rate level proposed by European Union (COM/97/30), β_m is the minimum excise level proposed by the above mentioned directive and A_i is the environmental component of the tax, proportional to the kgs of CO_2 emitted by the fossil

[11] On this basis I have identified the aggregated goods which constitute my demand system.

fuel *i* under consideration. This term was equal to 10 Lire (EUR 0.005) per kg of CO_2 released in the combustion of 1 kg of fuel up to 2.75 kg of CO_2. For emissions levels in the range 2.75 to 4 kg of CO_2 per kg of fuel a linear increase of 400 Lire (EUR 0.20) for each additional kg of emissions was decided. This procedure has allowed to set out the excise rates for mineral oils to be applied starting from January 1st 2005, used as reference level. The annual tax increases was related to the difference between current and target levels, but every year the increase can not be greater than 30% of this difference. Considering the joint effect of price changes and taxation, if the petrol price rise was assumed to achieve 20% of the targeted increase, then the government should achieve around a 10% total increase in unleaded petrol taxation over the five year period. Meanwhile, taxes on liquid petroleum gas (LPG), an alternative, low-polluting transport fuel, will fall. The excise burden in 2005 would reflect the carbon content of each fuel: examining fuels used in power generation, the excise is higher for coal than for oil products and natural gas. The tax on heating fuel was lower for industrial users than for households. The natural gas tax for households is lower in some areas of southern Italy, to promote economic development. Dealing only with products directly consumed by households, Table 1.14 gives an indication about the scale of the carbon tax effects, showing excise rates in 1999 and 2005 along with their percentage variation.

Table 1.14 – Excise burden changes due to the Italian carbon tax

Product	**Unit of measurement**	**Excise burden**		**% excise variation**
		1999	**2005**	
Unleaded petrol	Euro/1000 l	570.66	594.05	**4**
Diesel (fuel)	Euro/1000 l	403.21	467.84	**16**
LPG (fuel)	Euro/1000 kg	284.77	206.58	**- 27**
Natural gas (fuel)	Euro/1000 mc	10.85	51.65	**376**
Diesel (heating fuel)	Euro/1000 l	403.21	467.84	**16**
LPG (heating fuel)	Euro/1000 kg	189.94	206.58	**8**
Heavy fuel oil (heating fuel)	Euro/1000 kg	64.24	218.49	**240**
Natural gas (heating fuel)	Euro/1000 mc	173.01	180.24	**4**

Source: DPCM 15/1/1999.

Excise rates augmentation were moderate in almost all cases except for natural gas and heavy fuel oil. The excise rate of LPG diminished compared with 1999. The environmental tax introduced with Law 448/98 added an additional fiscal levy on energy products on the basis of their carbon content (in terms of emissions produced): for this reason, this measure should be defined as a “carbon-energy excise tax”. It increased the price of all the energy products and indirectly raised the electricity price according to the energy source used in its generation.

Fuel producers had to pay the increase in excise burden whereas consumers felt the knock-on effects of higher prices. The budget specified that responsible organizations will have to make tax payments quarterly, and it also fixed fines of up to four times the due amount if the tax is not paid on time. There is a significant difference between pure carbon-energy taxes and excise taxes (Barker and Kohler, 1998): carbon taxes are included in the basic prices of the energy industries whereas excise taxes are to be paid further down the productivity chain. The first step of the Italian “carbon tax” introduction was represented by a tax reduction for industries – ignoring retroaction on prices – because of the reduction of social contributions; the higher excise rates affected transport and heating fuels and, for the most part, households.

According to the government, revenue from the tax did not simply gone into the treasury, but it was to be earmarked to support employment in the South of Italy, reduce employment charges and fund environmental improvements in sectors such as transport and heating. In particular, under the plan 60.5% of the revenue raised in the tax’s first year were to be spent on reducing compulsory contributions on labour. Specifically, this revenue would have financed welfare contributions incurred by employers hiring new staff in Italy’s poorer South and half the pension contributions of young businessmen who change jobs. The Italian tax reform represented therefore a targeted version of ETR: it targeted the unemployed workforce in the poorer regions. Revenue from the tax would also be recycled to improve transport of remote mountain areas to offset increases in diesel and heating oil prices.

The environmental fiscal reform has been the subject of heated debate since its introduction. The dispute became politically explosive when the price of mineral oil products increased dramatically due to the high world market prices for crude oil and the devaluation of the Euro. The sense and the economic and social feasibility of the environmental fiscal reform were called into question. Opponents called for the tax to be postponed or even abolished, because they feared negative effects on economic growth and believed that the reform could be socially unjust.

In January 1999 Italian fossil fuel prices jumped with the carbon tax entry into force. The taxation was in line with CIPE resolution (19.11.1998) objective to reduce CO_2 emissions, in order to comply with the obligations of the Kyoto Protocol. It is worth mentioning that, unusually for a southern European country, Italy was also introducing an ecological component as part of the tax reform. Ten months after the implementation of the Italian carbon tax, the International Energy Agency (IEA, 1999), surveying Italian energy policies, recommended that the government set a long-term objective of clarifying and improving the fuel tax structure. The IEA particularly criticized Italian new tax on CO_2 emissions, which could have been used to reduce distortions but which in practice had kept most of the existing tax structure and maintained distortions in inter-fuel competition. The Italian energy tax attempted to incorporate very different goals, fiscal, social and regional as well as environmental ones. One result was that tax differentials between coal and other fuels were much larger than the differentials in their carbon content, while energy taxation should be more focused on the internalisation of external costs. The IEA also stressed that Italy had to improve energy efficiency of household electric appliances: it suggested that the government incorporate EU directives on energy labeling for washing machines, light sources and other appliances and take more proactive steps within the EU to set new energy efficiency standards. Carbon taxation introduced in 1999 did not take into consideration the issue linked to electricity consumption and for this reason I will not only simulate the distributional impact of proposal taxation, but I will also simulate a scenario where electricity consumption is charged.

At the beginning of November 1999, Italian retail petrol and diesel prices fell by an average of 30 Lire (EUR 0.015) per litre following a government decree aimed at curbing inflation (ENDS, 2000). Italian fuel prices had risen by a similar amount at the beginning of the year when a carbon tax had been introduced, affecting all fossil fuels. The reduction was only intended to remain in force until the end of the year or beginning of the year after because preliminary figures showed that the Italian short-term inflation rate was in danger of breaching the upper limit allowed under the Maastricht stability pact. The government estimated that lower prices for transport and heating fuels will cut the overall rate of inflation by 0.02%. In this situation, the decree represented a necessary intervention, but the tax cut should only be tolerated as a temporary measure[12]. The carbon tax introduced by the Italian government in January had had a "minimal" effect on petrol price rises: unleaded fuel prices had risen by 240 Lire (EUR 0.12) per litre since the beginning of the year, whereas the carbon tax had added only 32 lire per litre (EUR 0.016). Since the green reform was essential to Italy to achieve its Kyoto protocol commitment to cut greenhouse

[12] Similar policy measures aiming to curb inflation but which are likely to have negative environmental effects, were adopted in the same period in Spain which cut the subsidy programme for renewable energy sources and reduced motorway taxes.

emissions by 6.5%, reducing the scope of the tax seemed counterproductive. In any case, this did not rule out that caution might be needed in the way carbon taxation was applied to avoid causing inflationary pressures. In April 2000, the Italian environment minister Edo Ronchi said that the carbon tax would be re-applied in June to gradually counteract expected growth in petrol consumption, following the recent decision of the Organization of Petroleum Exporting Countries (OPEC) to increase crude oil production. Carbon tax rates for 2000 were likely to be higher than the rates in force for 11 months in 1999. The differential between leaded and unleaded petrol was designed to close a current gap in favor of unleaded by the time that leaded fuel would be outlawed in Italy in 2002. Autumn 2000 was characterized by two important events. First, the Italian government proposed an amendment to its 2001 budget, allocating 1.5% of revenue garnered annually from the carbon tax to promote wider use of renewable energy sources, in order to ensure permanent public investment in this field. Second, Italy's Court of Accounts approved the allocation of the revenue from the carbon tax. According to Law 448/98 (art. 8), part of the revenue deriving from the introduction of carbon tax had to be used to finance project linked to emission reduction, energy efficiency and renewable energy development. The Technical Appendix of DPCM 15/1/1999 made some projections for the raised revenue in 1999 and the following two years, hypothesizing that consumption remains constant (Table 1.15)[13].

Table 1.15 – Revenue raised from carbon taxation in Italy (millions/Euro)

	1999	**2000**	**2001**
Revenue raised:	1,125.9	1,172.9	1,172.9
. transport fuels	723	753.2	753.2
. heating fuels	232.4	242.1	242.1
. industrial uses	134.3	139.9	139.9
. electricity generation	41.3	43	43

Source: DPCM 15/1/1999.

In 1999 the revenue share to be used for ecological projects financing amounted to EUR 155 million. The conference State-Regions had to choose the utilization criteria which should be aimed at promoting investments projects associated with the Kyoto flexible mechanisms. In particular, the Ministerial Decree 2001/05/21 has established the distribution of financing to the regional "Carbon Tax" programs: the Appendix I of the

[13] In the values related to transport fuels and heating, fiscal exemptions, which respectively amount to 167 and 136 millions of Euro, are not included. According to Environmental Accounts published by ISTAT (Italian National Statistical Institute) the overall revenue raised by excise taxation on oil products has amounted to EUR 24,657 million in 1999.

decree lists the subdivision by regions of the financing for the ecological projects (Table 1.16)[14].

Table 1.16 – Financial transfers made available in 1999 from carbon taxation (millions/Euro)

Region	**Financial transfer from carbon taxation**
Val d'Aosta	2.281
Piemonte	12.269
Lombardia	24.721
Autonomous Province of Trento	3.071
Autonomous Province of Bolzano	2.903
Veneto	12.777
Friuli Venezia Giulia	4.829
Liguria	5.706
Emilia Romagna	12.960
Toscana	9.450
Umbria	3.762
Marche	4.602
Lazio	10.530
Abruzzo	4.072
Molise	2.212
Campania	7.529
Puglia	9.851
Basilicata	2.639
Calabria	3.824
Sicilia	9.555
Sardegna	5.458
Total	***155.000***

Source: Ministerial Decree 2001/05/21.

In 2001, Italy decided to reform its carbon tax which was previously linked to specific energy sources. The new environment minister, Altero Matteoli, wanted it to be applied to all carbon dioxide emissions irrespective of the source. Meanwhile, the government imposed a freeze on the 2002 tax rate at the same level as 2001, aimed at slowing down the rise in energy prices. In Spring 2002, a committee of Italian MPs recommended the abolition of the controversial carbon tax, arguing that the government should replace the ineffective measure with an adequate and rational tax policy (ENDS, 2002). After stating that Italy's "weak" energy sector hindered the country's economic performance, the committee suggested that market liberalization should be accelerated, power infrastructures upgraded and transmission networks improved.

[14] Carbon tax revenue should have funded emission reductions, transport projects, renewable energy source development and energy-saving; in actual fact, in February 2004 Italy's Court of Auditors had accused the government of failing to spend as required on energy efficiency and environmental protection measures EUR 155 million raised in 1999 from the carbon tax (Corte dei Conti, 2004).

In September, the government proposals to put Italy's carbon tax on ice and to offer conditional support to renewable energy sources arrived in the lower house of Parliament. Introduced in 1999, Italy's carbon tax should have subjected to in-built annual increases but it was dropped shortly after, thus proving ineffective. The new legislative proposals put it on ice and offered support through incentives to the energy sources (with similar levels of emissions) that are more widely available and that guarantee security of supply[15]. This was a sensitive issue, because Italy relied very heavily on imports of natural gas and electricity for its energy needs. Under the draft law, the quota of electricity generated from renewable sources would increase by 0.35 percentage points annually, between 2005 and 2012. The Italian strategy to cut national greenhouse gas emissions by 6.5% on 1990 levels by 2008-12 relied on the Kyoto protocol flexible mechanisms to deliver half of the required emissions cuts. This new approach clearly pleased Italian industry groups, which had urged the government to minimize command and control measures to meet Kyoto targets. Italy was the second EU country to be forced to rely on the flexible mechanisms for half of required emission cuts, following an example set by the Netherlands. Compared to an intervention on prices, which falls almost completely over consumers, the new approach represented a serious strategy shift. Clearly the draft law needed some investments to be operational. They were supposed to require no additional taxation or budgetary provisions, but simply to redirect towards these measures excise taxes on fuel and a higher share of the carbon tax. Maybe to change something – not until the point of abolishing it – in the Italian carbon tax was necessary, also because Italy's inability to achieve targets set in previous CO_2 emission reduction programs was attacked by the Court of Auditors, the country's principal monitoring authority.

Forecasts in Second CIPE Deliberation have shown that the carbon tax would have brought about an emission reduction of 12 Mt CO_2 eq. in 2005 when the excise objective level would have been reached. This amount represents around a third of the Kyoto commitment for Italy. In the transport sector, the emission reduction would have been limited (less than 1 Mt CO_2 eq.) because price increases would have not be very high. The carbon tax would have produced the most relevant effects in the thermoelectric (-6 Mt CO_2 eq.) and industrial sectors (-3 Mt CO_2 eq.), due to the increased use of natural gas and the improvements in energy efficiency. With regard to the drivers of emission reduction, according to the simulations, around two third would have been linked to the adoption of

[15] This argument was used to promote coal utilization for electricity production.

more efficient technologies and the utilization of fuels with lower carbon content, whereas less than one third would have been due to the energy products elasticities. This result highlights a low energy demand elasticity – maybe due to the increased wealth level of consumers – and a technology market more dynamic. The estimation of a complete demand system, and the computation of price elasticities, will provide additional information on these issues and confirm or contradict these forecasts.

The environmental aim of the carbon tax requires the gradual excise increases to be coherent with the motivations which have led to its introduction, independently from changes in international and national economic trends (for instance, oil prices and their potential effects on the inflation rate). This should have been guaranteed even considering that the carbon tax had a marginal impact on the overall excise on energy products but it was likely to be environmentally effective, contributing to the achievement of Kyoto targets. The Italian carbon tax was in fact similar to the one introduced in Netherlands in 1996, because of its limited incidence on prices. The United Kingdom, instead, even not having formerly introduced environmental taxes, has increased by 6% per year the excise duties on fuels starting from 1997, a rate well above the Italian annual excise increase.

Chapter 2

2.1 Taxation and public goods

In this paragraph I intend to briefly review the link between taxation and public good provision; in our case, carbon dioxide reduction represents the concerned public good. I follow here Musgrave-Musgrave (1994) and Samuelson (1954) definitions of public goods. They define public goods by identifying two specific technical characters of the good, that is excludability from consumption and rivalry in consumption. A pure public good is then defined by non-excludability and non-rivalry. Existence of pure public goods can result in a misallocation of scarce resources and requires public intervention to ensure their socially optimal amount to be provided. Distributional issues then do not arise with respect to the level of provision *per se*, but only as far as the financial costs of its provision differ across socioeconomic groups. In reality, there are very few pure public goods in the environmental field because most environmental goods are partly or fully rival. The imperfect public good nature of environmental quality makes the distributional effects of environmental regulation even more important.

The sub-paragraph 2.1.1 will address the development of the optimal taxation literature, while the sub-paragraph 2.1.2 will examine the marginal cost of fund measures, which can be used for the assessment of environmental tax reforms or for projects' sensitivity analysis.

2.1.1 The optimal taxation literature

According to the benefit principle of taxation, taxes allocation should be set as prices designed to correspond to the marginal utility derived from the provision of public goods. In other words, the benefit principle of taxation draws an analogy between the pricing process of private goods in a market economy and the allocation of taxes according to individual preferences. Analysing benefit taxation, a common feature is represented by the interest in whether such taxation, once properly defined, would be progressive, regressive, or proportional. Moreover, considering the progressivity of a benefit tax in isolation from the distributive incidence of the public goods it finances is misleading: in particular, Kaplow (2006) has developed a measurement approach that allows to address how the distributive incidence of a public good affects the extent to which the good should be provided. Then, a particular formulation of a benefit tax can be identified, named the benefit-absorbing tax, reflecting a particular notion of the distributive incidence of public goods[16]. A benefit-absorbing tax represents a tax adjustment that, for each level of income, fully absorbs the benefits of the public good, leaving each individual indifferent between not having the good and having it while being subject to the foregoing tax adjustment. Thus, the incidence of the benefit-absorbing tax adjustment will be progressive (or otherwise) precisely to the extent that the incidence of the public good being financed is progressive (or otherwise).

Before asking who bears direct and indirect costs of taxation and enjoy its benefits, some issue regarding taxation allocation and its criteria should be taken into account. Optimal taxation is intended to be a guide to policy-making and its basic idea is answering to questions as what should be optimised and which constraints should be considered. Economists have frequently tried to describe desirable characteristics of tax systems. Smith (1776) listed “four maxims with regard to taxes in general’: tax payments should be in proportion to income (equality); tax liabilities should be clear and certain (certainty); taxes should be collected at a time and in a manner convenient for taxpayers (convenience of payment); taxes should not be expensive to collect, and should not discourage business (economy in collection). In particular, the second and third points have not been widely discussed in economics literature, perhaps because they are self-evidently desirable. Differently, the first and the last maxims have absorbed the main interest. The idea of equality has been widely discussed – there are many differing views on what constitutes a fair distribution of tax burden – and it is still a major part of any tax policy proposal evaluation. Many authors have handled the issue linked to administrative costs and effects on incentives (the discouragement of business). Taxation proposals have therefore frequently been analysed in terms of three criteria: 1) the need for taxes to be fair; 2) the need to minimize administrative costs; 3) the need to minimize disincentive effects.

The difficulty with having three separate criteria is that a particular policy proposal will typically satisfy one criterion but not another. The approach of the optimal taxation literature is represented by using economic analysis to combine these criteria into one, implicitly deriving the relative weights that should be applied to each criterion. This is done by using the concepts of individual (or household) utility and social welfare.

Social welfare is considered an indicator of the well-being of society and it is assumed to depend on the utility of individuals: it is not simply given by the sum of individual utilities, but it also depends on how equally these utilities are distributed. Assumed that social

[16] The benefit-absorbing tax is related (but not equivalent) to the idea of Lindahl pricing, and it differs more substantially from some other formulations of benefit taxation.

welfare decreases as inequality of utility increases, the concept of social welfare reflects the idea of fairness in the tax system. Social welfare reflects criterion 2), in fact high administrative costs require a greater amount of gross tax revenue to finance government services and this reduces utility. Criterion 3) is also incorporated, since the discouragement of work would lower individual utility and hence social welfare. In this way, the three criteria are converted to aspects of social welfare and they become commensurable, and the policy that should be chosen is the one that gives the highest level of social welfare. Since it is quite difficult to model the relationship between tax rates and administrative costs, attention has been typically devoted on finding tax systems that will provide the best compromise between equality and efficiency (criteria 1) and 3)). These same basic ideas have also been applied to the study of tax reforms, where the aim is to identify whether specific tax changes will raise social welfare. There is clearly a close connection between the analysis of optimal taxation and tax reforms: an optimal tax system is one in which there are no possible reforms that will increase welfare (Ahmad and Stern, 1984).

Several arguments justify looking at utility functions rather than measuring people welfare by their real after-tax incomes. In particular, when taxes are levied on consumption goods, relative prices will change and consumers will respond by changing their consumption patterns. This should result in a change in weights used in the price index that converts nominal to real income. It is not possible to ensure that weights change properly without any knowledge of consumer preferences as represented by a utility function. It is then more convenient to use the utility function directly. The effect of a tax change can be divided into an income effect and a substitution effect, just as in the standard economic analysis of price changes. The income effect of a tax increase is represented by a reduction in after-tax income and an increase in the individual’s labour supply, trying to compensate the reduction in consumption. The substitution effect consists in a reduction of marginal return, thus leads to a reduction in labour supply. Then, the effect of an income tax increase on labour supply could be in either direction, depending on which effect is stronger. However, in revenue-neutral tax changes the average taxpayer does not have an income effect, and only the substitution effect operates. The dominance of the substitution effect that results from revenue neutrality leads to a general emphasis on the compensated elasticities of supply and demand in the evaluation of the distortionary effects of taxation (Heady, 1993).

The literature on optimal commodity taxation is mainly concerned with the design of final sales taxes, such as value added tax and the excise taxes on alcohol, tobacco and petrol; it also deals with the taxation of intermediate goods and international trade, and it can be used to analyse the taxation of savings. The first analysis of optimal sales taxes was undertaken by Ramsey (1927) and he considerably inspired the literature on optimal income taxation, even focusing on a rather different question: designing sales taxes to raise a given amount of revenue at the least possible distortionary cost. Ramsey showed that, when only a very small amount of revenue had to be raised, the taxes should produce equal proportional reductions in the consumption of each good. He then argued that this result continued to hold, even for substantial revenue requirements, if there were no income effects and if the demand curves for the goods were linear, conditions unlikely to hold in practice. A direct indication of which goods should be most heavily taxed can be obtained by making an additional simplifying assumption: the demand for each good is independent from the prices of other goods. He stated that a uniform *ad valorem* tax on all forms of consumption and on leisure would work like a non-distortionary lump sum tax on the value of the consumer's exogenous time endowment. Since governments cannot observe and tax the consumption of leisure, any real-world tax system will tend to cause distortionary substitution towards leisure. Ramsey derived the inverse elasticity rule: goods with more price-inelastic demands should be taxed more heavily and in this way the optimal tax system distorts quantities as little as possible. According to this rule, the optimal commodity tax system causes an equi-proportionate reduction of the compensated demands for all goods and services. This rule needs considerable revision when income inequality is taken into consideration. However, the rule has had wide influence and its logic is probably partly responsible for the high taxation of alcohol, tobacco and petrol all over the world. Corlett and Hague (1953) adopted a different perspective: they looked at a situation where there are two consumption goods taxed at the same rate and they asked whether efficiency could be improved by introducing some non-uniformity (raising the tax on one good and lowering the tax on the other). They showed that the commodity which is less substitutable for leisure should carry a relatively high tax burden in order to offset the tendency of the tax system to induce substitution towards leisure. Then, uniform taxation is optimal only in the special case where goods and services not differ in their degree of complementarity or substitutability with leisure. Atkinson and Stiglitz (1976) showed that it is not optimal to differentiate taxes across commodities if the government can use a non-linear labour income tax. The intuition behind this important result is clear: when all commodities are equally substitutable for leisure, there is no second-best efficiency case for distorting the choice between them in order to offset the labour-leisure distortion. In this sense, there is no equity case for imposing differentiated taxes, since a labour income tax would be the better-targeted instrument for redistribution under the hypothesis that innate differences in labour productivity are the only source of inequality.

The next major step in the development of the theory of optimal commodity taxation came with the analysis of an economy with inequality by Diamond and Mirrlees (1971). They showed that the introduction of distributional considerations alters the equal proportional reductions rule substantially. The most significant alteration is that goods which are consumed particularly heavily by the poor should experience a lower-than-average proportional reduction. In the case of independent demands, Diamond and Mirrlees results show that the optimal tax rate on a good should depends not only on the inverse of its price elasticity of demand, but also on its income elasticity. The significance of this modification can be appreciated when one notes that many goods with low price elasticities also have low income elasticities, for example in the case of necessity goods. The major results on whether differential sales taxes are desirable in an economy where households differ only in their incomes and not in their underlying preferences are shown in Atkinson and Stiglitz (1980). An important aspect of their analysis is the role of the uniform payment to all households (or the income tax exemption level). If all goods are normal, in the sense of being consumed in larger quantities by people with higher incomes, the poor will always benefit more by an increase in the uniform payment than by an equivalent reduction of the sales tax. With regard to the question of whether differential sales taxes will reduce the disincentive effect on labour supply of an income tax, the answer depends on differences in the degree of complementarity between individual goods and leisure. An obvious difficulty that arises in attempting to apply the Atkinson and Stiglitz results is that their model ignores differences in preferences that might arise from differences in households demographic characteristics. Deaton and Stern (1986) develop the idea according to which the direct payments to households are more efficient in order to accomplish redistribution among different groups if compared to the interventions on sales tax rates, which remain the best solution to deal with problems of efficiency. They show that uniform taxation is still desirable if preferences are weakly separable and if households in each demographic group receive an optimally chosen payment, which is uniform within each group but differs between groups.

Sorensen (2007) focuses on the implications of optimal tax theory for the controversy on whether taxes should be uniform or whether – even in the absence of externalities – they should systematically discriminate between different economic activities. In the Ramsey framework, examining whether indirect taxes should be differentiated is equivalent to asking whether the labour income tax should be supplemented by selective commodity taxes. When production or consumption of commodities implies externalities, differentiated Pigouvian taxes or subsidies are widely imposed; on the other hand, in absence of externalities there is much less agreement. Even if strong administrative and political economy arguments still favour uniform taxation, recent advances in optimal tax theory suggest that the information needed to implement differentiated taxation may be easier to obtain than previously believed. Since governments find it difficult to collect the information and have not the administrative capacity to implement differentiated taxes on specific goods and services, they ultimately prefer uniform commodity taxation. Sorensen argues that once one accounts explicitly for the coexistence of household and market production, it becomes easier to identify the specific commodities that are candidates for special treatment under an optimal indirect tax system.

The classical analyses by Ramsey (1927) and Corlett and Hague (1953), together with their modern generalizations, seem to provide support for non-uniform commodity taxation. At the same time, they identify obvious practical obstacles to the implementation of an optimal commodity tax system: very little is known about the size and the sign of the compensated cross-price elasticities between leisure and the various goods and services, so the empirical basis for differentiating indirect taxes is very weak. Moreover, policy advisers typically stress three other points. The first one is that uniform taxation is much easier to administer and much less susceptible to fraud; second a commodity tax system differentiated according to Ramsey principles would require frequent changes in tax rates in response to changes in tastes and technologies, adding risk and uncertainty into the tax system and hampering long-term planning and investment. A third point is that acceptance of differentiated taxation might constitute an incentive for interest groups to lobby for low tax rates.

Then, there appears to be a strong case for uniformity in indirect taxation, except for areas with an obvious need for internalisation of externalities. However, once one allows for household production, the case for uniform taxation is weakened considerably (Sorensen, 2007). Productive activities within the household, which almost always depend on market production of goods, take the form of production of services and represent very close substitutes for services that may also be delivered from the market. Furthermore, a high tax on complements to leisure may not be an efficient way of stimulating tax-discouraged labour supply to the market when such a commodity tax encourages substitution of home production for market production: in fact, taxes should distort the pattern of market activity as little as possible. When goods and services are equally substitutable for leisure (entering into a homothetic sub-utility function), so that uniform taxation would be optimal in the absence of home production, services should definitely be taxed at a lower rate than goods when they can be produced in the household sector as well as in the market. Kleven (2004) developed an inverse factor share rule, stating that the optimal tax rate on a given commodity is inversely related to the share of commodity input in total factor input required in the relevant household production activity. Moreover, he states that the larger the time input relative to total factor input into some household activity, the higher is the optimal tax rate on the commodity input into this activity. Then, the optimal tax system imposes relatively high tax rates on commodities whose consumption requires a large input of household time. In this way the optimal tax system minimizes the amount of time that is diverted from market work to consumption activity within the household sector. At a basic level this is coherent with the conventional Ramsey approach: tax policy should aim to minimize tax-induced substitution towards non-taxable uses of time. From a practical perspective, an interesting insight from Kleven's approach is that the optimal tax policy depends solely on observable factor shares rather than on unobservable compensated price elasticities. Even if a number of goods and services ca not be taxed, Kleven's analysis suggests that data on the allocation of household time can help policy makers to determine a rational structure of indirect taxation.

2.1.2 Marginal cost of funds measures

Summary measures such as the marginal cost of funds (MCF) are important for two reasons. First, they are useful for assessing tax reforms on particular public goods: in particular, they provide a framework which enables to decentralize policy analysis, without needing access to a complete model of the economy. Second, they facilitate sensitivity analysis for particular projects. Intuitively, the MCF measures the inefficiency of tax policy, as it generally costs more than a dollar of private income to raise fiscal revenue by one dollar. In fact, relevant questions for government policy makers are what public goods, in what quantities, they should provide, and what level and mix of taxes they should use to pay for them. Differences in approaches dealing with the income effects of taxation used to finance spending on public goods could lead to substantial differences in policy conclusions. Stiglitz and Dasgupta (1971) and Atkinson and Stern (1974) identified a previously-ignored income effect as a potentially important influence on the costs of labour taxes used to provide public goods. The intuition is the following: leisure is a normal good, raising taxes reduces disposable incomes and hence the demand for leisure, increasing the supply of taxed labour. The estimates of the marginal cost of funds raised for the provision of public goods should take these income effects of taxation into account. Mayshar (1990) suggested an approach which measures compensated impacts on consumer welfare via an expenditure function, but uses uncompensated government revenue by including the effects of tax-induced income changes on consumption or supply of taxed goods: in a similar framework, the marginal income gains from provision of public goods is clearly omitted. On the contrary, many studies shifted from traditional approaches to the marginal cost of funds (Browning, 1976; 1987), based purely on compensated responses. Atkinson and Stern (1974), Auerbach (1985) and Ballard and Fullerton (1992) suggest that the income effects associated with raising taxes may reduce the social costs of taxes on labour and hence expand the range of public goods optimally provided by governments.

Ballard (1990), Mayshar (1990), Creedy (2000) and others have argued that the approach used to calculate the costs of taxes used for public goods provision should differ from that used for evaluating balanced-budget changes in tax rates. Under this view, two different MCF measures are needed, depending upon the type of policy measure examined. This approach could be potentially misleading, especially since the ultimate uses of the funds raised may not be known when they are raised. Anderson and Martin (2007) highlight that the relevant issue is to treat symmetrically the income effects resulting from public good provision with those associated with tax financing.

The compensated MCF measures are preferable because they allow for potential compensating international transfers. In this context, they measure the actual transfer from outside the system to the private sector that would have the same effect on welfare as the combination of the change in public good provision and in the taxes needed to finance their provision. Given that the compensated measures can be used for differential-incidence problems in which taxes are changed while holding government revenue constant (Ballard, 1990), the compensated MCF can be used for both differential-incidence and balanced-budget analysis.

Here I want to give a brief overview of some incidence measures proposed by the literature on the marginal cost of funds. The aim of studies on the welfare change caused by actual or hypothetical taxation reforms is to provide a money measure of the change in welfare faced by different types of individuals when prices change. Changes in commodity or income taxation give rise to the concept of excess burden resulting from taxation, that measures the cost of not being able to impose lump sum taxes. Alternative concepts of excess burden arise, depending on whether compensating or equivalent variations are used; moreover approximations which do not require the form of the utility or expenditure function to be known can be used, needing only elasticities evaluated at current consumption levels (Creedy, 2000).

A comparison with respect to the absence of taxes can be developed considering the amount, in excess of taxation paid, that the individual would give up to have all taxes removed. This approach gives an excess burden, B_E, based on the equivalent variation, as

$$B_E = EV - R(p^1, x^1) \tag{2.1}$$

where $R(p^1,x^1)$ is the revenue collected from the individual with budget x at the post-tax prices p^1. In the case of taxes per unit of output t_i (such as the excise taxes), this is given by

$$R(p^1, x^1) = \sum_{i=1}^{n} t_i q_i (p_i^1, x^1) \tag{2.2}$$

where q denotes Marshallian demand. Alternatively, excess burden may be defined in terms of the amount, in addition to the revenue collected from the individual, that would be needed to keep utility at the pre-tax level.

This gives a burden, B_C, based on the compensating variation, as follows:

$$B_C = CV - R(p^1, c(p^1, u^0)) \tag{2.3}$$

The revenue subtracted from the CV is higher than in (2.2) because it arises from the compensation involved in maintaining utility at u^0. The relationship between the Marshallian (q) and Hicksian (h) demand curves is such that

$$q(p, x) = q(p, c(p,u)) = h(p,u) \tag{2.4}$$

Hence the revenue in (2.3) can be written as

$$R(p^1, c(p^1, u^0)) = \sum_{i=1}^{n} t_i h_i (p_i^1, u^0) \tag{2.5}$$

Equations (2.4) and (2.5) highlight the role of the Hicksian demands in obtaining raised revenue; given its relevance also in computing EV and CV, the excess burden with a single tax could be relevant even if the taxed good in question has a low uncompensated own-price elasticity of demand, because of the substitution effects which arise in response to tax reforms.

An approach to measurement difficulties, bypassing the requirement of detailed information on utility or expenditure function, is computing an approximation of welfare changes. For example, taking a Taylor series expansion of $c(p^1, u) - c(p^0, u)$ and neglecting the third and higher order terms gives

$$c(p^1,u)-c(p^0,u)=\sum_{i=1}^{n}\frac{\partial c}{\partial p_i}+\frac{1}{2}\sum_{i=1}^{n}\sum_{i=1}^{n}\frac{\partial^2 c}{\partial p_i \partial p_j}dp_i dp_j \tag{2.6}$$

The tax revenue can be expressed, using $dp_i=p_i^1-p_i^0$, as

$$\sum_{i=1}^{n} q_i dp_i = \sum_{i=1}^{n}\frac{\partial c}{\partial p_i}dp_i \tag{2.7}$$

which is the same as the first term in (2.6). Hence the excess burden is approximated by

$$B=\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} s_{ij}dp_i dp_j \tag{2.8}$$

where s_{ij} is the *i, jth* element of the symmetric matrix *S*, with $s_{ij}=\partial x_i^H/\partial p_j=\partial^2 c(p,u)/\partial p_i \partial p_j$; this is called the Slutsky matrix. This enables the excess burden to be approximated without knowing the precise form of the utility function, so long as estimates of compensated changes are available. Furthermore, for such small changes there is no distinction between the burden defined in terms of compensated and equivalent variation. The use of this method makes the calculation of excess burdens relatively quick: in fact, very often the elasticities to compute the approximations of excess burden are taken from demand studies. This approach clearly implies the disadvantage that often elasticities are computed under a high level of aggregation and they are not enough differentiated in order express the individual response to price changes. The introduction of demographic variables in demand systems estimation or their translation (see Paragraph 3.4) could represent potential solutions in order to solve this limitation.

2.2 The double dividend hypothesis

In order to analyse the overall distributive impact of an environmental tax it should be considered that its benefits are given by the possibility of gaining a double dividend: obtaining improvements in environmental quality and, at the same time, a reduction in other existing distortionary taxes increases the appeal of taxes in comparison with other environmental policy tools. Empirical investigations of the potential importance of double dividend date to the early 1990s, in connection with growing concern on climate changing. They used several different types of models and had widely varying results. In particular, many simulations exploring the double dividend in Computable General Equilibrium (CGE) models were carried out in this period (Nordic Council, 2006). The difficulty with these studies is that they are highly dependent on parameters which are included as exogenous by researchers. Technology, in particular, is a crucial parameter which is not well captured in such models. Also the scope for improved efficiency by means of changes in production factors use is often assumed, away by neoclassical theory's assumption of optimality and rationality in firm management.

If the government aims at two objectives, it should in principle employ two instruments. Conceptually, therefore, one can view a green tax reform aimed at reaping a double dividend as consisting of two separate policies. One policy is aimed at improving the quality of the environment, the other one is targeted at the non-environmental objective. While efficient environmental improvements presumably constitute the basic dividend from the use of market-based instruments, there has been a great deal of attention paid to the second dividend. One can list some restrictive conditions whose verification determines the double dividend existence: the presence of some distorsive taxes; the incidence of environmental tax falls on a factor fixed and produces a limited excess burden; a large tax base; substitutability between factors; wages are rigid (then a reduction in social contribution will diminish labour cost and will increase employment); translation on consumption is reduced; political acceptability, also at international level (in particular coordination is needed, in order to handle competitive issues).

The possibility of lowering labour taxes, when environment assets are factored in, exists both with environmental taxes and with the auctioning of emissions trading permits. Obtaining a double dividend requires careful consideration of the revenue recycling method. The most straightforward method is to recycle revenue by lowering social security contributions paid by employers and employees. However, a tax interaction effect may occur as the increase in energy prices causes employees either to lower labour supply or demand higher salaries in compensation, with the result that a double dividend in terms of an increase in employment will not emerge. Certainly, an excess burden is also attributable to environmental taxation, in particular through indirect effect on others economic variables. Environmental policies enhance welfare by reducing pollution, but they can reduce it by discouraging labour supply: the net welfare change depends on the relative size of these two impacts. In reality, this negative tax interaction effect occurs mainly in stylised analyses, where distortions in current tax system are not taken into consideration; for example, the presumption of negative labour supply elasticity is not confirmed in Nordic studies (Nordic Council, 2006).

The double dividend argument suggests that one may wish to push the role of environmental taxes beyond that of solely an instrument for environmental protection and employ them also as a revenue-raising device to cut distortionary taxes. On the contrary, Bovenberg and de Mooij (1994) demonstrate that environmental taxes, by driving up the price of (polluting) goods relative to leisure, tend to compound the distortions caused by taxes in labour markets, producing a negative welfare impact termed the tax-interaction effect. They demonstrate that, in the presence of pre-existing distortionary taxes, the optimal pollution tax typically lies below the Pigovian tax (which fully internalizes the adverse external effects of pollution) because of the competition between the collective good of environmental quality and other collective goods. Hence, when we are not in the first best case (in which there is no need to finance public spending through distortionary taxation) the marginal costs of environmental policy rise with the marginal cost of public funds. At the Pigovian tax rate, the environmental benefits associated with less dirty consumption would exactly offset the adverse welfare effects due to an erosion of the tax base. Moreover, changes in employment would not affect welfare: in absence of distortionary labour taxation, the social opportunity costs of additional employment exactly offset the social benefits. Differently, in presence of a distortionary tax on labour, the optimal environmental tax depends on employment response to a change in the tax mix. A drop in the real after-tax wage comes about because the lower tax rate on labour income does not fully compensate workers for the adverse effect of the pollution levy on their real after-tax wage. The offset is only partial because of erosion of the environmental tax base: in fact, the higher environmental tax induces households to switch to cleaner consumption commodities and this behavioural effect erodes the environmental tax base, producing a negative tax-base effect. Given a fixed before-tax wage, the real after-tax wage falls if the tax base erodes: if the government needs to maintain overall tax revenue, then it is unable to reduce the labour tax sufficiently to offset the adverse effect on the real after-tax wage. The resulting lower income from an additional unit of work, if the labour-supply curve is upward-sloping, erodes the incentives to supply labour. Then, positive uncompensated wage elasticity determines that distortionary labour taxes raise the marginal cost of environmental protection above its social benefit. This result depends on the separability assumptions regarding utility function. Private goods are weakly separable from public goods (environmental quality and public consumption), that do not directly affect private demand. Then clean and dirty consumption are aggregated by a homothetic sub-utility function into a composite consumption good. If environmental quality was a closer substitute for private consumption than for leisure, a heavier reliance on environmental taxes would imply smaller income effects on labour supply. The government can use the revenue from pollution taxes to cut labour taxes or to raise lump-sum transfers. In the last case the associated higher levels of distortionary taxation and transfers imply that employment would decline more than in the case in which labour taxes are cut. The lower level of employment erodes the base of the labour tax, thereby further worsening pre-existing tax distortions. In the presence of distortionary taxes, therefore, pollution taxes become more attractive if the revenue is not recycled in a lump-sum fashion, but rather they are used to cut distortionary taxes.

Furthermore, relative tax distortions play an important role in this result: revenue recycling through a tax cut can be welfare worsening relatively to lump-sum recycling if the tax cut increases relative distortion between energy and other consumption goods (by reducing existing taxes on these goods). For this reason, Babiker et al. (2003) find out opposite results with respect to Bovenberg and de Mooij (1994); they observe that the weak double dividend does not hold unambiguously, because of relative tax distortions. This suggests that a careful assessment of which distortions to reduce is necessary or one can do worse than lump-sum recycling. The authors demonstrate the weak double dividend is unlikely to hold for a number of European countries, result that can be traced to the high existing energy taxes in most European countries. Placing a carbon constraint on top of existing fuel taxes raises the effective tax on fuels: then, redistributing the revenue by reducing existing taxes on non-energy consumption goods further worsens the relative distortions between energy and these other consumption goods. This result shows that the interplay between carbon policies and pre-existing taxes can differ markedly across countries, depending greatly on the existing levels of different distortionary taxes existing in an economy. Much of the empirical evidence on the double dividend has been drawn from the USA where energy taxes are very low compared to most other developed countries and they are, therefore, particularly unlikely to apply elsewhere (Babiker et al., 2003). In fact, many developed countries heavily tax consumption of fuels whereas fuels prices are often subsidized in developing countries as a means of making energy affordable to consumers. As both energy taxes and carbon constraints directly affect fuel use, it is perhaps not surprising that correctly representing distortions in these markets is essential to rightly evaluate the economic impacts of climate policy. One must be cautious in extrapolating the results from a country specific analysis to other countries, and one must accurately represent existing distortions in energy markets to accurately estimate the economic impacts of climate and fiscal policy.

2.3 The incidence analysis

The paragraph devoted to incidence analysis, given its significance for the estimation of the distributional welfare effects, is divided into four sub-paragraphs. Paragraph 2.3.1 describes the different options available for welfare measurement, namely the choice between lifetime income, current income or consumption. An overview of the tax incidence concept is provided in Paragraph 2.3.2, while Paragraph 2.3.3 goes into details of the incidence measurement in terms of equivalent variation, compensating variation and consumer surplus. Finally. Paragraph 2.3.4 briefly synthesizes the issues related to social welfare measurement and Paragraph 2.3.5 synthesize the equivalence scales theory, with particular focus on their relevance as devices to perform welfare comparisons.

2.3.1 Welfare measurement

The analysis of the distributional effects of environmental policies implies some reflections linked to different welfare measures and wealth proxies that could be employed. Different options can be applied, including household current income, household life time income, household expenditures or expanded notions of wealth. In principle. lifetime income is a better measure of individual welfare than current income. Some categories of individuals may be not poor in a lifetime context given their high, expected future earnings; in addition, a reasonably well-off person may appear poor in a particular year due to transitory factors, such as temporary unemployment or illness. In order to measure household income, lifetime income could be a better proxy of individual well being than current income: it's in fact designed to remove the confounding effects of similar people at different stages of their lifecycle.

When the effects of policies last more than one period – even if inter-temporal separability holds – a static analysis of the household's welfare could give a misleading picture. The bias associated with static welfare analysis has been demonstrated empirically by Poterba (1989; 1991), in his examination of the incidence of indirect taxes. He showed that when the distribution of the tax burden is measured using current income as a proxy for household welfare, indirect taxes appear more regressive than when welfare is measured using household consumption (which approximates permanent income). This suggests that significant errors can be made by ignoring the "lifetime incidence" of policies.

However, lifetime income is far more difficult to measure than current income, as it requires tracking households over extremely long time periods: it can be measured through econometric methods relating income to education, age, and other demographic variables, or proxied by annual consumption (Poterba, 1989). As discussed in Kriström (2003), the definition retained may affect the results regarding environmental policy regressivity. Metcalf (1999), surveying some studies which employ lifetime income measures, shows that tax regressive impacts are more limited in a lifetime context. Given the controversy surrounding income measurement, studies often have adopted alternative measurement options, such as consumption, assuming that income was better proxied by household expenditure. Consumption is a better indicator of welfare than annual income and using it the value of welfare loss from the policy change can be scaled. University students and retired people, for example, may have very low incomes but high levels of consumption, and thus high welfare; on the contrary, working households can maintain levels of welfare in the face of temporary reductions in income by taking money from savings or by borrowing.

Moreover, in a static context the appropriate welfare indicator should be a function of total expenditure rather than income. The permanent income and life cycle hypotheses suggest that current (i.e. annual) income is likely to be an inaccurate proxy for the standard of living because of inter-temporal consumption smoothing. Households with temporarily low incomes can have high levels of total expenditure through borrowing, and then exhibit high consumption to income ratios; differently, the reverse can hold for households with unusually high incomes. The biases associated with household income as welfare measure arise from the omission of price and demographic effects in measuring welfare. An implication of the permanent income hypothesis is that the distribution of total expenditure is quite different from the distribution of income. Households with low incomes are disproportionately represented by those with temporary reductions in current income, whereas households with high income levels are over-represented by those with transitory increases in income; other things equal, one would expect less dispersion in the distribution of total expenditure relatively to the income distribution. For example, Slesnick (1994) has found that the expenditure distribution is more equally distributed than the income distribution in the USA, and it exhibits substantially less movement over time.

For these reasons, and since the *Indagine sui consumi delle famiglie* contains detailed and accurate data on household expenditure, I use total consumption expenditures as the proxy of welfare. As the welfare measure used is a critical determinant of incidence, so does the choice of unit of analysis. Any study that adopts the family as the unit of analysis is clearly more comparable to a lifetime approach than one that adopts the individual. The kind of taxation I examine, levied on goods whose consumption is rarely on an individual basis (only in case of one-adult household), allows to identify households as the more suitable unit of analysis: most studies on this subject in fact employ household expenditure.

2.3.2 The incidence concept

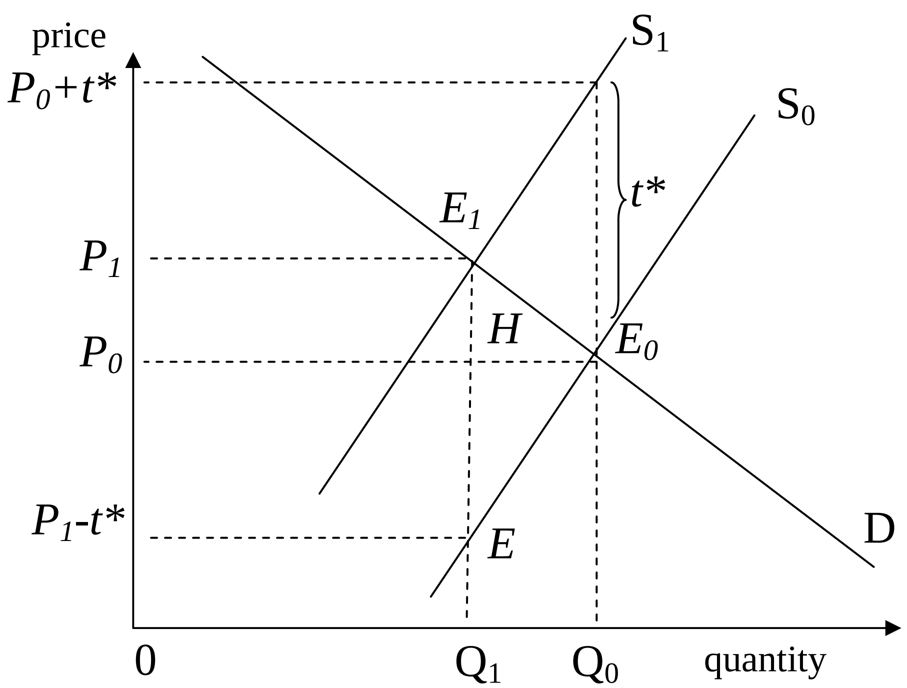
Taxation has many different economic effects, both on micro and macro level: effects on the distribution of income and the efficiency of resource use belong to the first group, whereas effects on the level of output, employment, prices and growth to the second one. Clearly, all these effects are interdependent and, for example, the distributional effects of a particular budget measure are likely to be linked to its effects on employment or output. Furthermore, a policy could be preferable with respect to its distributional outcomes but not with respect to its efficiency results.

Dealing with the distributional effects, tax incidence refers to the way in which the taxation burden is shared among households. The overall burden imposed to the private sector tends to exceed the amount of revenue collected, because the tax interacts with consumer's choices, distorting expenditure patterns: this additional burden constitutes the excess burden or deadweight loss. Input effects (change in factor supply and then in total output) and employment effects (linked to aggregate demand changes) constitute other reasons why tax revenue and total burden (measured by the loss of income for private use) may differ.

Two distinct kinds of tax incidence can be distinguished (Musgrave and Musgrave, 1989). The statutory incidence refers to the legal obligation, namely the person on whom the legal liability for payment rests. Although this statute in the end is a reflection of voter's preferences, once legislated the individual taxpayer will try to avoid or to pass the burden on to other. After this process of shifting, the second concept of incidence can be defined: the economic incidence indicates how the economic supply and demand conditions in the market for the taxed item determine the final distribution of the tax burden among suppliers and consumers. After this first distinction, there are three ways in which the problem of incidence may be viewed, namely as absolute, differential or budget incidence. The absolute tax incidence examines the distributional effects of imposing a particular tax while holding public expenditure constant, without taking into account the macro effects which follow from the resulting decline in aggregate demand. The differential tax incidence broads this view and analyses the distributional changes which result if one tax is substituted for another while total revenue and expenditure are held constant. Finally, the budget incidence considers the changes in household income resulting from the combined effects of tax and expenditure changes. My incidence analysis, since it follows from demand system estimation, does not take into account the role of government and is not associated to an input-output approach; then, an absolute tax incidence approach is adopted.

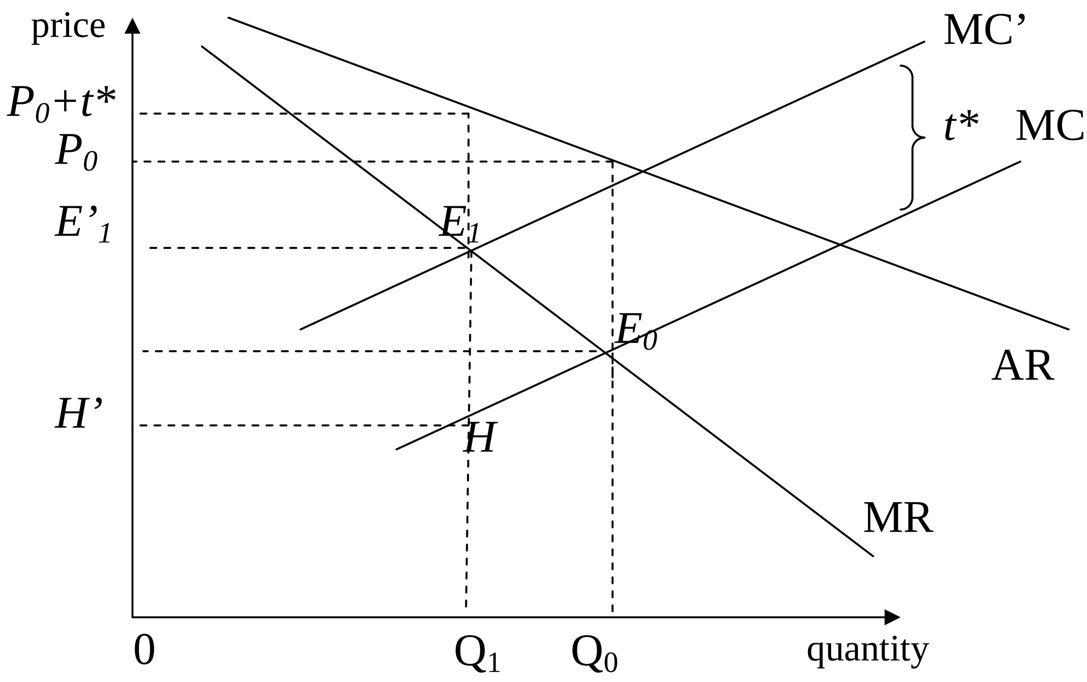
To summarize, the final incidence, or burden distribution, will depend on how the tax is imposed initially, what rate structure is used, how the basis is defined and how general is its coverage. In the end, economic incidence depends on conditions of demand and supply, on the structure of markets, and the time period allowed for adjustments to occur. Adjustments to a tax will cause factor and product prices to change, and these changes will affect households from both the sources and uses sides of their accounts, thus determining the burden distribution among them. The final outcome depends on the interaction of these changes in a general equilibrium system. However, I will adopt a partial equilibrium approach, only considering what happens in the marked of the taxed inputs and not taking into account the impacts of the introduction of carbon taxation on other markets.

Figure 2.1 – The division of the tax burden in a competitive market



Examining Figure 2.1, the tax burden is $P_1E_1P_1$-t^*E: this burden is shared by buyers and sellers, such that the buyer pays $P_1E_1P_0H$ and the seller P_0H P_1-t^*E. The former area reflects the additional amount which the buyers must pay for quantity OQ_1, compared with what they would have paid at the old price. The latter, similarly, reflects the smaller amount which the sellers receive in net income for the sale of OQ_1, compared with what they would have received before. This approach suggests an important rule – namely, that the burden of the tax is divided between buyer and seller as the ratio of elasticity of supply to elasticity of demand in the relevant range of the demand and supply schedules[17]. If the demand is inelastic and the supply is elastic, the tax tends to fall on consumers; on the other hand, when the opposite conditions hold the tax mainly fall on producers. Then, in examining a product tax incidence, the elasticity of demand and supply plays a key role in determining which set of conditions applies. Moreover, since markets are not perfect, imperfections must be allowed for. While Figure 2.1 shows the adjustment to a unit tax in a competitive market, in Figure 2.2 is depicted the price adjustment in a monopolistic market. *AR* and *MR* represent respectively the average and marginal revenue schedules before tax, and *MC* is the marginal cost schedule.

Figure 2.2 – The division of the tax burden in a monopolistic market



Output is set at the intersection of *MC* and MR and equals OQ_0, while price equals OP_0. As the unit tax of amount t^* is imposed, the *MC* schedule shifts up to *MC'*. Output falls to OQ_1 and the price rise P_0 P_0+t^* falls short the unit tax t^*. The tax revenue equals

[17] It is worth to be mentioned that this is not a wholly satisfactory way of looking at the tax burden and its division, since the problems linked to the excess burden are not taken into account. In fact, if taxes are to be related to ability to pay – then based on economic indices such as income, consumption or wealth – they are likely to interfere with economic activity and distort efficient choice (Musgrave and Musgrave, 1989).

$E_1'EH_1'H$ and, as in the competitive case, the resulting changes in output, price, and revenue depend on the elasticities of demand and supply. Another particular process of price adjustments arises in an oligopoly context. Here prices and output are not set in the traditional profit maximizing manner. The price tends to be established by the price leader in the industry: in fact, each other firm does not raise the price for fear of loosing its sales and it does not try to undercut the price, in order to avoid that its competitor follow suit. In such a situation, an increase in the tax rate may act as a signal to firms to raise the price in concert: since each firm has reason to expect that the others will act similarly, it can raise price without concern for its competitive position. The energy products market is well represented by an oligopolistic market, and for this reason the hypothesis of complete translation on consumers prices of carbon taxation is reasonable.

An excise tax might be called either a consumer-level tax (e.g., the gasoline excise tax, collected at the pump) or a producer-level tax (e.g., the alcohol and tobacco taxes, collected from manufacturers), but this is not enough to identify on whom it impacts. As the Figure 2.1 shows, the distinction could not reflect the economic division of the tax burden: consumers and producers are both affected to some degree, regardless of the statutory label. How they share the burden of the tax depends entirely on their responsiveness to the price changes, the slopes of the supply and demand curves, and the market structure.

My choice to examine the impact of carbon taxation on household consumption is linked to the hypothesis that the firms pass all abatement costs – in the specific energy products case represented by excise augmentation – into prices, and therefore consumers ultimately bear the full burden of this costs. The assumption of full pass through of abatement costs is reasonable given that the market of oil products, such as fuels and heating fuels, can be considered oligopolistic, then the firms are price makers. Thus, a carbon tax can be hypothesised to be fully shifted forward to consumers. Shifting occurs directly, as fuel producers raise their prices to account for the tax, and indirectly, as all producers raise their prices to cover the increased cost of fuels and other inputs. In the end, each product’s price rises in proportion to its direct and indirect use of the taxed fuel. Because of lack of data, my distributive analysis will not use an input-output approach, only being devoted to the examination of the direct component.

2.3.3 Incidence measurement

I want to specify that, according to the tradition to carry out the distributive analysis in utility terms, my model will simulate the effects on household consumptions and will estimate related distributive impacts in terms of some measures of incidence, represented by compensating and equivalent variation, both defined in utility terms. In the empirical analysis, it has relevant importance to provide a quantitative measure of welfare changes linked to market intervention. For this purpose, the measures generally used are represented by Equivalent Variation (EV), Compensating Variation (CV) and Consumer Surplus (CS) which, differently form the previous ones, is only an approximation of the really occurred welfare change.

Welfare changes evaluation is based on building indicators of utility: in this context, cost functions represent a useful tools because, given some prices, they measure the minimum expenditure necessary to achieve a given utility level. In particular, given $e(\bar{p}, v(p,x))$, where $\bar{p}$ are constant prices and *v(p,x)* is the utility level (correspondent to prices $\bar{p}$), let consider a price change from p^0 to p^1. These two vectors of prices define two utility levels, given by $u^0 = v(p^0,x)$ and $u^1 = v(p^1,x)$. Starting from here, *u* will always indicate utility, *p* vector of prices, *w* budget shares, *q* quantity consumed and *x* total expenditure (or income, proxied by it).

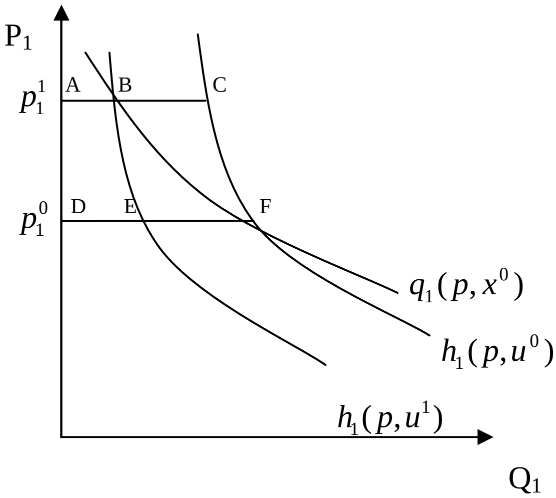
By taking as the reference price vector alternatively p^0 or p^1, respectively EV and CV can be constructed:

$$EV(p^0, p^1, x) = e(p^0, v(p^1, x)) - e(p^0, v(p^0, x)) = c(p^0, u^1) - c(p^0, u^0) = c(p^0, u^1) - x \quad (2.9)$$

$$CV(p^0, p^1, x) = e(p^1, v(p^1, x)) - e(p^1, v(p^0, x)) = c(p^1, u^1) - c(p^1, u^0) = x - c(p^1, u^0) \quad (2.10)$$

EV can be interpreted as the maximum amount by which a consumer would have to be compensated before a price change in order to reach the same welfare level as with the price change. Conversely, CV is defined as the minimum amount by which a consumer would have to be compensated after a price change in order to reach the same welfare level as before. Both of them are expressed as the difference in costs of reaching the same utility level at two different price vectors, so they are not a ratio but simply a sum of money. These two measures also have an interpretation in terms of compensated demand (or Hicksian demand) functions: in the case of EV the relevant demand curve is $h(p,u^1)$, referred to final utility level, whereas in the case of CV is $h(p,u^0)$, referred to initial utility level. If a market intervention embed a price change only relatively to a good, that is only $p_i^1 \neq p_i^0$ and other prices remain equal ($p_k^1 = p_k^0$ for $i \neq k$), then EV and CV have a straightforward graphical interpretation. In order to compute them, one has to make reference to the price before or after the change on the Hicksian demand curve. They are represented by the surfaces ABED (EV) and ACFD (CV). This clearly shows that they can be different and provide a different information about welfare effects.

Figure 2.3 – Equivalent variation, compensating variation and consumer surplus



More precisely, EV and CV are respectively given by

$$EV(p^0,p^1,x)=\int_{p_i^0}^{p_i^1} h_i(p,u^1)dp_i \tag{2.11}$$

$$CV(p^0,p^1,x)=\int_{p_i^0}^{p_i^1} h_i(p,u^0)dp_i \tag{2.12}$$

then the potential difference is due to the relevance of income effect. In fact, in the particular case where income effect is zero, $h(p,u^1)= h(p,u^0)$ and then the two measures, besides to being equal, will also equal consumer surplus (ABFD in Figure 2.3). Consumer surplus may differ from the equivalent and compensating variation for many reasons; here I will highlight the one linked to the income effect. The equivalent (compensating) variation is the area under the compensated demand curve, corresponding to the level of utility after (before) the tax change, which will differ from the area under the uncompensated demand curve unless the income elasticity of demand is zero. Consumer surplus is defined with reference to Marshallian demand and is given by

$$CS(p^0,p^1,x)=\int_{p_i^0}^{p_i^1} q_i(p,x)dp_i \tag{2.13}$$

In the absence of income effect, the Marshallian demand will equal Hicksian demand; this implies that CS is a good approximation of EV and CV if the income effect is not very important. For individual products price increases there is usually very little difference between the three welfare measures, as long as the share of spending on this good is a small fraction of income. But this may not be the case when a wide range of product prices are simultaneously increased, and the relevant budget share is more substantial.

For a single price change, constancy of the marginal utility of income enables to say that consumer surplus provides an exact measure of the change in welfare. Some problems arise with changes in more than one price, as in the case of the simulation of carbon tax implemented in 1999 in Italy. The change in consumer surplus must be evaluated using a line integral defined over the path of price changes. This extension is conceptually straightforward, but line integrals generally depend on the paths over which they are evaluated. Since we only observe the initial and final price vectors, the change in consumer surplus must be independent of the path, condition that, in turn, occurs if the uncompensated price effects are symmetric. A rational consumer will exhibit compensated price effects that are symmetric, but uncompensated demands will have this property only if income effects are always equal. This requires equality of the income elasticities which can only occur if they are equal to one and preferences are homothetic.

Differently, the compensated demand for a good is characterized by the symmetry of compensated price effects, so the surplus measure is single valued because the integral which define it is path independent. Then, because of their relationship with compensation criteria, and because their measurement is not dependent on the path of price change, Hicksian welfare measures are widely regarded as desirable measures of the benefits or costs of price changes. Since CV and EV are both equal to areas under Hicksian compensated demand curves rather than areas under Marshallian demand curves their measurement has proved more difficult than that of the more-frequently used Marshallian surplus. However, the adoption of the expenditure function approach provides a reasonably straight-forward method for the measurement of CV and EV, either by using estimated parameters of complete demand systems, derived from maximization of a well-behaved utility function, or by integrating back from Marshallian demand curves to Hicksian demand curves via Roy’s identity. In general, the Marshallian surplus lies between the theoretically grounded measures of welfare change CV and EV. When the price of a normal good decreases, the following disequality is true: $CV < CS < EV$; conversely, for a price increase it holds that $EV < CS < CV$. Only when the income elasticity for the good considered is zero, all three measures equal each other.

A considerable work has been done on the importance of the differences between these three measures and on the possible use of CS as an approximation of CV and EV. Willig (1976) indicates that in most practical situations the differences between CS and CV/EV does not exceed 5%, depending on the income elasticity of the good and the share of the CS of the good in question in the total consumer’s expenditures. The consumer surplus can differ from the other measures for the variations for different reasons, linked to income effects (differences between the compensated and uncompensated demand curve), cross-price elasticities, and assumption of constant-elasticity demand curve. The divergence between CV and EV is theoretically grounded and it is inescapable without severe restrictions on consumer's preferences. This divergence poses the problem of the most suitable measure to be used. One distinction can be made on the base of property rights implied by each of the two measures. The CV can be defined as a measure of the maximum willingness to pay (WTP) to obtain the price decrease using the initial level of utility as a reference point, implicitly assuming that the individual has no claim on the price change. The EV measures the minimum willingness to accept (WTA) to forgo the price decrease, considering the (new) utility level the individual would reach with the price decrease as a reference point, hypothesizing that the individual has a right to the price decrease and needs to be compensated if it is not attained. Equivalent and compensating variation can be used to estimate the WTP/WTA for environmental quality: such an approach makes more evident how other assumptions, for instance linked to property rights, are relevant in choosing the most appropriate between the two welfare measures. In the case of multiple price changes there is an additional issue to be considered. Freeman (1979) states that the CV is independent of the order of evaluation, while the EV will be independent of the order of evaluation only in the special case in which the income elasticities of the goods are unitary. Unless this unlikely condition is met, there is no unique EV in the case of multiple price changes and in such cases the CV is therefore the best measure.

As pointed out by Markandya (2004), another issue arises when the measures of welfare change have to be used for the ranking of two alternative policies. In this case, EV is shown to be superior to CV. He argues that considering two alternative policies, both of which embed multiple price changes which lead the consumer from the initial indifference curve U_0 to the same final curve U_1, for both policies the measure of the welfare change should be the same. The EV is the same whatever price change is considered, as long as the EV is based on the initial set of prices. On the other hand, CV is different for the two policies, the final set of prices being different, even if both sets of prices allow the consumer to reach the same utility level U_1.

The problem of determining the not observable structure of consumer preferences deducing them from market choices has been solved developing the revealed preferences approach, originally proposed by Samuelson (1938). This has required the individuation of some properties of demand functions, represented by the axioms of revealed preferences; depending on the hypothesis on preferences characteristics, these properties constitute necessary or sufficient conditions under which the connection of market choices and utility maximization is possible. The issue, known as integrability of demand systems, was already faced by Antonelli (1886), and after by Pareto (1906), Hicks and Allen (1934), Georgescu-Roegen (1936), Samuelson (1950) and Hurwicz and Uzawa (1971).

In particular, supposing that the inverse of the demand system exists (namely, hypothesizing that only a price system exists in which a bundle of goods is demanded), then this function is integrable, the utility function represent an integral and the marginal income utility represent the integration factor (Antonelli, 1886). Integrability requires several conditions with local character: then, they must hold in order to assure that market choices are referable to an utility maximization problem. Georgescu-Roegen (1936) and Samuelson (1950) have proved that integrability conditions are equivalent to the symmetry properties of Slutsky matrix, whose elements express the substitution possibilities between different couple of goods. Simmetry condition alone is not enough to assure that the integral of inverse demand function represent the consumer utility function: in other words, the mathematical integrability does not imply the economic integrability. The authors have shown that the Slutsky matrix must also be negative semi-definite. The method described could not be applied to indifferences curves which present corners: in order to solve this limitation Hurwicz e Uzawa (1971) proposed to derive demand functions directly integrating demand and not its inverse : at this purpose, they referred to the dual structure of the maximization problem and used the envelope theorem, according to which the partial derivatives of the expenditure functions with respect to price should be equal to compensated demand.

There is only a scarce amount of studies that use theoretically grounded welfare measures such as equivalent variation or compensating variation to measure carbon tax incidence: Cornwell and Creedy (1997), Brannlund and Nordstrom (2004), West and Williams (2004) represent some examples. In these cases, through the adoption of some representation of preferences, such as a cost function or an indirect utility function, a consistent demand system is derived and on this basis incidence measures are computed. This is relatively easy because from demand system estimation one obtains directly cost or indirect utility function parameters, which can be employed to compute the described measures. The coefficients of a demand system also allow to estimate demand elasticities, and this represent already a first step in evaluating different distributive impact among households with regard to the introduction of a green tax reform.

The utilitarian approach evaluates different price systems or bundles of goods on the basis of the utility they allow to reach. In this context, welfare measures are generally derived through the observation of preferences revealed by individual choices, and interpreted in terms of the numerical representation of these choices. Therefore the notion of welfare is able to catch only the item for which a money metric exists, resulting from the economic rationality of utility maximization. In some cases, evaluating public policies only using utilitarian approach could embed adverse effects on individual welfare. In fact this conception relies only on the welfarist criteria of utility (in theory) and income (in application). The income approach to welfare measurement can be intended only as a mean to reach an acceptable standard of living, and in no way as an end in itself, since there could be other important dimensions of human welfare that income does not account for: health, education, social relationships, longevity, employment, environmental conditions, housing conditions (Sen, 1979).

Sen proposed an approach aimed to innovate the traditional notion of welfare as satisfaction of individual preferences, widening the information basis of which rational agents dispose and focusing on some objective realisations, called functioning (Sen, 1979). The way utility is measured in the utilitarian approach can in fact provide only a partial picture of human well-being, limiting its significance to the consideration of welfare effects[18]. Sen major contributions (Sen, 1979; 1995; 1999) all stress the centrality of individual entitlements, opportunities, and rights as conceptual foundations of economics and social choice, introducing the so-called capability approach. While in the utilitarian approach, utility, intended as measure of preferences satisfaction, is the only reference for the measurement of individual welfare, in the approach developed by Sen it represents only one of the set of functioning relevant to obtain a measure of individual well-being.

The implementation of the approach described has mainly dealt with the computation on indicators alternative to Gross Domestic Product, following the first contributions developed by Sen (1985) and the United Nation Development Program (1990) or to the analysis of poverty (among others, Myles and Picot, 2000; Grasso, 2002; Grusky et al., 2006). Certainly a micro-economic analysis such as demand system estimation can not easily be developed adopting capabilities approach (to my knowledge it has never been the

[18] In what follows, the term well-being will be used with a wider meaning with respect to welfare, adopting the approach introduced by Sen (1979).

case), since it is based on consumer choices rationality and just for this reason it offers a very high rigour in its implementation. In fact, a relevant issue in capabilities approach is the information requirement, in particular with regard to the availability of data suitable for well-being measurement in functionings space. Before this the capabilities in the functioning space should be identified: this obstacle tends to limit the empirical investigations to the measurement of functioning, which are, even if indirectly, observable.

2.3.4 Aggregation and social welfare measurement

Since the goal of empirical welfare analysis is often an assessment of the effects of policies on groups of households, the aggregation problem must be examined. In order to study the overall impact of tax reforms on taxpayers, a method for aggregating the estimates of household welfare must be developed. The most common approach is assuming the existence of a representative consumer and using market demands as the basis for the measurement of social welfare. This is unappealing both because distributional issues are ignored and because aggregate demands could be inconsistent with the behaviour of a single representative agent. To go beyond this framework requires normative judgements concerning the measurability and comparability of welfare across heterogeneous agents. Any effort to develop an index of group welfare must inevitably make normative judgements in which the gains to some are weighed against the losses to others. Should a policy be implemented if the welfare of the poor increases slightly but the welfare of the rich decreases dramatically? The answer ultimately depends on the extent to which welfare can be compared across the population and on the weights assigned to individual agents.

The effort to make the Pareto principle operational using compensation mechanisms started in the 1930s. In particular, the Kaldor-Hicks-Samuelson approach described by Chipman and Moore (1971) provides a stringent criterion for comparing policies' outcomes; it states that policy 2 is preferred to policy 1 if, for any allocation under policy 1, is possible to find an allocation under policy 2 that is Pareto superior to it. Making this approach operational is problematic, because it is prohibitive to examine all the possible lump-sum redistributions of goods across the population; the efforts have focused on aggregate index numbers as indicators of change in potential (social) welfare, but both Paasche and Laspeyres aggregate expenditure turn out to be reliable indicators only if preferences are identical and homothetic (Chipman and Moore, 1971). Given this negative results, efforts have then concentrated on summary statistic other than aggregate expenditure to describe changes in potential welfare. Blackorby and Donaldson (1988) and Ruiz-Castillo (1987) show that the sums of the individual equivalent or compensating variations can reveal the direction of change in potential welfare only under conditions similar to those obtained by Chipman and Moore (1971). This suggests that even accepting the Kaldor-Hicks-Samuelson criterion as the basis for measuring the change in welfare, there is no obvious method of implementing it without imposing very strong assumptions on preferences.

An alternative approach is to define a function of the individual surplus measures as an explicit representation of the change in social welfare. Such an approach to aggregation was advocated by Harberger (1971), among others, in his effort to make consumer surplus the standard tool for applied welfare analysis. At a conceptual level, such measures of social welfare are presented as natural extensions of the positive analysis of welfare measurement at the micro level. This is obviously not the case, because aggregation necessitates normative judgements related to the treatment of unequally situated individuals. Simply summing the surplus measures embodies a version of utilitarianism and ignores distributional concerns. This (as other approaches to aggregation) requires assumptions concerning distributive ethics and there is no way around this issue. The differences in the various approaches lie in whether these assumptions are implicit or explicit.

The growing availability of data on individual consumption has changed the problem connotation, since the necessity to refer to excessively restrictive aggregation models has been reduced. Furthermore, individual differences in preferences can be introduced in the model specification through a vector of demographic characteristics (see Paragraph 3.4). Then, I will face the problematic issues linked to the representative consumer approach by computing the elasticities and the incidence measures distinguishing for households characteristics and their welfare (total expenditure) level. I will also compute the aggregate compensating and equivalent variation by weighting the individual welfare measures with the numerousness of each household profile included in the simulation. My scope is not represented by providing an evaluation of social welfare, but simply by aggregating the impacts estimated at individual level, in order to compare this result with raised revenue. So, I will not develop any consideration on social welfare changes consequent upon the carbon taxation introduction. On the contrary, I will extend the individual results obtained to the whole population, through the utilization of ISTAT weighting coefficients.

2.3.5 Equivalence scales

The consumer demand literature is plagued with multiple meanings and interpretations of the terms “equivalence scales”. It is used to refer to at least four different techniques for incorporating demographic variables into demand systems, and it also stands for a class of welfare comparisons among different household types performed basing on demand system estimates. Here I will address the meaning linked to welfare analysis.

Because of the relevant policy implications, a number of studies attempt to measure the welfare effects of changes in household characteristics such as family size. In order to compare incomes and expenditures of different household types equivalence scales can be used. An equivalence scale is the amount by which household consumption expenditures should be multiplied to make that household as well off as some reference household. Equivalence scales are supposed to address welfare issues by measuring the relative costs of demographic variation, such as the cost of being old versus young or the cost of having children in a family.

A two-component household without any joint consumption requires twice the expenditures of a one-component household in order to attain the same standard of living: so, if one chooses one individual as the reference household, the equivalent scale for this household is two (Lewbel, 1997). If the household consisted of one adult and one child, the equivalence scale will be less than two. In this case, the equivalence scale is intended to measure the number of adult equivalents (in terms of total expenditure) in the household. In general, any equivalence scale depends on the price regime and utility level at which the comparison between households having certain characteristics and the representative household is made.

Equivalence scales are designed to address the welfare theoretic question of the additional expenditure required to maintain a given level of welfare as household characteristics change. The answer to this question can be represented as either the difference or ratio of expenditure functions. Rather than accounting heterogeneity through household size alone, equivalence scales depend on additional characteristics that influence demand patterns such as the age, race and gender of the members. If a_R is the vector of characteristics of the reference household, the additional expenditure required for a household with attributes a_K to attain utility u_R is

$$\Delta W_k = c(p, u_R, a_K) - c(p, u_R, a_R) \tag{2.14}$$

which is analogous to the equivalent variation. In index form, household equivalent scales are defined by [19]:

[19] It is evident, when equivalence scales are expressed in this form, their similarity with the True Cost of Living Index that I will introduce in the following paragraph (Perali, 1999).

$$c_0(p,u_R,a_K)=\frac{c(p,u_R,a_K)}{c(p,u_R,a_R)} \tag{2.15}$$

In measuring the welfare effects of changes in prices and expenditure, efforts have been directed towards incorporating price and expenditure effects flexibly in the demand functions. Demographic variables are often treated as an afterthought in an effort to account for heterogeneity. With equivalence scales, the issue is how modelling demographic effects in a way that does not overly restrict preferences. Among the simplest methods of incorporating demographic variables is to deflate the demands and expenditure by a general equivalence scale, so that the Engel curve becomes

$$x_K / c_0(a_K) = x(c_K / c_0(a_K)) \tag{2.16}$$

This method is attributed to Engel (1895) and is widely used because it is easily estimated using a simple cross section; however, the demographic variables have the same effect on all commodities, which could seem overly restrictive.

Given the arbitrariness in the choice of the reference price vector for the computation of money-metric utility functions, the ranking of social states need to be invariant to this choice. To make the equivalence scale base independent, that is to say invariant with respect to the utility level at which the expenditure comparison is made, it is required to hypothesize some structure on preferences across household types. If preferences satisfy base independence, then the household equivalence scale does not vary across household income levels. The usefulness of base-independent equivalence scales is related to various aspects. First, an equivalence scale may ensure governments that redistribution is fair, by making sure that each member of the transfer target population ends up with the same level of welfare. Moreover, policy makers can succeed to design transfer programs that do not create incentives for participants to modify their household composition to increase their level of welfare. Second, accurate equivalence scales permit to exploit household data for social evaluation, for example represented by the construction of inequality indices.

On the other side, the invariance of base-independent equivalent scales implies a restriction on household preferences and, therefore, embeds restrictions on the shapes of expenditure share equations across household types. If base-independence property is not satisfied by preferences, then the conventional and convenient use of base-independent equivalence scales is inappropriate. Pendakur (1999) constructed a semi-parametric estimator of a household equivalence scale under the assumption of base independence without putting any further restrictions on the shape of household Engel curves. This estimator uses cross-equation restrictions on a system of estimated non-parametric Engel curves to identify equivalence scale parameters. Testing the hypothesis of base independence against a fully non-parametric alternative, the author found that preferences are consistent with the existence of a base-independent equivalence scale for some inter-household comparisons.

2.4 Other studies review

My attention, among all the environmental policies, will be focused on a carbon tax: this choice was determined by criterion of representativeness, with regard to different environmental policy options, and of actual and potential economic relevance, referring to the relatively wide use among different countries.

This paragraph discusses the sizeable empirical literature on a variety of energy taxes, including gasoline and carbon taxes, whose primary incidence effects are transparent, assuming tax payments or permit rents are fully passed on in higher prices. The review will be held following a chronological order and distinguishing between different kinds of taxation, represented by gasoline taxes, energy taxes, carbon taxes and other taxes. Care is needed in comparing studies as they may measure incidence and household welfare differently, some of them considering behavioural responses to price rises induced by the policies while others not doing so, and some relying on a partial equilibrium approach while others on a general equilibrium one. A general finding is that, prior to revenue recycling and on the basis of annual income, most energy taxes look regressive, since lower income households tend to spend a disproportionately larger fraction of their income on energy, which is a necessity good. Using lifetime income, considering increases in prices of other goods for which energy is an input, and recycling revenue can mitigate this regressivity, at least in part.

2.4.1 Gasoline taxes

A gasoline tax is, for the most part, a final product tax. Poterba's (1989) study of gasoline taxes (and other federal excise taxes) is among the first to emphasize the quantitative significance of different measures of income for the degree of regressivity. Computing the budget share on gasoline for each quintile, he finds that the budget share of the bottom income quintile was 5.3 times that for the top income quintile if expressed in terms of annual income, but 1.5 times that for the top income quintile if expressed in terms of lifetime income, proxied by annual consumption expenditure.

West and Williams (2004) examine the incidence of an increase in the gasoline tax, using total expenditure as a proxy for lifetime income. They divide the sample into quintiles that are intended to reflect individuals standard of living, even if a given level of total household income clearly needs some adjustment for household size. Then an equivalence scale is used: it weights adults and children equally, but allows for economies of scale in consumption. The demand system is estimated separately for each quintile using working households that consume gasoline, separately for one and two-adult households.

Their study appears particularly useful in order to examine the different options of incidence measures that can be employed: West and Williams perform their incidence analysis adopting for different incidence measures. The first of the measures they use is the equivalent variation, which has already been used in other studies of the incidence of carbon taxes (Cornwell and Creedy, 1997; Brannlund and Nordstrom, 2004). This measure implicitly accounts for cross-price effects through the cross-price derivatives of the indirect utility function; a problem of this incidence measure is that the indirect utility function is often unavailable. The second measure they consider is represented by an approximation of the consumer surplus change and requires much less information; it is shown in the following equation

$$\Delta CS_h = \sum_k \left\{ \frac{x_{hk}^0 p_h^0}{\varepsilon_{hk} + 1} \left[1 - \left(\frac{p_{hk}^1}{p_{hk}^0} \right)^{\varepsilon_{hk}+1} \right] \right\} + Y_h^1 - Y_h^0 \qquad (\ 2.17\ )$$

where x_k represents the initial consumption of good k, ε_k is the uncompensated own-price elasticity of demand for good k (which is allowed to vary across the income groups h), Y is the income and the indices 0 and 1 refer to scenarios before and after tax. On one hand, the measure in equation (2.17) is much simpler to implement than the equivalent variation: one needs to know only the spending on the taxed good before the imposition of the tax, the percentage change in price and change in income induced by the tax, and the own-price demand elasticity for any good whose price changes. On the other hand, this measure is likely to differ from the equivalent variation for the reasons examined in Paragraph 2.3.3. In particular, the cross-price effects in determining the incidence of a carbon tax have a relevant role (Tiezzi, 2005), and one of the advantages of Almost Ideal Demand System (AIDS) and Quadratic Almost Ideal Demand System (QAIDS) is that they are sufficiently flexible to provide meaningful estimates of cross-price elasticities. The authors compute a third measure very similar to (2.17): it differs only in assuming that demand elasticities do not vary across households; in fact, the average demand elasticity for all households is used to calculate incidence. Demand elasticities are very likely to vary with income, and then this third measure will overstate the incidence on income groups with relatively elastic demand, and understate the incidence on groups with relatively inelastic demand.

For example, poor households may respond more to price changes than the wealthy, because they have smaller budgets; on the other hand, if poor people have fewer transportation options, they may be less price-responsive. The last incidence measure ignores demand responses altogether, and thus it implicitly assumes all demands are completely unresponsive to price. In this case, incidence is simply computed as the difference between expenditure levels before and after the tax plus the change income resulting from the policy, according to (2.18)

$$\sum_h (p_{hk}^1 - p_{hk}^0)x_{hk}^0 + Y_h^1 - Y_h^0 \qquad (2.18)$$

This approach is used, for instance, by Metcalf (1999) to estimate the incidence of a range of environmental policies, Poterba (1991) or West (2004) of transport fuels tax. Since it does not reflect any demand responses (cross-price or own-price), this fourth incidence measure will differ from both the equivalent variation and the consumer surplus (unless all demand elasticities are equal to zero). In particular, it will tend to overstate the burden of tax increases, because it ignores consumers' shift away from the newly taxed good. Again, this difference will be insignificant relative to the burden of the tax for a sufficiently small change, but will become important for larger changes.

West and Williams (2004) compute incidence for ten representative individuals: a representative one-adult household and a representative two-adult household for each of the five quintiles. Then they calculate incidence for each representative household and aggregate the one and two-adult households in each quintile, weighting by the fraction of each household type in the quintile. Comparing these incidence estimates across different income groups demonstrate how regressive or progressive a particular tax shift is. The results show that the potential differences between the consumer surplus measure, that allows elasticities to vary by quintile, and the equivalent variation measures (cross-price effects, income effects, and the assumption of a constant-elasticity demand curve) have relatively little effect: the two measures yield very similar results. Even considering large price changes, the authors find out that these differences are sufficiently weak that taking them into account makes little difference in the incidence analysis. Comparing the two consumer surplus measures (the first allowing income to vary across households, the second not), the authors point out the importance of allowing demand elasticities to vary by quintile. This distinction is particularly important in estimating the progressivity or regressivity of the policy: assuming that demand elasticities are constant across quintiles makes the gas tax look more regressive than if elasticities are allowed to vary across quintiles.

Unlike Poterba (1989), West and Williams (2004) focus on behavioural responses in their incidence calculations and so estimate gasoline demand elasticities by income quintile. Ignoring behavioural responses, or assuming the same demand elasticity across different income groups, makes the tax increase appear more regressive: this is because lower income groups have more elastic demands for gasoline, implying an important reduction in their burden. Behavioural responses play an essential role, in particular in an economy with a pre-existing labour tax. Almost none of the prior studies on distributive impacts of a carbon tax estimate them: nearly all assume that leisure is separable from other goods in utility, and many even assume that labour supply is fixed. They finds out that upper income quintiles are less responsive to gas price changes than lower-income quintiles. The authors estimate short-run elasticities, which implies that households do not respond to gas price increases by, for example, buying more fuel-efficient cars. To the extent that wealthier households may be more able than poor households to avoid gas taxes in the long run by switching vehicles, the use of short-run elasticities will result in incidence estimates that are biased towards greater progressivity.

West and Williams (2004) consider three different assumptions about the revenue raised by the environmental tax: that it is discarded, that it is used to cut taxes on wage income, and that it is returned through a uniform lump-sum distribution. The first assumption implies that the net wage and lump-sum income for each household will remain constant: only the price of gasoline changes. The second assumption implies that net wages will rise because the recycled revenue will lead to a drop in marginal tax rates. They assume that this is an equal percentage-point cut in all brackets. The third assumption implies that household lump-sum income will rise. They assume that this transfer is based on the number of adults in a household; thus, a two-adult household will receive twice the transfer a one-adult household would get. In each case, they calculate the demand for each good implied by a given income and vector of prices for each of the representative households and then solve numerically for the tax cut or increase in the lump-sum transfer (depending on how the revenue is recycled) that will exactly offset the increased gas tax revenue. Their results show that the gasoline tax is generally regressive prior to revenue recycling. Regressivity is reduced if revenue is returned through an equal percentage reduction in the marginal tax rate on labour income for each income group. Since labour income is a greater fraction of total income for low-income households than for high-income households, regressivity is reduced if revenue is returned through an equal percentage reduction in the marginal tax rate on labour income for each income group.

Bento et al. (2005) estimate a random coefficients model of vehicle choice and miles travelled, and they simulate increases in the gasoline tax respectively equal to 10, 30, and 50 dollar cent per gallon; two different scenarios are adopted, according to which revenue is rebated to households in proportion to their gasoline tax payments and in proportion to income. The authors find that with tax-based recycling, the impact of the tax across income groups is close to proportional. With income-based recycling, on the other hand, low-income households pay more as a percentage of income than high-income households.

Espey (1998) uses meta-analysis to determine if there are factors that systematically affect price and income elasticity of gasoline: several data sets and model assumptions were employed in studying gasoline demand, and consequently a wide range of price and income elasticities were estimated. The meta-analytic process cannot indicate what is the "right" way of modelling demand, but it is valuable in evaluating the sensitivity of estimates to modelling assumptions and data characteristics. The study is based on a review of articles published between 1966 and 1997, covering the time period from 1929 to 1993; many of these studies involve multiple models that differed by region, by functional form, by estimation method, or by the variables included. Four econometric models are estimated, using long-run and short-run price and income elasticity estimates[20] from previous studies as the dependent variables; their explanatory variables include functional form, lag structure, time span, national setting, estimation technique, and other features of the model structure. Elasticity estimates, rather than the coefficient estimates for price and income, are used as the dependent variables because they are unit-free, easily interpreted, and comparable across studies.

In the studies included by the authors, the estimates of short-run price elasticity for the demand for gasoline range from 0 to 1.36, with an average of 0.26; differently, the estimates of long-run price elasticity estimated range from 0 to 2.72, with an average of 0.58. Short-run income elasticity estimates range from 0 to 2.91 (average 0.47) and long-run income elasticity estimates from 0.05 to 2.73 (average 0.88). The basic result of this analysis is that the variation in the estimates of elasticities arises because of differences in: the assumptions inherent in the behavioural model underlying the demand; the measures of

[20] "Short-term" generally means up to a year. Long-term elasticities tend to be about three times higher than the short term.

quantity, price, income, vehicle ownership adopted; the countries included and the time frame of the data; the specifications of the estimated demand function; the econometric estimation technique. Linear regression is used to investigate potential causes of variation in the estimated elasticity coefficients for fuel consumption, including variables which model the demand specification adopted, data features, geographical and environmental characteristics, and estimation technique.

The results of the meta-analysis corroborate the hypothesis according to which models including some measure of vehicle ownership and fuel efficiency effectively measure the influence of price and income changes on driving only, while models omitting one or both of these variables measure_changes in consumption through driving as well as through changes in vehicle ownership or fuel efficiency. Then, the exclusion of vehicle ownership would be expected to positively bias the estimated coefficient on income, namely to provide more elastic gasoline demand.

In general, cross-sectional studies tend to produce significantly more elastic estimates for price elasticity, while cross-sectional-time series data produced less elastic estimates when compared to pure time-series studies. While there was not a significant difference between studies that used state or provincial level and those using national level data, the estimates from panel data and those from national level data significantly differ, with panel data producing more elastic short-run estimates. This might be due to the greater level of detail and variation in the data available in panel studies, which may capture more subtle responses resulting in more elastic estimates. With respect to the difference between static and dynamic approaches[21], static models appear to overestimate short-run elasticities and underestimate long-run price elasticities, but they pick up the full long-run income responsiveness.

The factors included in the meta-analysis carried out by Espey (1998) together explained between one-quarter and one-third of the variation found in the elasticities: this is a low explanatory power also considering that the estimated elasticities already are highly aggregated. A similar approach was applied by Goodwin et al. (2004), although not with exactly the same definitions as Espey: in particular, the static results were separated out from the dynamic results. The authors results can explain a high proportion of the

[21] Dynamic methods of estimation are those — always using time series data — in which allowance is made for a progressive build-up of effects over an explicitly identified time scale. This is now standard in the fuel consumption literature and increasingly common in the traffic literature. Static (or equilibrium) methods are those — either using cross-section or time series data — in which there is no explicit allowance for any time scale of response, which their users hope relate to an end state, of indeterminate date, when all responses have been completed.

elasticities differentiation, taking out many important sources of variation, for instance between short- and long-run effects, or between effects on fuel consumption and traffic volume. The authors find three main implications: first, price elasticities are positively related to price level, and will rise and fall as real price rises and falls; price elasticities are also negatively related to income, and therefore tend to fall over time; finally, they have a definite relationship with travel time elasticities.

Many surveys have attempted to convey and synthesize the information on automobile fuel demand (Espey, 1998; Graham and Glaister, 2002; Goodwin et al., 2004): in most cases, the focus was placed in giving assessments of the most likely values of price and income elasticities, while trying to explain the differences between results. On the contrary, the survey realized by Basso and Oum (2007) focuses on the various approaches and methods used, and which have sometimes challenged some of the accepted core results in the literature. These approaches include: co-integration techniques, use of disaggregate data at the household level and flexible functional forms, and structural models of automobile fuel consumption. In particular, studies that use disaggregate data have shown that it may be important to provide greater flexibility to the functional forms used for the demand model and, more importantly, that the demographic profiles of households play a major role in determining automobile fuel consumption. When demographics are not properly included in the demand model, their effects are partially captured by the income elasticity. The results from disaggregate data seem also better suited to assess the distributional impacts of different policies.

According to Goodwin et al. (2004), the main conclusion is that there is clear evidence that gasoline demand elasticities are different in the short-run than in the long-run. In the long-run, there will be a significant response in gasoline demand to changes in price and/or income. Hence, the range of responses open to people in the long-run is wider than the short-run adaptation of driving less: costs of automobile use influence people's decisions on car ownership, type of vehicle, and employment and household location. Johansson and Shipper (1997) support this result asserting that in the long-run, the largest fraction of the response to changes in fuel price comes from changes in car fuel efficiency. This also confirms the widely held belief that in the long-run, adaptation through driving less is not the most important response and, therefore, fuel tax will be more effective in reducing fuel consumption than measures targeted at reducing traffic volume.

Each approach offers insights on certain aspects of fuel demand while having different data and estimations costs and, as shown, automobile fuel demand modelling is a rather dynamic field with a continuous flow of new papers and, therefore, with many directions for new research. In addition, Goodwin et al. (2004) believe that the application of formal econometric decomposition methods to price and income elasticities would reveal rich information for formulating gasoline conservation policies, as they would allow to decompose elasticities into various sources. These methods, which were developed and applied extensively in productivity and cost analysis literature[22], have never been applied in the gasoline demand literature.

2.4.2 Energy taxes

Gasoline can be assumed to be a final good, directly consumed by households, in fact household consumption accounts for the bulk of gasoline use. However, this assumption is not reasonable for many other goods that might be taxed on environmental grounds: for example, direct household consumption accounts for only about two-fifths of electricity sales. Electricity is an intermediate good in the production of consumer products, because it is divided into industrial and commercial users. Then, it is potentially important to allow for increases in prices of other final goods that are indirectly affected by the tax.

In their study of taxes on electricity, coal, natural gas, gasoline and other refined oil products, Casler and Rafiqui (1993) compute price effects on 89 final goods consumed by households, using input-output tables. They assume that taxes are fully passed forward to consumers, and that firm's input-output ratios and household product demands are fixed. They combine these price calculations with data on the 89 commodities by income quintile, and income is measured on an annual basis. They find that the greater is the share in output of the intermediate taxed good, the less regressive the tax. Overall, the tax burden to income ratio for the lowest quintile is only modestly larger than that for the top quintile across the different taxes simulated.

Bull et al. (1994) use a similar approach to analyse a tax based on energy content and a tax based on carbon content. They consider a broader range of household income measures than Casler and Rafiqui, including annual income, annual consumption, and lifetime income. On the basis of annual income, the direct components of carbon taxes result quite regressive, while the indirect components are less regressive. On the basis of lifetime income, the direct component remains regressive, but the indirect component becomes

[22] For a detailed explanation and application of the methods for decomposing a firm's or an industry's unit cost changes into various sources: changes in input prices, productive efficiency, output scale/size, and other operating environments, see, for example, Oum and Yu, 1998.

mildly progressive; overall, the taxes look much less regressive on a lifetime income basis than on an annual income basis.

2.4.3 Carbon taxes

Nichele and Robin (1995) assess the consequences of two reforms in French indirect taxation system, represented by VAT harmonization and carbon taxation introduction, levied at $10 per barrel of oil. The effects of these tax reforms are estimated adopting a model of household expenditure behaviour. Estimation is obtained by using the property of perfect aggregation over household of the Almost Ideal Demand System on pooled micro data on household consumption and macro data on prices. The aim of their contribution is to provide an econometric procedure for matching individual cross-sections and aggregate time-series so as to estimate price effects on household consumption as well as income effects. In theory, using perfectly aggregable demand systems (Deaton and Muellbauer, 1980b) should make it possible to construct an aggregate version of the micro-economic model; unfortunately, the aggregation generally requires available statistics about the dispersion of total expenditure in the entire population. In their paper, the authors control for changes in income dispersion over time by including trends and time dummies in the estimation of aggregate data. Micro and macro estimations are then optimally combined using a minimum distance econometric procedure. Using this theoretically efficient procedure, simulations are performed in order to provide information about the behavioural reactions to tax changes, the impact on government revenue and the distributional effects of the reforms. Regarding the effects of the carbon tax on household behaviour, the tax burden appears to be regressively distributed. Due to strong substitution effects, the consumption of group heat and light increases as its price increases; this has a significant impact in the calculation of government revenue: the overall prediction is a 1.17% increase in government revenue.

Cornwell and Creedy (1997) study the introduction of a carbon tax, assuming that the prices of goods increase in proportion to their carbon content. They estimate parameters of a linear expenditure system for different income groups, and then use these parameters to calculate the resulting compensating and equivalent variations. On the basis of annual income, the tax is regressive: both compensating and equivalent variation as a fraction of income fall as income rises.

Symons et al. (1998) examine the impact of a carbon tax on five European countries, France, Italy, Germany, Spain and the UK: the tax burden faced by consumers varies according to the proportion of total expenditure allocated to each good and it differs across the income distribution. The results show different patterns: in Germany, France, and slightly in Spain the imposition of the taxes is regressive, while this was not the case for the UK and Italy.

Metcalf (1999) analyses a revenue-neutral package of environmental taxes, including a carbon tax; prices of energy goods, electricity, natural gas, fuel oil and gasoline increase substantially, and although the overall package taxes disproportionately hit low-income groups, it can be made distributionally neutral – under a range of different income measures – through targeting of income and payroll tax reductions.

Labandeira and Labeaga (1999) examine the effects of a tax levied on Spanish energy-related CO_2 emissions, considering a tax rate obtained through the actual damage cost method. Their empirical analysis proceeds in two stages: an input–output demand model is employed to calculate the price changes after the introduction of carbon taxation, then a simulation with Spanish household micro-data is performed, to estimates its effects on final consumption. In particular, the environmental (in terms of behavioural responses), distributional (in terms of tax payments and welfare measures) and revenue outcomes are computed. A similar combination of input–output analysis and micro-simulation of demand responses had already been used to assess the economic and distributional effects of carbon taxation (Symons et al., 1994; Cornwell and Creedy, 1996). Employing an input-output methodology allows to disentangle the complex industrial relationships which characterize any developed economy: given the generalised dependence of contemporary societies upon CO_2 emissions, the authors prefer not approximate the influences of carbon taxes by focusing on a single sector.

A key assumption when assessing the effects of a carbon tax levied on fossil fuels on the output prices is the full shifting of carbon taxation to consumption: this assumption 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 following the introduction of the carbon tax, which is obviously related to the incidence presumption; therefore, the results should only be taken as a short-term approximation for the impacts of taxes on inputs. As I will explain in the next chapter, I will adopt a similar approach.

Due to the generalised dependence of developed economies upon CO_2 emissions and to the difficulties in modifying behaviours in the short run, the hypothetical carbon tax would raise considerable tax revenue. On the other hand, the carbon tax has limited environmental effectiveness, since Labandeira and Labeaga (1999) find a limited short-run reaction to the carbon tax. The tax burden is not regressively distributed across households:

the percentage increase in tax payments (relative to the pre-reform situation) by decile of expenditure appears to be proportionally distributed. Using sub-samples corresponding to some socioeconomic variables, it is noticeable that there are not significant differences in the relative tax-payment increase by demographic class.

Brännlund and Nördstrom (2004) use data from Sweden to analyse a carbon tax with revenue recycled in a reduction in the general value-added tax (VAT), or in a reduction in the VAT on public transport. The model utilizes micro and macro data and in this way simultaneously relaxes assumptions of some previous studies, represented firstly by separability between the labour-leisure and consumption choices: labour supply is included in the model so that separability between labour supply and demand for non-durable goods can be explicitly tested. The basic model employed is essentially a two-stage budgeting model. In the first stage, it is assumed that the household determines how much to spend on non-durable goods and how much to spend on durable goods (including savings). In the second stage, it is assumed that the household allocates its total expenditure for non-durable goods on each non-durable commodity. They take the quadratic AIDS (QAIDS) as basic specification and model the differences in consumption patterns between different household categories by adding intercept and slope parameters in the budget share equations of the demand system. They include in the model not only household income but other household characteristics, represented by: number of children 0–2, 3–6, and 7–17 years old, number of children over 18 years with and without employment, number of adults, age of the head of the household, and locational variables. The preferences are characterized in such a way that, in each period *t*, the household *h* makes decisions on how much to consume of the examined commodities, conditionally on various household characteristics and labour-market decisions (female and male hours of work). To the intercept term they also include a set of purely deterministic time-dependent variables, like seasonal dummies and a time trend. QAIDS system is estimated adopting the Stone index in order to simplify the simulation; for this reason, in absence of the non-linearity linked to the Translog Index, the authors can perform GMM and two stages OLS estimators. The basic motivation for the simulations is the Swedish commitment in the Kyoto-protocol: the authors consider different scenarios designed to assess the macro-economic as well as micro-economic impacts on the Swedish economy of various policies to reduce greenhouse gas emissions. The first scenario includes a 100% increase of the CO_2 tax, with a tax replacement in the form of a lower general VAT; the second scenario includes a 100% increase of the CO_2 tax, but with a tax replacement in the form of lower VAT on public transport. Thus both scenarios are revenue neutral, and they were both considered as options in a green tax reform. After having obtained price elasticities that vary by income quintile, the authors simulate the effects of the tax policies; they find that the tax is regressive under the first recycling scenario, but less regressive in the second one.

Tiezzi (2005) simulates the ex ante effects on households of the environmental tax reform introduced in Italy at the beginning of 1999, taking into consideration different households profiles. The environmental effectiveness of the fiscal reform is analysed through estimation of the demand elasticities for fuels, and compensating variation is employed in order to investigate the distribution of the welfare change across different households types and different expenditures levels. Tiezzi increases monthly prices linearly, by 20% per year of the total rise to be achieved at the end of the fourth year, as indicated by the Budget Law. She squeezes the price increases to four rather than six years (as provided by the law) and for this reason the simulation is likely to produce welfare changes that might be overestimated. After having obtained True Cost of Living Indices[23] for the no carbon tax scenario (*a*) and carbon tax scenario (*b*), monthly compensating variation (CV) for each type of household and each welfare level was calculated. The difference in the compensating variation calculated for the two scenarios *a* and *b* indicates the amount of income that would allow households to enjoy the same level of welfare they would have had without the fiscal reform. This is given by:

$$CV_{n,b}^{h,t} - CV_{n,a}^{h,t} = (TCOL_{n,b}^{h,t} - TCOL_{n,a}^{h,t})y_n^{h,t} \tag{2.19}$$

where $CV_{n,b}^{h,t}$ is the *CV* of household *h*, at time *t*, at the welfare level *n*, calculated according to scenario *b*; the following *CV* is the same but calculated according to scenario *a* and $y_n^{h,t}$ is the welfare level *n* of household *h* at month *t* (proxied by total expenditure). In order to obtain an aggregate measure of the welfare change, the number of households in each household and expenditure class has been multiplied by a coefficient (published by the Italian National Statistical Institute) that convert the sample used into the real number of households of that type living in Italy in the examined year. A relevant result is that variation of welfare losses across different levels of total expenditures does not allow to sustain the presumed regressivity of carbon taxation, as the cost of living of households in the lowest income groups is not the most adversely affected by the tax increases. The results show, contrary to what has been found in other similar studies, that the tax burden is

[23] True Cost of Living Indices constitutes a devise to reduce the comparison between two different standard of living (represented by two different price systems) to a single scalar; for a detailed description of such indices see Paragraph 3.5.

progressively distributed across households at different welfare levels. Since the reform mainly hit transport fuels, and increased relatively less heating fuels prices, the presumed regressivity of carbon taxation is not sustained. As Smith (2000) has pointed out, this result might be due to 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 distributive effect became opposite. Concerning environmental effectiveness, the way various individuals react to policy changes plays a fundamental role: the price and revenue elasticities of transport fuels are very high, probably due to availability of alternative transport options.

Unlike other studies that consider proposed carbon taxes, Wier et al. (2005) examine the existing CO_2 tax in Denmark, based on actual tax rates paid directly and indirectly by households. They use input-output tables for the year 1996, assuming taxes are fully passed through to consumers in higher product prices, and a consumer expenditure survey of over 3,400 households. On the basis of annual income, they find that (excluding revenue reutilization) the CO_2 tax is regressive and the direct component of the tax accounts for most of the regressivity. This study confirms that the regressivity can also depend on the way income is measured: using total expenditures as a proxy for lifetime income, the regressive effect is greatly reduced, though not entirely eliminated.

Labandeira et al. (2006) continue the previous analysis (Labandeira and Labeaga, 1999) exploring consumer choices in electricity, natural gas, liquefied petroleum gases (LPG), and car fuels for private transport; their demand system also incorporates public transport, food and other non-durable goods. The authors include demographical explanatory variables such as place of residence, household size, age, education or labour force participation: in this way, they can control for observed heterogeneity in the energy profiles of different households. A noteworthy contribution of the paper is represented by the estimation of the model with different sub-samples to capture varying responses to energy price changes by households living in rural, intermediate and urban areas. The results show the relevance of including explanatory variables capable to take heterogeneity into account: in particular, a significant relationship was found between spending on different energy goods and place of residence, household composition and work status (active or retired). For these reasons, I distinguish for this characteristics in my simulation. As rural, intermediate and urban households do not face the same opportunities to consume energy goods and transport services, Labandeira et al. (2006) find a gradual substitution of transport fuels and LPG, respectively with public transport and natural gas, when the population size of the municipality increases. Concerning price elasticities, the authors show that energy products are rather inelastic in Spain. Electricity is the most elastic good, in contrast to the price independence of natural gas. With regard to income elasticities, food, electricity and LPG are normal goods, natural gas, car fuels and public transport are luxuries, whereas LPG constitutes the most income inelastic energy source. Income and price elasticities vary by grouping different types of households with respect to their place of residence (type of municipalities): this has important efficiency and distributional implications, because some households have limited possibilities to substitute energy goods. Poorer households are more responsive to changes on energy prices, which is obviously related to a larger share of energy on total expenditure. Again, the authors observe significant differences in some goods related to the place of residence, and these findings have important efficiency and distributional consequences.

As price elasticities indicate only a limited short-term effectiveness of pricing policies to restrict Spanish energy household consumption, Labandeira et al. (2006) suggest that other regulatory approaches should be contemplated. Only electricity consumption seems to be fairly price sensible; on the contrary, car fuel demand is found to be particularly price inelastic, and this implies a formidable challenge for public regulators due to the uncontrolled and unsustainable pattern of consumption rises seen in the last decades.

2.4.4 Other taxes

Even if West (2004) considers a particular kind of environmental tax, such as a motor vehicle tax, her contribution could be useful in order to highlight some methodological issues. She integrates behavioural responses into an incidence analysis of motor vehicle taxes and subsidies. The policies she considers are a tax on vehicle size, a mileage tax, and a subsidy to vehicle “newness”. She finds that households in the lower income deciles have more elastic demands for miles travelled than those in the higher income deciles. Looking at estimated tax payments as a share of lifetime income (proxied by annual consumption) without considering behavioural responses, or assuming the same demand elasticity across different income groups, the tax appear more regressive. Interestingly, the tax payments as a share of income, or consumer surplus change as a share of income, become larger from the lowest decile to the middle deciles, but then fall and drop sharply for the top decile. Some of this impact is due to the fact that low-income households do not own a vehicle: the regressivity of the tax is greater when only households who own vehicles are considered.

To conclude, a short synthesis of quoted studies controversial aspects will be given. Focusing on the system employed in order to estimate consumption changes, the majority of calculations use the same demand system and vary the incidence measure. It might be interesting for future research to compare the results of alternative approaches that vary the assumptions made in the estimation, holding the incidence measure fixed.

Households welfare losses can be confronted with the tax revenue expected from the introduction of the tax, in order to allow for a possible compensation; the revenue is often calculated without accounting for behavioural responses: this produces a distortion in the revenue available for redistribution. On this subject, it would be necessary to remove the hypothesis, generally adopted in consumption changes calculation, that firms completely transmit on prices the higher costs resulting from the emission tax introduction. It should be noted that even using an input-output framework does not directly allow for substitution possibilities in production, and this gives rise to two opposing biases in the model. If substitution possibilities do exist in production, but are omitted in the analysis, the post tax pollution level is overstated, since the tax would cause a shift of techniques such that goods produced were less pollution intensive. However, substitutability in production would also reduce the incidence of the tax on consumer prices, and therefore on consumer behaviour, thus lessening the effect of the tax on pollution reduction.

Chapter 3

3.1 The empirical assumptions

The analysis of the allocation of family income to goods and services is of interest to economists and policy makers because examining price and income elasticities helps to clarify the impact of economic policies. Identifying relevant factors and their magnitude will give producers the ability to forecast market demand and it will help government to select appropriate fiscal policies. In addition, every policy reform which implies price changes will produce welfare redistribution among households: analysing households expenditure patterns over time can help to highlight the social impacts of taxation reforms (Musgrave and Musgrave, 1989).

Demand studies could be classified into two broad categories. The first group is concerned with finding a model explaining the relationship among the quantity consumed of a single commodity, its price, the prices of related commodities, and total income. Such a demand model can be considered as part of a demand system, and it can be tested for theoretical properties (such as homogeneity of degree zero in prices and income). The second group deals with the allocation of total expenditure to an exhaustive set of different commodities. It is usually assumed that the problem of deciding how much to consume at any given time has been solved, concentrating on the problem of allocation. The demand system underlying my simulation is a model belonging to the second group, represented by an extension of the Almost Ideal Demand System of Deaton and Muellbauer (1980b) and Quadratic Almost Ideal Demand System (Banks et al., 1997). I will estimate both models and then test the quadratic term significance. They allow the expenditure on specific commodity groups to depend on both the price of that group and the relative price of other groups together with household characteristics. My study focuses on incidence of carbon taxation on household consumption, ignoring the distribution of the external benefits. Incorporating such benefits would probably reduce tax burdens for all income groups and may have important distributional effects if the benefits are unevenly distributed across income groups.

When a tax is introduced, the full burden is not necessarily borne by consumers. Part of it may also fall on producers (in the form of lower rate of return on capital) and workers involved in taxed goods production or other goods (in the form of lower wages). In this sense, the overall tax incidence can be calculated only in a general equilibrium framework, because it generally depends on the market structure and on the price elasticity of supply and demand. In particular, low price elasticity of demand and high price elasticity of supply imply that the largest part of the tax burden is borne by consumers whereas in the opposite case most of the tax burden is borne by producers. The longer the time period over which factors can adjust, the more the cost of the policy is borne by consumers. Focusing on the introduction of a carbon tax, in the long run capital and labour would leave carbon-intensive industries until returns to factors in those industries reflected returns throughout the rest of the economy. An ideal measure of tax incidence would begin by calculating the general-equilibrium changes in prices that would occur throughout the economy in response to the change in the tax rate, and then computing the effects of those price changes on households welfare. It should be noted that I do not allow for possible general equilibrium effects. Calculating such effects requires a great deal of information, most notably the demand and supply elasticities for all relevant sectors, together with the distribution of ownership of firms in those industries. Thus, for simplicity's sake, many incidence studies assume that the supply of consumer goods is perfectly elastic: in particular, it is assumed that a carbon tax is fully shifted forward to consumers and increases the price of goods in proportion to their carbon content. For energy goods at least (e.g. oil), which are traded on international competitive markets, and in the case of a small open economy, this hypothesis is reasonable. The price changes produced by carbon taxation can be regarded as equivalent to a set of indirect taxes on consumer goods. In this case, distributional effects are determined by demand elasticities and market characteristics. In my analysis I will assume that the entire cost would be passed forward to the consumers.

My goal here is not to produce a perfect estimate of the incidence of the gasoline tax, but rather to compare different measures of incidence. Given a particular set of price changes, the question is how to measure the effect on household welfare. I compare different incidence measures, namely equivalent and compensating variation, which are computed using the demand system estimates for different household profiles.

The empirical model I develop is inspired by the framework employed by Brännlund and Nördstrom (2004), who analyse the implementation of the carbon tax in Sweden, hypothesizing revenue recycling in a reduction in the general or public transport value-added tax. The authors take the QAIDS as basic specification and they model the differences in consumption patterns between different household categories, by adding intercept and slope parameters in the budget share equations of the demand system. For the analysis of the demand for various goods that are relatively energy intensive, I will consider only current expenditure in non-durable goods. Regarding this issue, I will not follow Brännlund and Nordström (2004), who estimated a two-stage budgeting model.

My empirical work, devoted to the Italian case, has been particularly inspired by Tiezzi (2005); I will integrate the analysis she pursued considering the welfare effect generated on different households profiles and macro-regions. Furthermore, my empirical model will not only analyse the Italian carbon tax proposed in 1998, but it will simulate other scenarios, hypothesizing an impact only on certain groups of goods (fuels, heating fuels) or choosing different excise augmentations; doing this, I will be able to compare the distributive impact corresponding to each scenario and its potential regressivity. The period during which consumption will be examined covers nine years from 1997 to 2005.

With regard to methodological steps, I will follow Symons et al. (1998), who conduct their analysis in three stages. First, I will calculate the changes in prices caused by changing the tax rate; I want to specify that I will not analyse the effect on prices using an input-output approach, but I will simply add excise rates increases on consumer prices. The empirical model will be used to study the taxation of final goods, directly consumed from households, rather than to compute the price increase of other final assets, indirectly influenced by the introduction carbon tax. Second, I will investigate the expenditure patterns of consumers; third, the price changes derived from tax increases will be linked to consumer demand and the implication for consumers will be estimated by calculating the effects of those price changes on household welfare. I will use True Cost of Living Indices rather than other price indices, following Tiezzi (2005): they have the advantage of making the measure of welfare change more precise by incorporating behavioural responses. When information about households expenditure function is available, the calculation of exact measures of welfare change, such as compensating and equivalent variation, is fairly easy and gives more reliable information about welfare changes and distribution of the burden of a tax reform.

3.2 Some technical issues on demand systems

When estimating a demand system, one has to look for the more adequate specification referring to the studied problem, in particular to the specific taxation reform and the goods concerned. This issue must be satisfied assuring at the same time demand system theory constraint verification and providing a robust econometric basis. Moreover, it is important to find the correct level of aggregation between consumers, which enables to understand both the aggregate effect of a policy reform and its distributive impacts on different households' expenditure patterns.

3.2.1 Aggregation over goods and consumers

To be useful for most policy analysis applications, large complete demand systems need to be specified in terms of disaggregated commodities. However data requirement may be prohibitive if, at the same time, one wants to use parametric specifications that are not too constraining, such as standard flexible functional forms[24]. Moreover, the theory of consumer behaviour is based on individual consumer preferences. Data are usually available for aggregate commodity groups and aggregate groups of consumers; then some conditions are needed, which allow to consistently treat aggregate groups of commodities and consumers, given that the theory is based on micro-economic relationship. The first of these problems, aggregation across commodities, has been solved by using separability concepts and by imposing restrictions on the problem solved by consumers. Typically a separable structure for consumer preferences is assumed, that allows the consumer's expenditure allocation problem to satisfy multistage budgeting rules. A simplified two-stage budgeting is possible under two alternative conditions: homothetic weak separability of the direct utility function, or strong separability of the direct utility function into group sub-utility functions (Gorman, 1959). Utility function is weakly separable if and only if the marginal rate of substitution between two commodities belonging to the same group is independent of the level of consumption of a third commodity in any other group. Conversely, strong separability implies that the marginal rate of substitution between the two commodities is unaffected by the consumption of a third commodity which may belong to the same group of commodity. Additive preferences are closely related to this concept: preferences are additive if the direct utility function, except for a monotonic transformation, can be written as the sum of different functions that can be expressed only in terms of the quantities of commodities appearing in that particular group. The Linear Expenditure System is an example of a system derived from additive preferences.

In general, what is required is the aggregation of consumption into a composite commodity. One way to do this is to invoke the Hicks-Leontief Composite Commodity Theorem, which states that a group of goods can be treated as a single aggregate if their prices move in parallel. In absence of the Hicks-Leontief aggregation, an alternative approach is assuming separability of the commodity for which there are data from all other

[24] For a definition of flexible functional form, see Paragraph 3.3.

goods. This suggests that changes in welfare can be measured using a single demand equation as long as demand patterns are consistent with the separable structure of the utility function. In general, preferences of this type require strong elasticity equality restrictions among the goods that compose the composite commodity; tests of weaker forms of separability usually reject it. Note also that this form of separability does not actually solve the data problem that often motivates single equation methods. Without aggregating goods, collinearity of prices result in insignificant parameters estimates, since each equation in a demand system depends on the prices of all goods in the system. If prices of goods within groups were perfectly collinear, then, by the Hicks (1936) and Leontief (1936) Composite Commodity Theorem, the collinearly priced goods can be aggregated and the resulting aggregate demand system will remain integrable. Lewbel (1996) provides a generalization of the Hicks-Leontief Composite Commodity Theorem that allows aggregation without separability, under the more realistic assumptions that within-group prices are multicollinear but not perfectly collinear.

Grouping goods into aggregates is generally rationalised by assuming preferences are separable; different forms of separability exists and they have different theoretical and empirical implications on preferences. Strong or additive separability is rarely used across goods, because it imposes constraints on preferences that are often empirically violated (Deaton and Muellbauer, 1980a); this kind of separability is generally assumed to hold only across time periods. In practice, weak homothetic separability represents the form of separability more often assumed: in fact, it rationalises the standard practice of constructing a price index for each good and of using it to divide total expenditure on that good in order to define quantities. Weak homothetic separability implies that cost functions, direct and indirect utility function possess all the same properties as the corresponding functions of individual goods.

Although direct weak separability is neither necessary nor sufficient for standard two-stage budgeting, it provides the necessary and sufficient conditions for the existence of conditional (second-stage) demand functions, defined only on group prices and group expenditure allocations (Pollak, 1971). Such conditional demand functions typically depend on a small set of variables and some empirical studies have pursued the estimation of second-stage demand functions in isolation. First, separability assumptions usually result in the reduction of unknown parameter to be estimated: in fact, the demand analysis can concentrate on aggregate commodity group. This allows to focus on food demand, for instance, expressed as a function of the prices of food items and total food expenditure.

Price changes in other commodity groups affect food quantity demand through their impact on total food expenditure. Even if in certain cases a conditional analysis can provide useful information, generally conditional demand parameters are only of partial interest for policy analysis, so that such a widespread approach is questionable. Economic analysis and political questions often require to recover unconditional demands and, under direct weak separability, to estimate both first-stage and second-stage expenditure allocation functions. If one insists on not weakening the assumption of direct weak separability, then estimation of a complete demand system requires a consistent parametric specification for the two budgeting stages. While second-stage demand functions can easily be derived by Roy's identity applied to a specification of the (separable) group indirect sub-utility function, derivation of first-stage expenditure allocation functions appears more difficult, requiring an explicit solution of the conditional utility maximization problem.

Moreover, separability restrictions are not imposed without some costs. It is usually stressed that separability implies strong restrictions on the elasticities of goods contained within groups. Furthermore, using the same price index for every households implies that goods are purchased in the same proportions within groups: on the contrary, it would be more appropriate to construct price indices that vary across households. A popular choice is Stone's index (Stone, 1954a), given by a weighted average of the log of the prices of every aggregate good, whose weights are the households average expenditure shares on these goods. Furthermore, strong separability (perfect price aggregation) implies that there exists an approximate linear relationship between price and income elasticities. This very serious limitation runs counter the most empirical results, even if conditions for perfect price aggregation underlie a certain number of multistage complete demand systems. In any case, these conditions are often deemed too restrictive and for this reason more flexible forms that not impose additivity should be adopted; attempts have been made to model demand based on the hypothesis of direct weak separability only.

Generally, it is worth to be mentioned that all empirical results should be treated with some caution, because if the degree of aggregation across goods is quite large, the aggregation across households involves some approximations concerning the total expenditure distribution, and standard assumptions such as price exogeneity, time separability, and common functional forms across agents may be violated.

Regarding the problem of aggregation across consumers, an issue of importance for empirical analysis of consumer behaviour is the conditions that guarantee the existence of theoretically consistent aggregate demand. This is because consumer theory describes individual unitary households behaviour, but several significant empirical issues require the ability to make statements about aggregate demand. The two most common situations that call for aggregate demand are: 1) time series estimation from aggregated data 2) welfare effects about the aggregate consumer. The usual approach has been assuming identical preferences across consumers, expressing variables in the demand function in per capita terms, and turning to the "representative consumer" argument. More specifically, it is assumed that expressing aggregate demand function in per capita terms, the theoretically micro or individual results approximately carry over to the aggregate or market demand functions. But this has little theoretical foundation: it is necessary to obtain some conditions under which consistent aggregation across consumers is permitted. If preferences belong to a Price Indipendent Generalized Linear class[25] (PIGL), then market demand can be represented as if it was the outcome of decisions taken by a rational representative consumer (Deaton and Muellbauer, 1980a). Data on demographic composition of households or population, and then on distribution of demographic characteristics in the sample examined, enable to have a detailed description of purchasing behaviour. The knowledge of demographic characteristics distribution plays a key role in the comprehension of the consumption patterns' evolution at aggregate level: for this reason, it is important evaluating the impact of these characteristics on individual consumption choices. This problem can be reconnected to the issue of aggregation among individuals: the question is if a synthetic representation exists, which models purchasing behaviour in a consistent and not excessively restrictive way. If disaggregated data on household consumption are available, it is possible specify models that reflect households heterogeneity, determined by the presence of different demographic characteristics (see Paragraph 3.4).

3.2.2 Rank

According to Gorman (1981) results, in exactly aggregable demand system integrability imposes the restriction that the rank of the matrix of Engel curve coefficients[26] can not exceed three. Lewbel (1990) defined the concept of full rank functional form in demand systems estimation. This information is very important because full rank demand systems provide parsimonious representations of income effects. In fact, a demand system that is not full rank has terms that are linear combinations of other terms, which means that there

[25] For more details on Price Indipendent Generalized Linear class of preferences, see Paragraph 3.3.
[26] Being the Engel curve Marshallian demand holding price constant ($q=g(x)$), the matrix of its coefficient contains the derivatives of demand with respect to income.

are redundant parameters that do not add information to the functional form. Since degrees of freedom are usually a concern in most econometric studies, parsimonious functional forms are important.

The rank of any demand system can be defined as the maximum dimension of the function space spanned by the Engel curves associated to the demand system (Lewbel, 1991). This definition allows the concept of rank to be employed referring to any demand system, extending the previous definition of Gorman (1981), which only applied to exactly aggregable demand systems. In other words, the rank indicates the flexibility degree that Engel curve can have with the chosen demand system specification. For example, a demand system having all linear Engel curves is rank two, unless the Engel curves are all rays from the origin, in which case it is homothetic and hence rank one. Quadratic Engel curves can be either rank two or three. Any demand system has rank R if R goods exist such that the Engel curve of any good equals a weighted average of the Engel curves of those *R* goods. More formally, the rank of any given demand system *g(p,x)* is the smallest value of *R* such that each g_i can be rewritten as

$$q_i = g_i(p,x,m) = \sum_{r=1}^{R} \phi_{ir}(p,m)(p,x,m) \tag{3.1}$$

for some functions ϕ_{ir} and f_r. All demand system have rank $R \leq N$, the number of goods.

Generalizing Gorman (1981), when utility is homothetically separable into L groups of goods, then the rank of the demand system is a lower bound on L. Furthermore, if the household utility function is a social welfare function over *M* homothetic sub-utility functions associated to each of the *M* member of the household, then rank is also a lower bound on *M* (Lewbel, 2003). Exactly aggregable demands are useful because, as their name implies, they can be summed across consumers to yield closed form (though not necessarily representative consumer) expressions for aggregate demands (Jorgenson et al., 1982). On the other hand, the fact that utility derived demand systems must be homogeneous of degree zero in *x* and *p* greatly limits the types of Engel curves that the demand system can possess.

Rank has numerous implications for separability, for functional form, and for aggregation across goods and agents. Most conditions required for aggregate demands to resemble those of a representative consumer require either rank one or two. A demand system has rank one if and only if it is homothetic, meaning that all income elasticities equal one. Homothetic demand systems ($V(p,x) = a(p)x$) and Gorman polar form demand systems ($V(p,x) = a_i(p) + b(p)x$) result in budget shares, $p_i q_i / x$, that are constant across the income distribution. These systems are known as rank one demand systems: that means that the rank of the matrix of derivatives of demand with respect to income (proxied by total expenditure), *x*, is one. This implication is too restrictive for many commodities, even if acceptable for a small group of commodities. Because of the limitations of these functional forms, an adequate representation of demand for most commodities requires functional forms that are of rank greater than one. Theoretical restrictions on demand, such as Slutsky symmetry, place strong restrictions on the rank of demand systems. Gorman proved that the maximum rank of exactly aggregable demand systems is three: this implies that adding terms that are cubic or higher in income will not add new information to a demand system.

Lewbel (2003) highlights how asserting that utility maximization requires demands to have rank three or less constitutes a misinterpretation of Gorman (1981) results. In fact, these results only apply to the class of exactly aggregable demand systems (namely, utility derived demands that are exactly aggregable), while Lewbel (1991) has shown that all demand systems have a rank. Then, rank can be higher than three in not exactly aggregable demand systems, namely in utility derived deflated income demands, without violating utility maximization. To support this point, the author proposes a large set of rank four demand systems which possess two important features: they are consistent with utility maximization and they nest commonly used exactly aggregable demand systems of lower rank as special cases. Differently from utility derived demands that are exactly aggregable, derived deflated income demands must have rank less than or equal to four. The author aims to construct a demand system which has rank four without violating rationality. After having elaborated a parametric formulation for such a system[27], it is used to parametrically test the null hypothesis that the rank is three (or less) versus rank four, without imposing irrationality under the rank four alternative. The functional form used is log polynomial and it nests popular models like the Translog, Almost Ideal, and Quadratic Almost Ideal demand systems. Apart from testing, the new functional form developed by Lewbel (2003)

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[27] The "Nearly Log Polynomial Rational Rank Four Demand System" is derived considering the class of indirect utility functions given by

$$u^{-1} = \left(\frac{\ln[x - a(p)] - b(p)}{c(p)} \right)^{-1} + d(p)$$

where *a*, *b*, *c*, and *d* are functions of prices. Homogeneity requires that *c* and *d* be homogeneous of degree zero and that exp(*b*) and *a* be homogeneous of degree one in p.

Applying the Roy identity a deflated income demand system can be obtained which have rank four, provided that no one of the functions *a*, *b*, *c*, or *d* can be written as a function of the other three. The rank three QAIDS (Quadratic Almost Ideal) model of Banks, Blundell, and Lewbel (1997) equals the special case of this model in which $a(p) = 0$, and the rank two Almost Ideal Demand System of Deaton and Muellbauer (1980) equals the special case of $a(p) = 0$ and $d(p) = 0$.

could turn to be useful when estimating systems where a large number of different goods is included and then where demands of high rank are suspected.
Often income distribution tails contain significant non-linearities: rank could be lower when lowest and highest expenditure level households are dropped from the sample. For this reason, the popular AIDS and Translog models (which are PIGLOG, then they have budget shares linear in total expenditure) fit Engel curve data relatively well, but they are inadequate for encompassing households in tails. So, Engel curvature in the upper and lower income quintiles does not provide an effective preferences' representation when consumption is aggregated across consumers of all income levels.

3.2.3 Flexibility

Perhaps because of computational limitations, the earlier demand systems used specifications that could be estimated using linear or only slightly non-linear regression methods. In his pioneering study, Stone (1954a) developed and implemented the Linear Expenditure System and, much later, Hausman (1981) focused his attention to functional forms that could be estimated using linear regression. Even if easy to implement, linear demand functions may not be sufficiently flexible to measure demand responses to price and expenditure changes. The estimated elasticities may reflect the functional form assumed rather than the demand patterns revealed by the data. Out of this concern grew the development of what have become known as "flexible functional forms": any specification is likely to be incorrect, and the best one can hope for is an approximation to the demand or utility function. Functional flexible forms have been widely used in economics in order to approximate direct utility functions or cost functions. Albeit a flexible form is defined as a second order Taylor approximation of an arbitrary function (i.e. an utility function) it should be remarked that it is possible to make inference on the empirical results only in the local point in which the second order approximation neatly fits the theorethical general form. The principal flexible form is the Translog utility function, that possesses enough parameters to approximate any elasticities at a given point.
A demand system specification is said to be Diewert (1974) flexible if the values of the Marshallian demands, their derivatives and the cost functions can locally approximate the demand of any utility function. In other terms, they can all equal the corresponding values of any integrable demand system at one value of p and x. In most datasets the variation of total expenditure levels across consumers is quite large, whereas the amount of relative price variation is limited. Therefore, given an adequate specification of Engel curves,

almost any Diewert flexible specification for the price effects will be appropriate for modelling specific datasets.

The flexibility issue often refers to another kind of problem, linked to the negativity property. Focusing the attention on the AIDS system, the coefficients of the Slutsky matrix are not constant but depend on prices and income, according to the equation

$$S_{ij} = \frac{x}{p_i p_j}\left[\gamma_{ij} + w_i w_j - \delta_{ij} w_i + \beta_i \beta_j \ln\left(\frac{x}{P}\right)\right] \tag{3.2}$$

Then the inequality restrictions of negativity can hold only locally, for some specific values of prices and income, so that Slutsky matrix coefficient became constant. For example, the sample mean can be chosen as normalisation point and, in this case, the matrix of substitution effects will be negative semi-definite at the sample mean. In order to solve flexibility issue, a meaningful approach could be represented by imposing local curvature in consumer-demand systems (Diewert and Wales, 1987; Ryan and Wales, 1998). Moschini (1998) used this technique to impose curvature locally in the Almost Ideal demand system as a step in the development of a semi-flexible Almost Ideal model. When the unrestricted parameter estimates violate concavity, one can restrict the rank of the Slutsky substitution matrix, which in general is *(n-1)* for the case of *n* goods, and consider a model with a rank a substitution matrix of rank *K<(n-1)*. This procedure may be useful to achieve convergence of the parameters of the locally concave model, and it is known as the semi-flexible technique. Restricting the rank of the substitution matrix in such a locally concave demand model thus yields the Semi-flexible Almost Ideal Demand System (Moschini, 1998), because the price coefficients are estimated with less information.

The “bottom line” of discussions on flexible functional forms risks to be one of a trade off between plausible economic models with many theoretical restrictions versus possibly better data fitting with less economic foundation.

3.3 Demand system estimation

There are two different approaches to the derivation of theoretically plausible demand systems, that can be also connected to the distinction between choice based demand theory and preference based demand theory (Moro, 2004). The first one starts with the specification of a particular utility function (well behaved, that satisfies certain axioms of choice) to be maximized. After having considered the budget constraint, maximization yields a set of simultaneous demand functions. Choice based theory is only concerned with rational choice as defined by axioms of revealed preference: it is agnostic about the existence of preferences behind choices. This approach is based on choices, which are directly observable. On the contrary, preference based demand theory (the classical approach) is directly based on consumer theory and begins with axiomatically defined preferences, deriving rational choices from them. Integrability is concerned with determining whether observed demand functions are coherent with consumers preferences system and utility maximization process: it is this rationalisation that gives to the areas under demand curves economic welfare implications. So, this alternative approach chooses an arbitrary demand system and then it imposes restrictions on the system of demand functions, such as homogeneity conditions or Slutsky symmetry constraints.

More precisely, all theoretically plausible demand systems should satisfy four properties, the so-called integrability properties: adding-up, homogeneity, symmetry and negativity.

According to the adding-up restriction, budget shares of both ordinary and compensated demand functions sum to one; equivalently, both ordinary and compensated demand must sum to total expenditure (Walras law):

$$\sum_k p_k h_k(p,u) = \sum_k p_k q_k(p,x) = x \tag{3.3}$$

where h_k represents the Hicksian demand and q_k the Marshallian demand for each of the k goods. Homogeneity states that the purchased good remain the same if all prices and income increase by the same proportion. Hicksian demands are homogenous of degree zero in prices, whereas Marshallian demands are homogenous of degree zero in *(p,x)*; then (3.4) holds

$$h_i(\theta p, u) = h_i(p,u) = h_i(p, v(p,x)) = q_i(p,x) = q_i(\theta p, \theta x) \tag{3.4}$$

Slutsky's symmetry condition asserts that the substitution effects matrix is symmetric, that is to say

$$\frac{\partial h_i(p,u)}{\partial p_j} = \frac{\partial h_j(p,u)}{\partial p_i} \tag{3.5}$$

Shephard's lemma enables to rewrite symmetry property in terms of cost function second order derivatives:

$$\frac{\partial^2 c(p,u)}{\partial p_i \partial p_j} = \frac{\partial^2 c(p,u)}{\partial p_j \partial p_i} \tag{3.6}$$

and the Young Theorem ensures the equality constraint is verified. Both homogeneity and symmetry can be checked by imposing parametrical restriction on the demand systems parameters.

Finally, negativity restriction is also related to the compensated price elasticities and implies that the matrix of substitution terms (Slutsky matrix) must be negative semi-definite[28]. This, in turns, yields to non-positive diagonal elements, which represent compensated own-price derivatives. Alternatively, this restriction can be expressed with reference to compensated demand curve, which must be downward sloping (the law of demand must hold). This property can be checked by imposing inequality constraints, and for this reason its tests are more complicated than those of the previous ones.

These properties have relevant implications on demand system estimation, because they assert that in a demand system composed by *n* goods there are only *n-1* independent expenditure shares, thus they allow to estimate only *n-1* parameters. Moreover, following Engel aggregation, only *n-1* income elasticities are independent; finally, being cross-price elasticities matrix symmetric, there are only *n(n-1)/2* independent cross-price elasticities.

Following this approach, the parametric form for the utility (or demand) function is assumed to be the same for all households. Observations on expenditure patterns are used to recover the utility function and measure the changes in welfare resulting from actual or simulated policies. Heterogeneity is accounted for by allowing preferences and demand to be functions of household characteristics, whereas unobserved differences can be accommodated through the stochastic specification of the econometric model.

Looking at the properties of indirect utility function and the expenditure function one can note that convexity/concavity and homogeneity are common functional features of these functions. The sample fact that these functions can be defined as solution of optimization problems implies convexity/concavity. Instead, homogeneity is a direct result of linear objective functions or constraints in the optimization problem that define the function. One important property associated to homogeneity is that if a function is homogeneous of degree *k* then its derivative is homogeneous of degree *k-1*. The expenditure function is homogeneous of degree 1 in prices and therefore, the Hicksian demands, obtained by applying Shephard’s lemma to the expenditure function, are homogeneous of degree 0 in prices. This feature has well-known implications of consumer theory: in fact, if all prices rise by 20%, Hicksian demands should be unchanged; if also total expenditure rises, the same holds for Marshallian demands.

With regard to the budget constraint, and in particular deriving it with respect to total expenditure, significant observable restrictions on income elasticities of demand come out. In very simple words, it is not possible for all goods to be luxuries or to be necessities (Engel aggregation). On the other hand, deriving the budget constraint with respect to

[28] Referring to the underlying expenditure function, this property ensure its the concavity in prices.

prices entails restrictions on the price elasticity of demand (Cournot aggregation). Own-price and cross-price effects can not be too large or too small; these restrictions are not as strong as the restrictions on compensated cross-price effects from Hicksian demand, because Marshallian demand includes income effects as well as substitution effects. For example, since the expenditure function is concave in prices, own-price elasticities must be negative (the diagonal elements of the Hessian of the expenditure function must be negative). Being the Hicksian demands homogeneous of degree 0 in prices, the sum of cross-price compensated elasticities from Hicksian demand should be equal to zero, a stronger restriction than the restriction on the Marshallian demand elasticities.

A different kind of problem is linked to the fact that the expenditure level which rationalises the aggregate budget shares may change if the prices change because in general aggregate expenditure depends on prices. In order to avoid this problem, the condition that aggregate expenditure x is independent of price *p* needs to be imposed. So expenditure *x* must take the form *v*

$$v = x_0^{-\alpha} \qquad v_h = \left(\frac{x_h}{k_h(p)}\right)^{-\alpha} \tag{3.7}$$

or alternatively

$$v = \ln(x_0) \qquad v_h = \ln(x_h / k_h) \tag{3.8}$$

where *k* is a price index and *h* index distinguish different households. Consequently, the form of macro expenditure functions will be either

$$c(p,u_0) = \left[(a(p))^{\alpha} + (b(p))^{\alpha} u_0\right]^{1/\alpha} \tag{3.9}$$

or

$$c(p,u_0) = (a(p))^{u0} b(p) \tag{3.10}$$

These functional forms are called price independent generalized linearity, PIGL (Deaton and Muellbauer, 1980b); in (3.8) budget shares are expressed as a function of *ln x*, as one can see by inverting the expenditure function to find the indirect utility function:

$$V(p,x) = \frac{\ln(x / b(p))}{\ln(a(p))} \tag{3.11}$$

Thus, the derivatives with respect to p will be functions of *ln x*: due to this property this functional form is called PIGLOG. It is the basis of the most widely used demand systems, as for example AIDS and Translog models. Another form of PIGLOG preferences can be obtained by taking the limit of (3.9) as $\alpha \rightarrow 0$. In order to ensure that $\partial c(p,u_0)/\partial p_i > 0 \quad \forall i$, β^{α} is replaced by $b(p)^{\alpha} - a(p)^{\alpha}$, where $b(p) > a(p)$; then one obtains

$$\ln c(p,u_0) = \ln a(p) + \ln(b(p)/a(p))u_0 = \ln a(p)(1-u_0) + \ln b(p)u_0 \tag{3.12}$$

By normalizing utility so that its range will be between 0 and 1, *a(p)* and *b(p)* can be respectively interpreted as subsistence and bliss expenditure levels.
The first attempt to compute a demand system has been made by Stone (1954a), who has estimated a demand system directly based on consumer theory. He has adopted a LES (Linear Expenditure System), proposed by Klein and Rubin (1947) and Samuelson (1947). Later developments have made flexible functional (FFF) more used specification of demand system. This notion has been introduced by Diewert and Wales (1987): flexible forms are first order Taylor approximation of some arbitrary demand function or second order approximation of some cost or indirect utility function. They are employed in order to approximate functions of interest which are unknown and unobservable; for these reasons, FFF must satisfy some theoretical properties and have a certain number of free parameters, so that they can be considered a good approximation. Demand theory provides a large number of flexible functional forms to describe the preferences of a representative household without assuming too strong prior restrictions. In particular, two flexible forms have been widely used, the TRANSLOG and PIGLOG model: the first one represents a second order approximation of an indirect utility function, whereas the second one a second order approximation of a cost function. The standard approach in the computation of expenditure share equations has hitherto been to assume a particular form for the functions, and to estimate the parameters of that function by minimizing some criterion function (either ML or GMM); some examples follow. The Working-Leser (Working, 1943) model posits that household expenditure share equations are log-linear in total expenditure. The Almost Ideal (Deaton and Muelbauer, 1980b) system also hypothesizes log-linear budget shares at any price vector; differently, the Integrable Quadratic Almost Ideal (Banks et al., 1997) model has non-linear share equations.
Among the many demand specifications in the literature, the Rotterdam model and the Almost Ideal Demand System have often been applied in consumer demand systems modelling. They are based on flexible functional forms, so they do not put a priori restrictions on the possible elasticities, i.e. they possess enough parameters to approximate any elasticity at a given point. These two models partly due their success to the possibility of being estimated without relying on non-linear estimation and of imposing and testing theoretical restrictions with ease. In addition, the AIDS model has other attractive features: the properties of the preference relations from which it is derived are known and it is generated from a known cost function with the desired properties. Deaton and Muellbauer (1980b) pointed out the striking similarity between these two models, showing that the

AIDS model with linear price can be rewritten in difference form so that it has the same dependent variable as the Rotterdam model expressed in absolute prices.

Different options available for demand system estimation will be described in the following sub-paragraphs, in chronological order, trying to highlight developments that have been made and to explain controversial issues. Paragraph 3.4.2, instead, will be entirely devoted to the description of a recent conceived demand system (Lewbel and Pendakur, 2008), which takes into account demographical households characteristics and for this reason because of its particular structure needs to be estimated on individual data.

3.3.1 Linear Expenditure System

An early functional form that was used to conduct empirical studies of consumer behaviour is the Linear Expenditure System (LES; Klein and Rubin, 1947; Stone, 1954a). It is obtained by solving the primal consumer optimisation problem. Let assume consumer has a direct utility of this form

$$U = \sum_i \beta_i \ln(q_i - \alpha_i) \qquad (3.13)$$

where q denotes the consumption of the ith good and α is the committed consumption, with $q_i > \alpha_i$, $0 < \beta_i < 1$ and the normalisation $\sum_i \beta_i$ = 1. Maximization subject to the budget constraint $x = \sum_i p_i q_i$ gives rise to the linear expenditure functions:

$$p_i q_i = \alpha_i p_i + \beta_i \left(x - \sum_j \alpha_j p_j \right) \qquad (3.14)$$

Dividing equation (3.14) by x one can obtain LES in terms of expenditure shares. Parameters α represent subsistence consumption level of each good, initially purchased by each individual; residual income $\left(x - \sum_j \alpha_j p_j\right)$ is allocated among different goods according to the β parameters, which represent marginal expenditure shares, constant with LES.

Concerning demand properties, LES satisfies homogeneity and adding-up by construction. LES is a demand system linear in income and it derives from quasi-homothetical preferences. It is the only demand system theoretically plausible where expenditure for every good is a linear function of prices and income. It is important to notice that the assumed linearity of the Marshallian demand functions can cause severe problems if economic data do not reflect this assumption. As long as the duality occurs, the cost (expenditure) function has to be concave in prices: this hypothesis directly affects (3.14), as β_i has to be strictly positive. In particular, the expression for income elasticity ($\partial q_i / \partial x$

$= \beta_i / p_i$) demonstrates one of the limitations of the linear expenditure system. Then, the linear model fails to consider the existence of inferior goods in the consumer's basket. Intuitively, it means that all the consumer's assets are substitutes; moreover, the linear model implies a Slutsky matrix such that the elasticity to expenditure is strongly correlated to the cross-prices elasticities. This hypothesis is hardly verified in economic data, then estimating LES constitutes a restrictive framework for many empirical analysis. One of the limitations of the Linear Expenditure System is that its Engel curves are straight lines, while econometric tests have often rejected one and two parameters Engel curves in favour of three parameter functional forms.

Then, even if the linear system proposed by Stone (1954b) is directly derived from the demand theory and it represents a powerful instrument to perform consumers analysis, it is better to consider how other models can satisfy the theoretical requirements allowing for a better fit of real data.

3.3.2 Translog

Another class of logarithmic functional forms is the Translog class (Christensen et al., 1975). This class generalizes the Cobb-Douglas functional form by adding quadratic terms to the log-linear terms in the Cobb-Douglas function. The addition of quadratic terms represents an approach frequently used by flexible functional forms. The idea of flexible functional forms is to specify functions containing a number of free econometric parameters equal to the independent economic parameters that need to be estimated. This specification implies that budget shares are independent of income. In other words, the specification requires that consumers at all points along the income distribution allocate their budgets identically. This is a consequence of the homotheticity of the indirect utility function. Homothetic functions are not useful for the specification of indirect utility functions because they imply that Engel curves are straight lines emanating from the origin. The behavioural interpretation of this property is that demand is proportional to income, or budget shares are independent of income; this is obviously an unreasonably restrictive assumption.

Implying that consumers have identical budget shares at all points along the income distribution, the homothetic Translog model is too restrictive for modelling consumer behaviour. So another member of the Translog class of models is needed to model consumer behaviour.

A widely used model is the log Translog model which has an indirect utility function that is specified as:

$$v(p,x) = -\sum_i \alpha_i \ln(p_i / x) - \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln(p_i / x)\ln(p_j / x) \tag{3.15}$$

By using Roy identity, (3.15) lead to the following budget share equation

$$s_i(p,x) = -\frac{\partial v / \partial \ln p_i}{\partial v / \partial \ln x} = \frac{\alpha_i + \sum_j \beta_{ij} \ln p_j - \sum_j \beta_{ij} \ln x}{1 + \sum_k \sum_j \beta_{kj} \ln p_j} \tag{3.16}$$

The designation log Translog has been assigned by Pollack and Wales (1969), others simply refer to it as the Translog. Both (3.15) and (3.16) are difficult models to estimate, because they are non-linear in the parameters; if normal errors are assumed, it is fairly straightforward to estimate the model by maximum likelihood. Pollack and Wales (1969) observe that another difficulty of this class of models is parameters interpretation: differently from linear expenditure system and Rotterdam models, the Translog parameters have not straightforward meanings so that elasticities have to be calculated.

3.3.3 Rotterdam

The Rotterdam model (Barnett, 1979) is one of the first demand systems, together with LES model, to be based on consumption theory. It can be obtained starting from Marshallian demand ($q_i=q_i(p,x)$) total differential:

$$dq_i = \frac{\partial q_i}{\partial x} dx + \sum_j \frac{\partial q_i}{\partial p_j} dp_j \tag{3.17}$$

It can be rewritten as

$$d \ln q_i = \varepsilon_i d \ln y + \sum_j \varepsilon_{ij} d \ln p_j \tag{3.18}$$

In this specification, differently from LES, price elasticities are not assumed constant. From equation (3.18), employing Slutsky equation and multiplying by w_i, one obtains

$$w_i d \ln q_i = w_i \varepsilon_i (d \ln x - \sum_j w_j d \ln p_j) + \sum_j w_i \eta_{ij} d \ln p_j \tag{3.19}$$

The parameters η_{ij} represents the elements of the Slutsky matrix: then this model allow to determine whether the different goods are substitute or complements, without imposing the restrictions wich characterized LES.

The absolute prices version of the Rotterdam model is given by

$$w_i d \ln q_i = \theta_i (d \ln x - \sum_j w_j d \ln p_j) + \sum_j \pi_{ij} d \ln p_j \tag{3.20}$$

The factor $(d \ln x - \sum_j w_j d \ln p_j)$ can be interpreted as proportional changes in expenditure.

Using the budget constraint, an equivalent form of expression (3.20) is represented by

$$w_i d\ln q_i = \theta_i d\ln Q + \sum_j \pi_{ij} d\ln p_j \tag{3.21}$$

Where $w_i d\ln q_i = \sum_j w_j d\ln q_j$.

$$\overline{w}_{it} \Delta\ln q_{it} = \theta_i \Delta\ln Q_t + \sum_j \pi_{ij} \Delta\ln p_{jt} \tag{3.22}$$

where $\overline{w}_{it}$ =1/2 $(w_{it} - w_{it-1})$

Differently from other functional forms, which are approximation in the variables space (quantity, price and income), the Rotterdam model can be better interpreted as an approximation in the parameters space. Then, while the AIDS or Translog models can represent an exact preference system, the Rotterdam model cannot, unless adopting strong restrictions. In particular, the Rotterdam model coefficients can be constant only if income and direct price elasticities all equal one. To summarize, the Rotterdam model is a valid linear approximation of any demand system, but it should not be referred to a specific representation function: in this case the model coefficients can be interpreted only as constant approximation of the real ones. However, Mountain (1988) demonstrated that the Rotterdam model can be interpreted as an approximation in the variables space and that its coefficients can be referred to a cost function. With this result, the model is as flexible as any other functional form and its approximation is not inferior to the one provided by any other model.

Although it has almost fallen into disuse because of its many documented problems, the Rotterdam system has the previously unrecognized virtue of depending only on differenced, and hence possibly stationary, prices (Lewbel, 1985).

3.3.4 AIDS

The Almost Ideal Demand System has been derived by Deaton and Muellbauer (1980b) from a specific class of preferences which represent market demands as if they were the outcome of decisions by a rational representative consumer (under the hypothesis of exact aggregation over consumers). The models presented before do not explicitly recognize the agents preference structure, as they simply maximize the representative agent problem, ignoring the aggregation requirements. Deaton and Muellbauer (1980b) propose a different approach, which reckon in aggregation and satisfies the properties of theoretical demand functions. In order to aggregate individual data and estimate the market demand, it is useful to investigate whether the Marshallian demands given by $q_i = f_i(x, p)$ can be represented only as a function of the aggregate income level, without imposing the strong condition for which the aggregate income mean is considered the only approximation of the income distribution. The authors suggests that, when Engel's curves are non-linear, it is possible to determine a generalised linearity condition under which the aggregate demands are function of a representative income level, which depends on the degree of non-linearity of the Engel curves.

In order to define a representative consumer, an indirect utility function *v(x; p)* and its corresponding cost function *c(u; p)* have to be defined. The Marshallian demand functions can be derived directly from the cost function since its price derivatives are the quantities demanded $\partial c(u,p)/\partial p_i = q_i$. Multiplying both sides by $p_i / c(u,p)$ we find

$$\partial \ln c(u,p)/\partial \ln p_i = p_i q_i / c(u,p) = w_i \qquad (3.23)$$

Then, Deaton and Muellbauer (1980a) demonstrates that the cost function of the representative agent must take the form:

$$c(u_0, p) = \theta[u_0, a(p), b(p)] \qquad (3.24)$$

(3.23) can then be rewritten as:

$$w_i(u_0, p) = \frac{\partial \ln \theta}{\partial \ln a}\frac{\partial \ln a}{\partial \ln p_i} + \frac{\partial \ln \theta}{\partial \ln b}\frac{\partial \ln b}{\partial \ln p_i} \qquad (3.25)$$

but, since θ is homogeneous of degree 1 in *a* and *b*, it becomes:

$$w_i(u_0, p) = u_0 \frac{\partial \ln a}{\partial \ln p_i} + (1-u_0)\frac{\partial \ln b}{\partial \ln p_i} \qquad (3.26)$$

If we consider the special case in which the expenditure levels are independent from prices, the representative cost function is given by:

$$c(u, p_i) = \left[a(p)^{\alpha}(1-u_0) + b(p)^{\alpha}u_0\right]^{\frac{1}{\alpha}} \qquad (3.27)$$

in which *a* characterizes the form of the Engel's curve and u_i is the utility of the representative
agent.

When α tends to zero, (3.27) becomes:

$$\ln c(u,p) = (1-u)\ln\{a(p)\} + u\ln\{b(p)\} \qquad (3.28)$$

These preferences are known as the PIGLOG class and are connected to a cost or expenditure function (3.28) which defines the minimum expenditure necessary to attain a specific utility level at fixed prices. In particular, *a(p)* and *b(p)* can be regarded as the prices of the intermediate goods that define the cost function, namely subsistence and bliss: the utility, in fact, lies between 0 (subsistence) and 1 (bliss). For a utility-maximizing consumer, total expenditure *x* is equal to *c(u,p)* and this equality can be inverted to give the indirect utility function, where u is a function of p and x[29]. In this way one can obtain AIDS demand functions in budget share forms.

Let us consider a cost function PIGLOG such as equation (3.28) where a and b are a function of prices, respectively homogenous of degree one and two in prices

$$\ln a(p) = \alpha_0 + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j \tag{3.29}$$

$$\ln b(p) = \ln a(p) + b_0 \prod_i p_i^{\beta_i} \tag{3.30}$$

The Hicksian demand functions in budget shares follow from Shephard's lemma:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i u \prod_j p_j^{\beta_j} \tag{3.31}$$

By inverting the utility function, the following expression of demand function (Marshallian budget shares) can be obtained

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i [\ln x - \ln a(p)] \tag{3.32}$$

The Almost Ideal Demand System functions add up total expenditure, are homogeneous of degree zero in prices and total expenditure, and satisfy Slutsky symmetry. Without changes in relative prices and real expenditure (p and x), the budget shares are therefore constant whereas changes in relative prices work through the terms γ_{ij} and changes in real expenditure through the β_i coefficients.

AIDS uncompensated cross-price elasticities e_{ij}^M and income elasticities e_i are respectively given by:

$$e_{ij}^M = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} + \frac{\beta_i \beta_j}{w_i}[\ln x - \ln a(p)] - \delta_{ij} \tag{3.33}$$

$$e_i = \beta_i / w_i + 1$$

where γ_{ij} and β_{ij} are estimated coefficients and δ_{ij} the Kronecker delta, equal to one when $i=j$ and zero otherwise. Conversely, the compensated cross-price elasticities e_{ij}^C are given by:

$$e_{ij}^C = \frac{\gamma_{ij}}{w_i} + w_j + \frac{\beta_i \beta_j}{w_i}[\ln x - \ln a(p)] - \delta_{ij} \tag{3.34}$$

When the model is in expenditure share form with price and income variables expressed in logarithms price and income elasticities can be obtained with the following expressions:

[29] The indirect utility function provides the theoretical background to obtain demand system budget shares coherent with consumer behaviour and utility maximization; since it is clearly not observable, in order to derive budget share equations one must invert it.

$$\frac{\partial w_i}{\partial \ln p_j} = (e_{ij}^C + \delta_{ij})w_i \qquad (3.35)$$

$$\frac{\partial w_i}{\partial \ln x} = (e_i - 1)w_i$$

The linear version of AIDS can be computed, where the TRANSLOG index (ln a(p)) is substituted by an easier to compute index, for example Stone index

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i [\ln x - \ln P] \qquad (3.36)$$

where $\ln P = \sum_k w_k \ln p_k$.

In this case, the expressions of Marshallian income elasticity, Marshallian and Hicksian price elasticities are given by:

$$e_i = \frac{\beta_i}{w_i} + 1$$

$$e_{ij}^M = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} - \delta_{ij} \qquad (3.37)$$

$$e_{ij}^C = \frac{\gamma_{ij}}{w_i} - w_j - \delta_{ij}$$

Consequently, the constraints related to theoretical properties satisfaction can be expressed as

Homogeneity $\sum_j \gamma_{ij} = 0$

Adding-up $\sum_i \alpha_i = 1 \quad \sum_i \gamma_{ij} = 0 \quad \sum_i \beta_i = 0$ (3.38)

Symmetry $\gamma_{ij} = \gamma_{ji}$

Negativity matrix [$\gamma_{ij} + w_i w_j - \delta_{ij} w_i$] must be negative semi-definite

In models expressed by means of budget shares in logarithmic form, income and price elasticities can be derived using these equations

$$\frac{\partial w_i}{\partial \ln p_j} = (\varepsilon_{ij} + \delta_{ij})w_i$$

$$\frac{\partial w_i}{\partial \ln y} = (\varepsilon_i - 1)w_i \qquad (3.39)$$

The popularity of the AIDS is certainly related to its properties. As other demand systems, simple parametric restrictions allow symmetry and homogeneity of degree zero both in prices and income to be handled. In addition, demand functions resulting from the Almost Ideal model possess non-linear Engel curves, while, at the same time, allowing for exact aggregation across consumers. This property is due to the fact that preferences underlying the AI model are of the Generalized Gorman Polar Form[30], a class that includes some other popular models such as a version of the Translog demand system. Non-linear curves imply that, in the event of a necessary good (income inelastic), an increase in income not only decreases the share of income allocated to that good but also reduces income elasticity. Another reason for the popularity of this model is that, while satisfying the number of desirable properties already enounced, a linear approximation can be estimated. The linear AI model specification employs a Stone price index and it gives an arbitrary first-order approximation to any demand system. It should not be forgotten that this linear model is not itself derived starting from a well-specified representation of preferences, and so it is worth being considered only as an approximation to the integrable non-linear AI model. Hence, it is important to guarantee good approximation properties for the linear AI model. Unfortunately, these properties are likely to be affected by the fact that the Stone index is not invariant to the choice of the unit of measurement for prices and quantities.

Empirical application of the AIDS can encounter other problems. First, the model does not explicitly consider concavity of the expenditure function (that implies that the Slutsky matrix is negative semi-definite), so that estimation results often violate this condition. Second, the model can become prohibitively demanding in terms of data requirement, as the number of good being examined increases. In particular, while the number of parameters to be estimated increases quadratically, the number of effective observations increases only linearly. For large demand systems, statistical properties of the estimated model can be affected by a degrees of freedom problem. A procedure to solve this inconvenient could be saving degrees of freedom by restricting the substitution possibilities across goods, then by diminishing the rank of the Slutsky substitution matrix (Moschini, 1998).

3.3.5 QAIDS

Lewbel (1990) has shown that a generic demand system must take one of the following forms: homothetic, PIGL, PIGLOG or quadratic. The homothetic form is a rank one demand system whereas the PIGL and PIGLOG forms are rank two demand systems. The quadratic logarithmic demand functions have rank three and they are the basis of the Quadratic Almost Ideal Demand System. The PIGLOG form has budget shares that are linear in $\ln x$ and the QAIDS has budget shares that are quadratic in $\ln x$. Then, the

[30] Gorman's aggregation result can be generalized by defining the representative consumer through budget shares instead of quantity demanded. This generalization defines PIGLOG preferences and allows the Engel curves to be non-linear in expenditure.

PIGLOG functional form allows budget shares to vary with log income in a linear manner, whereas the QAIDS allows budget shares to vary non-linearly in *lnx*.

Banks et al. (1997) specified the Quadratic Almost Ideal Demand System and generalize the AIDS adding a non-linear income term to the share equations. They derive a new class of demand systems that add higher order income terms to log income in the expenditure share equations. This is consistent with utility theory and allows flexible relative price effects, providing a practical specification for demands across many commodities (using a pooled data set of UK households).

Thus PIGLOG share equations $S_i = A_i(p) + B_i(p)\ ln(x/P)$ are generalized to:

$$S_i = A_i(p) + B_i(p)\ln(x/P) + C_i(p)g(x/P) \tag{3.40}$$

In particular, in equation (3.40) the $C_i(p)g(x/P)$ term allows for non-linearities and, at the same time, it could be near zero for the goods which are characterized by linear Engel curves. The rank of equations system (3.40) equals the rank of the *Nx3* matrix of Engel curve coefficients, with rows [$A_i\ (p)$:B_i:$C_i\ (p)$] for good *i*. This matrix has three columns so that this value corresponds to the maximum possible rank of the equation system.

The authors specify the log indirect utility function as a generalization of the indirect PIGLOG utility function:

$$\ln V(p,x) = \left\{ \left(\frac{\ln x - \ln a(p)}{b(p)} \right)^{-1} + \lambda(p) \right\}^{-1} \tag{3.41}$$

The functions *ln a(p)* and *b(p)* have the same parametric restrictions as the AIDS model and we also have the restriction $\sum_j \lambda_j = 0$. When $\lambda(p)$ is independent of prices, the indirect utility function (3.41) becomes equivalent to the PIGLOG class which includes the Almost Ideal and Translog models. Using both parametric and non-parametric tests, the authors demonstrate empirically that the quadratic logarithmic utility function appears to be the best rank three functional form for modelling demand.

Applying Roy's identity, share equations for the QAIDS are given by

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{x}{a(p)} \right) + \frac{\lambda_i}{b(p)} \left\{ \ln\left(\frac{x}{a(p)} \right) \right\}^2 \tag{3.42}$$

The function A_i in equation (3.40) corresponds to the *i*th *ln p* derivative of *ln a(p)* and the same holds for B_i and C_i. This functional form is obviously a generalization of the AIDS, which adds a term that is quadratic in the log of deflated income. This allows for non-linear changes in budget shares with respect to changing in prices or income levels. It also provides an easy way to test for these non-linear effects, by testing the null hypothesis that the parameters $\lambda_i=0$. For example, Tiezzi (2005), at an earlier stage of her analysis, specified the demand system as a QAIDS, but after having tested the significance of the quadratic parameters rejected this functional form. The model had therefore been restricted to the AIDS form.

To calculate QAIDS elasticities, the expenditure share form of the model (3.42) must be differentiated with respect to *lnx* and lnp_j, to obtain respectively[31]

$$\mu_i = \frac{\partial w_i}{\partial \ln x} = \beta_i + \frac{2\lambda_i}{b(p)}\left\{\ln\left[\frac{x}{a(p)}\right]\right\} \quad (3.43)$$

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i(\alpha_i + \sum_j \gamma_{ij} \ln p_j) + \frac{2\lambda_i}{b(p)}\left\{\ln\left[\frac{x}{a(p)}\right]\right\}^2$$

Budget elasticities *e* are given by

$$e_i = \mu_i / w_i + 1 \quad (3.44)$$

Banks et al. (1997) find that, when β is positive and λ is negative, this elasticity is greater than unity at low levels of expenditure and become less than unity as the total expenditure increases: then, the concerned good has the characteristics of luxuries at low levels of total expenditure and of necessities at high levels (for the authors, this is the case of clothing and alcohol).

With regard to uncompensated price elasticities e_{ij}^M , their equations are represented by

$$e_{ij}^M = \mu_{ij} / w_i - \delta_{ij} \quad (3.45)$$

where δ_{ij} is the Kronecker delta. Using the Slutsky equation, the set of compensated elasticities e_{ij}^C can be computed

$$e_{ij}^C = e_{ij}^M + e_i w_j \quad (3.46)$$

and the symmetry and negativity conditions can be assessed.

3.4 Demographic variables in demand system estimation

In this paragraph I will survey different ways to introduce demographic variables in demand system estimation. In particular, Paragraph 3.4.1 will describe two techniques, demographic translating and scaling; Paragraph 3.4.2 will deal with EASI, a demand system which considers demographic variables; Paragraph 3.4.3 will shift the attention on welfare comparison, differentiating by household profiles, carried out using equivalent scales.

[31] With respect to the AIDS model, the computation of elasticities clearly follows the same steps: for this reason the analogous of equations (3.44) has not been included in the previous paragraph, focused on the simplified AIDS functional form.

Consumer demand patterns typically found in micro data sets vary considerably across households with different characteristics and levels of income. This requires – and discourages any different one – an approach based on the consideration of demographic and other variables that allow to identify homogenous households groups.

3.4.1 Demographic translating and scaling

Demographic translating and demographic scaling are alternative procedures for incorporating major determinants of household consumption patterns, such as age and number of children, into complete systems of demand equations. Both methods can be decomposed into three steps: 1) specifying a class of demand system for every demographic profile; 2) indicating the parameters which depend on the demographic variables; 3) finding, for each of these parameters, a functional form relating it to the demographic variables. Demographic translating and demographic scaling differ just in the way they specify which parameters depend on demographic variables.

Demographic translating is basically an introduction of demographically-varying constant terms in demand equations. One may demographically scale and translate budget shares of goods, instead of quantities. This is a natural way of introducing demographic variation in models like the AIDS or the indirect Translog system, which are fundamentally budget share models. For example, AIDS has constant terms in the equations for budget shares instead of in quantity equations. To let these constants vary demographically represents an application of demographic translating. Demographic translating introduces *n* translation parameter $(d_{1,\ \dots,} d_N)$ into a demand system, and it postulates that only these parameters depend on the demographic variables. The specification is completed by postulating a functional form relating the translation parameters to the *N* demographic variables $(\eta_{1,\ \dots,}\eta_N)$. For instance, linear demographic translating is a functional form like

$$D^i(\eta) = d_i^* + \sum_{r=1}^{N} \delta_{ir}\eta_r \qquad (\ 3.47\ )$$

and it adds at most *n* x *N* independent parameters to the original demand system. If the original demand system is theoretically plausible, then the modified system will also be plausible. When translating is used to introduce demographic characteristics into complete demand systems, there is a close relationship between demographic variables and consumption patterns. A change in η_t causes reallocation of expenditure among the consumption categories but total expenditure remains unchanged, so any increase in the consumption of some goods must be balanced by decrease in the consumption of others. The sign of the effect on the expenditure share of a change in η_t cannot be inferred from the sign of its effect on d_i: there is no a priori presumption that an increase in a demographic variable such as family size will increase rather than decrease d_i, since changes in parameters d, regardless to their direction, imply a reallocation of expenditure among goods leaving total expenditure unchanged. The last result holds also when demographic scaling is used.

Demographic scaling is a general procedure for incorporating demographic variables into demand systems, and it follows very similar steps to the demographic translating approach. Demographic scaling can be considered as a commodity specific adult equivalent scale; it first introduces n parameters $(m_1, \ldots, m_n)$ into the original system, then postulates that only these depend on demographic variables. The specification is completed by postulating a functional form relating these parameters to demographic variables. For example, linear demographic scaling is given by

$$M^i(\eta) = 1 + \sum_{r=1}^{N} \varepsilon_{ir}\eta_r \qquad (3.48)$$

The distinctive feature of demographic scaling is the way in which it introduces the scaling factors into the original class of demand system $\{x_i = \underline{h}^i(p, x)\}$ which is replaced by the modified system:

$$h^i(p, x) = m_i \underline{h}^i(p_1 m_1, p_2 m_2, \ldots.., p_n m_n, x) \qquad (3.49)$$

If m_i is interpreted as reflecting the number of equivalent adults in the household, measured on a scale appropriate to good i, then preferences and demand behaviour can be viewed in terms of demographically scaled prices and quantities. It should be mentioned that, as it was for demographic translating, formally there is not even a presumption that an increase in a demographic variable will increase rather than decrease the m parameters. Under demographic scaling the effects of changes in demographic variables are closely related to the effects of price changes, and this is most clearly visible in elasticity form. Even if adult equivalent represent the oldest and most commonly used method of introducing variation into demand equation, the problem with this technique is that it only permits a very restricted range of demographic effects because of the close link with changes in prices. Sometimes because of the difficulty of modelling the interactions between these two different kinds of effects, many easier potential models have had to be ruled out. Some extensions have been proposed, such as demographic overhead or translation terms, and they help to alleviate the problem, even though they remain quite restrictive.

The main alternative to demographic and translating is to take specific demand equation or system, and let some of its parameters vary demographically (Stoker, 1979). This procedure allows for virtually any set of interactive demographic and price effects, but does not have any general applicability, being specific to the given starting model.

Lewbel (1985) proposed a method according to which functions of demographic variables, prices and expenditures are introduced into the cost (expenditure) function of a demand system. Using the so-called modifying functions, any demand system can be modified to contain scaling and translating terms that are functions of prices and expenditure levels, as well as demographic or other variables. Modifying functions represent a large middle round between the extremes of individual model modification and scaling and translating approaches. What is given is a large class of possible modifications, having both universal applicability and flexibility to allow the interaction of demographic variables with prices and expenditure in an almost unlimited variety of ways. The method is to introduce functions of demographic variables into the cost function of a demand system. The modified demand system can be written directly as a function of the original system, so the effect of modifying functions on the demand equations may be directly assessed, without consideration of the cost or utility functions involved. Modifying function can be interpreted as representing household technologies: the modified utility function equals the original utility function evaluated at the values of demographically varying intermediate goods. Modifying functions are indirect specification of the correspondence $q^*=g(q, r)$, the functional form g which connects demanded quantity q^* to input goods q and demographical variables r. Demographic scaling and translating are all special cases of modifying functions (Lewbel, 1985). Introducing demographic variables via some transformation of a cost function, that is to say selecting some parameters and letting them vary demographically, is completely dependent on the exact functional form of the chosen demand system, and then it lacks the general applicability of modifying functions. Rather than specifying a class of cost functions with certain properties, modifying functions represent a class of cost function transformations that preserve certain properties. So, the modified cost function inherits the properties of the starting cost function that makes it legitimate.

In particular, I will employ this technique to obtain a demographic modified AIDS (or QAIDS) system which will take into consideration family type and the geographical area of residence. More precisely, the Translog index will be expressed by

$$\ln a(p,a) = \ln a(p) + \sum_i A_i(a)\ln(p_i) \tag{3.50}$$

where $A_i(a) = \sum_k a_{ik} a_k$, parameters a_{ik} are linear in the translating intercepts $a=a_1\ldots a_k$ (which will represent family type, geographical area and season), $\sum_k a_{ik} = 0 \;\; \forall k$ verifying the adding-up property. The AIDS cost function (3.28) becomes

$$\ln c(u, p, a) = \ln a(p, a) + u \ln b(p) \qquad (3.51)$$

It will be used to estimate the following demand system

$$w_i(p, a, x) = \alpha_i + \sum_k a_{ik} a_k + \sum_j c_{ij} \ln p_j + b_i \ln\left(\frac{x}{P*}\right) \qquad (3.52)$$

where $lnP*=lnP+\sum_i a_{ik} a_k \ln p_i$.

3.4.2 EASI

This sub-paragraph will be devoted to the description of a demand system which allows for the introduction of demographic characteristics when working on individual consumption data; then, this functional form represents a potential solution to the problematic issues linked to aggregation among individuals, namely to the limits imposed by the representative consumer approach.

Lewbel and Pendakur (2008) consider a consumer with demographic (and other observable preference related) characteristics *z* that faces the *J*-vector of log prices *p*. Hicksian demand functions associated with the utility maximization problem, which express budget shares *w* as a function of *p*, *z*, and the attained utility level *u*, can be easily specified and have many desirable properties.

Given the log nominal total expenditures *x*, Lewbel and Pendakur (2008) show that, under some conditions, log real expenditures *y* (ordinally equivalent to *u*) can be expressed as a simple function of *w*, *p*, *z* and *x*. This result is used to directly estimate the so-called Pseudo-Marshallian demands, which are Hicksian demands after replacing *u* with *y*. Noting that *p'w* is the definition of the Stone log price index (Stone, 1954a), the authors define the Exact Affine Stone Index (EASI) class of cost functions, where *y* is equal to an affine function of the Stone index deflated log nominal expenditures, *x – p'w*. Their demand system has several positive characteristics, which can be resumed as: to be linear in parameters, linear in *p* and polynomial in *z* and *y*; not have any rank restriction; to have error terms that equal preference heterogeneity; to allow for an approximate version that can be estimated by linear regression.

Differently from standard methods, that obtain Marshallian demands from Hicksian demands by solving for u in terms of *p*, *z* and *x*, the authors construct cost functions that have simple expressions for log real expenditure *y* in terms of *w*, *p*, *z* and *x*, and substitute *y* for u in the Hicksian demands to yield what they call Pseudo-Marshallian demand functions. In this way, they circumvent the difficulty of finding simple analytic expressions for indirect utility or Marshallian demands. Pseudo-Marshallian demands can easily incorporate unobserved preference heterogeneity, since the error terms equal the random utility parameters ε. More in details (and not including for now preference heterogeneity), the Exact Stone Index (ESI) demand system is represented by a cost function $C(p,u)$ whose preferences verify $u=x\text{-}p'w$, so that real expenditures, which hold utility constant when prices change, are equal to Stone index deflated expenditures.

Shephard's lemma relates Hicksian (compensated) budget shares to regular cost functions by

$$w = \omega(p,u) = \nabla_p C(p,u) \tag{3.53}$$

Having an ESI cost function, u can be substituted out in the Hicksian demand functions $w=\omega(p,u)$ to obtain $w=\omega p$, $x\text{-}p'w$. The name, Exact Stone Index, is aimed to contrast with the approximate Almost Ideal demand system, which uses $x\ \text{-}p'w$ as an approximation to deflating x by a certain quadratic function of p. Instead, in an ESI cost function, the Stone index is the exact correct deflator for x. The idea is to construct models where utility is ordinally equivalent to some simple function of observable variables, in this specific case Stone index deflated nominal total expenditures.

ESI Hicksian and Pseudo-Marshallian budget shares possess the unattractive feature of not changing when all prices are squared, and then they must either be independent of p or non-linear in p. To avoid these problems, a generalization is proposed, represented by Exact Affine Stone Index (EASI) Pseudo-Marshallian demand functions. Thereby, homogeneity restrictions required by the ESI are relaxed. Specifically, instead of imposing the ESI restriction that u be ordinally equivalent $x\text{-}p'w$, the authors define EASI cost functions to be functions that have the property that u is ordinally equivalent to an affine transformation of $x\text{-}p'w$. So, the general class of EASI cost functions is represented by

$$C(p,u) = u + p'm(u) + T(p) + S(p)u \tag{3.54}$$

for some functions $T(p)$ and $S(p)$ homogeneous of degree zero in p. In order to explicitly include both observable and unobservable sources of preference heterogeneity, the authors define both an L-vector $z = (z_1\ldots z_L)'$ of observable demographic (or other) characteristics that affect preferences, and continue to let ε be a J-vector of unobserved preference characteristics (taste parameters). The log cost or expenditure function is now $x = C(p, u, z, \varepsilon)$, which equals the minimum log-expenditure required for an individual with characteristics z, ε to attain utility level u when facing log prices p. Typical elements of z

would include household size, age, and composition. A simple way to include these variables in the cost function without interfering with required price homogeneities is including them in the vector of functions *m(u)* and allowing the observable components to enter *T* and *S*. Including preference heterogeneity in the model, both from observable sources z and unobservable sources ε, the following equation is obtained

$$C(p,u,z,\varepsilon) = u + p'm(u,z,\varepsilon) + T(p,z) + S(p,z)u \qquad (3.55)$$

This broad class includes the following parametric model, which the authors take as baseline case for empirical work:

$$C(p,u,z,\varepsilon) = u + p'\left[\sum_{r=-1}^{5} b_r u^r + Cz + Dzu + \varepsilon\right] + \frac{1}{2}\sum_{l=0}^{L} z_l p' A_l p + \frac{1}{2} p' Bpu \qquad (3.56)$$

where each b_r is a *J*-vector of parameters with $1'_J b_0 = 1$, $1'_J b_r = 0$ for $r \neq 0$.

By Shephard's lemma, this cost function has Hicksian (compensated) budget shares

$$w = \sum_{r=-1}^{5} b_r u^r + Cz + Dzu + \sum_{l=0}^{L} z_l A_l p + Bpu + \varepsilon \qquad (3.57)$$

It can be checked from these formulas that $C(p,u,z,\varepsilon) = u + p'w - \sum_{l=0}^{L} z_l A_l p/2 - p'Bpu/2$, and solving this expression for *u* implies that log real-expenditures *y* can be written as an affine transformation of the log of Stone Index deflated nominal expenditures:

$$y = \frac{x - p'w + \sum_{l=0}^{L} z_l p' A_l p/2}{1 - p'Bp/2} \qquad (3.58)$$

Since log real-expenditures are ordinally equivalent to utility, they can be substituted into Hicksian budget shares to yield Pseudo-Marshallian budget shares

$$w = \sum_{r=-1}^{5} b_r y^r + Cz + Dzy + \sum_{l=0}^{L} z_l A_l p + Bpy + \varepsilon \qquad (3.59)$$

Apart from the construction of *y*, the Pseudo-Marshallian demand equations (3.56) are linear in coefficients, which simplifies estimation. In this model the *D* and *B* matrix parameters allow for flexible interactions between *y* and both *z* and *p*. Either or both of these matrices could be zero if such interactions are not needed. Note that if *B* was zero, then *y* in equation (3.57) would also be linear in parameters.

The demand functions (3.56) are linear in parameters except for the terms $\frac{1}{2}\sum_{l=0}^{L} z_l p' A_l p$ and $p'Bp$ that appear in the construction of *y* in (3.55). A similar non-linearity appears in Deaton and Muellbauer's (1980b) AIDS and Banks et al. (1997) QUAIDS. The problem can be solved in an analogous way, either by non-linear estimation or by replacing *y* with an observable approximation, for example with $\tilde{y}$ defined by

$$\tilde{y} = x - p'\overline{w} \qquad (3.60)$$

for some set of budget shares $\overline{w}$. Then, by comparison with equation (3.53) we have

$$w = \sum_{r=-1}^{5} b_r \tilde{y}^r + Cz + Dz\tilde{y} + \sum_{l=0}^{L} z_l A_l p + Bp\tilde{y} + \tilde{\varepsilon} \qquad (3.61)$$

where $\tilde{\varepsilon} \approx \varepsilon$ with $\tilde{\varepsilon}$ defined to make equations (3.55) hold. This model is called the Approximate EASI model. It nests the model $w = b_0 + b_1\tilde{y} + Cz + Ap + \tilde{\varepsilon}$, which is identical to the popular approximated Almost Ideal Demand System. An important difference is represented by the fact that in AIDS without the approximation *y* is equal to deflated *x*, where the log deflator is quadratic in p, whereas in EASI model without approximation *y* is equal to an affine transform of *x –p'w*. The approximate EASI model, substituting equation (3.54) into (3.55), can be estimated by linear regression methods, with linear cross-equation symmetry restrictions on the A_l and *B* coefficients. A natural choice for $\overline{w}$ is the sample average of budget shares across consumers. A better approximation to *y* would be to let $\overline{w}$ be each consumer's own *w*, so each consumer has his own Stone index deflator, based on his own budget shares, but this alternative implies endogeneity problems.

The authors estimate the approximate model with $w=\overline{w}$ using seemingly unrelated regressions, and they estimate the true EASI model using the Generalized Method of Moments. As in the approximate AID system, there is no formal theory regarding the quality of the approximation that uses $\tilde{y}$ in place of *y*, but the authors find empirically estimated parameters belonging to the approximate model have the same signs and roughly similar magnitudes than the estimates based on the exact *y*, providing good starting values for exact model estimation.

3.5 Exact price indices

In order to perform a so-called welfare or incidence analysis the first step is represented by the computation of a price index which constitutes the basis for computation of the incidence measures. In this paragraph the different choices with respect to the price index to be used for incidence analysis will be reviewed.

Hicks (1942) and Samuelson (1947) have noted that CV and EV are intimately related to the theory of true, or constant-utility, price indices which was first developed by Konus (1939). Samuelson and Swamy (1974), Diewert (1976) and Lau (1978) have been concerned with deriving indices which are true for particular forms of utility or production function.

The constant-utility cost of living index $P(p_0, p_1,u)$ is equal to the ratio of expenditures required to achieve a specified level of utility at final and initial price vectors p_1 and p_0. If the specified level of utility is the initial level u_0, then we have a Laspeyres base-weighted index

$$P(p_0, p_1, u_0) = \frac{c(p_1, u_0)}{c(p_0, u_0)} \tag{3.62}$$

whereas if the reference level of utility is the final level u_1, then we have a Paasche current-weighted true index:

$$P(p_0, p_1, u_0) = \frac{c(p_1, u_1)}{c(p_0, u_1)} \tag{3.63}$$

These two indices will be equal to each other if and only if the underlying direct utility function is homothetic. Such indices are sometimes referred to as true or exact. True indices can be derived for non-homothetic utility or production functions by substituting the expenditure or cost function associated with the assumed structure of preferences or production into the price index equations (3.62) and (3.63). Deaton and Muellbauer (1980a) provide the general formula for the Laspeyres true index using the logarithmic form of the price-independent generalized linear preferences (PIGLOG) model; they illustrate this results by using parameters for a specific form of PIGLOG preferences for the UK and estimate changes in the true cost of living for families in different income-household composition groups.

True indices can be used for the computation of CV and EV, and the relationship between these two measures is so close that both of them pose the same informational requirements: if we want to measure either we need information on the form of the underlying utility/expenditure function.

After having defined what an exact index is, here I will begin the review of the literature related to index number development: in general, they are devices for reducing the comparison between two complete price vectors to a single scalar. A first answer to the problem of evaluating individual welfare effects when price changes has been represented by the utilization of index numbers expressed in terms of price and quantity. The total derivative of utility function can be written as

$$\frac{\delta v(p, y)}{\pi} = -\sum_{i=1}^{I} q_i \delta p_i \tag{3.64}$$

where q represent the quantity consumed of the i consumption good, p its price and π the marginal income utility. From the budget constraint, hypothesized linear, equation (3.65) can be obtained

$$\sum_{i=1}^{I} q_i \delta p_i = \delta y - \sum_{i=1}^{I} p_i \delta q_i \tag{3.65}$$

That, once substituted in (3.64), leads to the following equation

$$\frac{\delta v}{\pi} = -\sum_{i=1}^{I} (\delta y - p_i \delta q_i) \tag{3.66}$$

The consumer welfare changes can be evaluated on the basis of one of the terms in equation (3.65): the possibility of considering only one term constitutes the reason for which this kind of indices number represents an approximation of the welfare effects induced by prices changes (see equation (3.67) and (3.68)). If the approximation error is not so high, equation (3.65) offers a straightforward way to compute consumer welfare changes because the variables included are easily observable. The element on the right side of equation (3.65) represents an index of consumption change evaluated at the initial period prices: when divided by the expenditure level, it constitutes a Laspeyres quantity index. The problem inherent to the approximation degree is caused by the fact that, for non infinitesimal price changes, equation (3.65) takes the form

$$dy = \sum_{i=1}^{I} q_i dp_i + \sum_{i=1}^{I} p_i dq_i + \sum_{i=1}^{I} dp_i dq_i \tag{3.67}$$

In order to precisely evaluate the total derivative of the utility function, the following integral should be computed

$$\int \frac{1}{\pi} dv = -\int \sum_{i=1}^{I} q_i dp_i \tag{3.68}$$

The approximation of (3.67) with the equation (3.65) and of (3.68) with the equation (3.66 **)** implies different results in presence of non infinitesimal price variations. In particular, the value of the integral in equation (3.68) depends on the integration path: the economic reason behind this mathematical property is that the marginal income utility is not constant, but changes when prices change. Only in the case of Leontief preferences individual welfare changes are equivalent to Laspeyres and Paasche indices[32], while in the case of homothetic preferences there is a constant ratio between equation (3.68) and (**3.65)**. In all other cases, and hypothesizing that all goods are normal, Laspeyres and Paasche indices implies an under or overestimation of welfare changes (depending on

[32] As in equation (3.63) for the constant-utility cost of living index, quantity Paasche index differs from Laspeyres quantity index only for the different base used in its the computation, represented by final period prices.

which expenditure shares are included in the computation, respectively the previous or following ones with respect to the price change). Examining tax introduction in a partial equilibrium context, the utilization of this kind of index corresponds to the hypothesis that the reduction in consumer purchase power or welfare equals the tax revenue, excluding the efficiency loss (deadweight loss) caused by the distortion of relative prices. In fact, the behavioural responses on the taxed products demand are not taken into account. Paasche and Laspeyres hypothesize that tax revenue equals the burden imposed on individuals in terms of utility reduction, but this assumption is only valid with very simplified preferences systems (homothetic or Leontief preferences): generally, taxes determine welfare losses that exceed the revenue provided, and this excess burden is connected to the demand and supply structures. The relevance assumed by this component changes according to the specific characteristics of the concerned goods' demand. Focusing on the demand side, clearly the welfare effects of taxation depend on the price change (and in this context revenue raising represents an important component) and its different impacts on individual consumption. The Laspeyres and Paasche indices do not consider substitution effects, assuming that the same bundle of goods is bought before and after the price change; for this reason, they are only a first order approximation of the True Cost of Living (TCOL) Index, referring, respectively, to the initial or final welfare level.

When relative prices change, some standard of comparison is required: every index number uses a measure of the standard of living as reference. One such measure can be some reference commodity bundle q^R: using this technique are constructed Laspeyres and Paasche indices. A single bundle is an unnecessarily restrictive interpretation of what is meant by a constant standard of living and the obvious alternative is taking a specific indifference curve as the reference that has to be kept constant. Following this approach, TCOLs can be constructed as the ratio of the minimum expenditure necessary to reach the reference indifference curve at the two set of prices. Cost (expenditure) functions to compute TCOLs can be obtained by direct estimation of their parameters, by performing demand system estimation: this requires the specification of the preference structure and, in this way, the efficiency loss caused by relative prices variation can therefore be assessed. Following this approach, the interpersonal comparison can be made easier by adopting equivalence scales. Moreover, the demand system estimation can be performed by adding demographical characteristics, and in this way the welfare indices obtained can be related to a specific household structure, for example, in terms of household members.

The True Cost of Living Index (Konus, 1939) solves many problems of the fixed-weighted indices: it is represented by the ratio between two expenditure functions and it can be directly connected to the money metric or Hicksian measures of equivalent and compensating variations. This could be easily checked. Given that CV and EV are respectively defined through the expressions $v(p^1, x\text{-}CV)=v(p^0, x)$ and $v(p^1, x+EV)=v(p^1, x)$, from these expressions the money metric measures shown in equation (2.9) and (2.10) can be obtained

$$CV = e(p^0, v(p^0, x)) - e(p^1, v(p^0, x))$$
$$EV = e(p^0, v(p^1, x)) - e(p^1, v(p^1, x))$$

where is $e=e(p^1,v(p^0,x))$ is the cost (expenditure) function in terms of the indirect utility function. The True Cost of Living Index is defined as

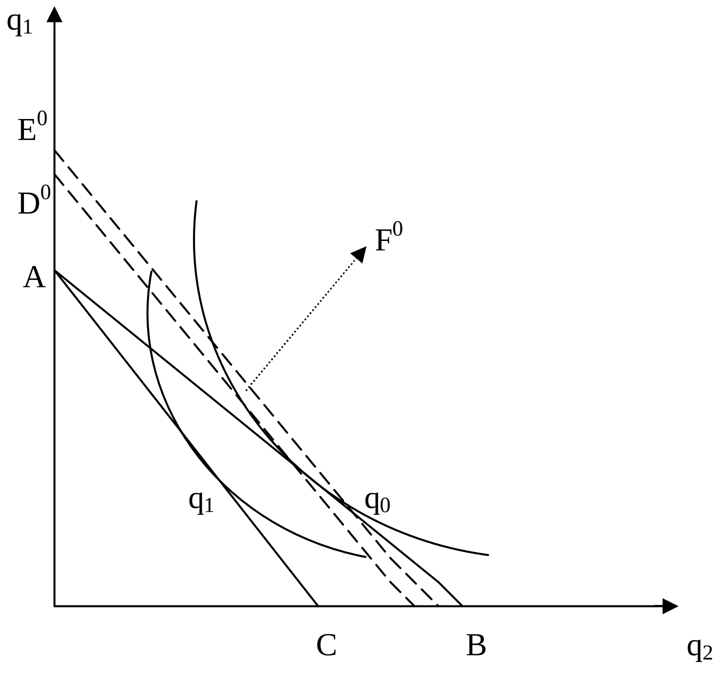
$$P(p^1, p^0, v_0) = \frac{e(p^1, v(p^0, x))}{e(p^0, v(p^0, x))} \qquad (3.69)$$

or

$$P(p^1, p^0, v_1) = \frac{e(p^1, v(p^1, x))}{e(p^0, v(p^1, x))} \qquad (3.70)$$

The difference between these two expressions lies in the different utility level chosen as the baseline level in the evaluation: in particular, the index in (3.69) is based on compensating variation, the index in (3.70) on equivalent variation.

Figure 3.1 – Different kind of price indices



In the Figure 3.1 the original budget line AB rotates, with the rise in p_2, to AC. The budget line necessary to buy q^0 at the new prices cuts the vertical axis at E^0; however, an identical standard of living can be obtained at F^0, and the corresponding budget line cuts OE^0 at D^0. Since p_1 is unchanged, distances along OE^0 are proportional to total expenditure; hence, the base quantity weighted index (Laspeyres price index in this case) is given by OE^0/OA, while the base utility reference index is OD^0/OA. Clearly the former exceeds the latter.

A similar reasoning can be developed in the case of current weighted index: the Paasche index can be no greater than the utility reference index. In both cases, the inequalities are caused by substitution effects; these inequalities are easily shown to hold, in general. The bundle q^0 is one way of reaching u^0 but not necessarily the cheapest when prices are p^1; hence, $p^1 \times q^0$, the cost of q^0 at p^1 is greater than or equal to $c(u^0,p^1)$, namely the minimum cost of u^0 at p^1. But, by the definition of q^0, $p^0 \times q^0$ is equal to $c(u^0, q^0)$. Hence we have that

$$\mathrm{P}(\mathrm{p}^1, \mathrm{p}^0, \mathrm{q}^0) = \frac{p^1 \times q^0}{p^0 \times q^0} \geq \frac{c(u^0, p^1)}{c(u^0, p^0)} = \mathrm{P}(\mathrm{p}^1, \mathrm{p}^0, \mathrm{u}^0) \qquad (3.71)$$

Similarly, since q^1 represent one way of obtaining u^1 at p^0, $p^0.q^1$ is equal or greater than $c(u^1,p^0)$ so that, since $p^1.q^1=c(u^1, q^1)$

$$\mathrm{P}(\mathrm{p}^1, \mathrm{p}^0, \mathrm{q}^1) = \frac{p^1 \times q^1}{p^0 \times q^1} \geq \frac{c(u^1, p^1)}{c(u^1, p^0)} = \mathrm{P}(\mathrm{p}^1, \mathrm{p}^0, \mathrm{u}^1) \qquad (3.72)$$

These inequalities, which date back to Konus (1924), do not imply that the true index lies somewhere between the Paasche and Laspeyres indices. In general, there is no unique true index and the base-weighted utility index that has the Laspeyres as an upper limit is a different number from the current weighted utility index that is no less than the Paasche index.

The True Cost of Living Index can be computed by taking as reference not the individuals but the households, which very often represent the decisional unit with respect to consumption choices. The differences between households are linked to the income level, to their different structure (in terms of number and age of their members) and to some socio-demographic characteristics, such as employment and geographical residence. These differences can be taken into account by adopting expenditure functions conditional to household characteristics. Indicating households characteristics with the vector a^h, the expenditure function concerning the household h will be given by $e(u, p, a^h)$. A TCOL index compares the cost of achieving a given level of welfare before and after a price increase, computing the extra income needed to return to the original welfare level; it is defined by the following expression

$$P(p^1, p^0; u, a^h) = c(u, p^1, a^h) / c(u, p^0, a^h) \tag{3.73}$$

where $c(u, p, a^h)$ is the cost (expenditure) function which defines the minimum expenditure level of the household *h* (with demographic characteristics expressed by the a^h vector) needed for the household to achieve the utility level *u* if price system is described by the *p* vector. In particular, p^0 and p^1 respectively stand for price system before and after an hypothetic price change. Thus, the price index *P* represent the ratio between the minimum cost needed to reach a welfare level given two different configurations of price system. As the equivalence scales compare the price structure of different household profiles, the True Cost of Living indices compare the welfare associated to different price systems. It should be noted that they can be employed to make comparison among different households that (because of different preferences' structures) deal with different relative prices systems.

The True Cost of Living Index defined in (3.73) can be straightforwardly computed knowing the cost function parameters: at this purpose, the estimation of a complete system of demand equation can be very useful. In what follows the TCOLs for the AIDS will be presented below: they are exact in the Diewert sense (Diewert, 1981), namely, they derive from the cost (expenditure) function on which the demand system is constructed. For simplicity's sake, demographic characteristics have been excluded from the equations even if, with reference to the translated AIDS, they will be included in the computation.

The cost function adopted in the estimation of an AIDS has a Translog form (equation (3.28 **)**) and in this case the True Cost of Living Index can be very easily computed as

$$\ln P(p^1, p^0, u) = (1-u)\ln[a(p^1)/a(p^0)] + u\ln[b(p^1)/b(p^0)] \tag{3.74}$$

In equation (3.74) *u* represents the reference welfare level, given by the following equation

$$u = \ln\left[x^r / a(p)\right] / \ln\left[b(p)/a(p)\right] \tag{3.75}$$

which represents the indirect utility function for an AIDS. If the reference welfare level *u* is computed in the initial period, *P* can be used to derive compensating variation with respect to the period which comes before the price change. By normalising prices to one in the first period, *P* takes the following form

$$\ln P(p^1, p^0, u) = \sum_{i=1}^{I} \alpha_i \ln p_i^1 + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} \xi_{ij} \ln p_i^1 \ln p_j^1 + [\ln(x_0) - \alpha_0](\prod_{i=1}^{I} p_i^{1\beta_i} - 1) \tag{3.76}$$

Conversely, if the reference period is set to the final period (after the price change has taken place), *P* can be connected to the equivalent variation

$$\ln P(p^1, p^0, u) = \sum_{i=1}^{I}\alpha_i \ln p_i^1 + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I}\xi_{ij} \ln p_i^1 \ln p_j^1 + [\ln(x_0) - \alpha_0 + \sum_{i=1}^{I}\alpha_i \ln p_i^1 + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I}\xi_{ij} \ln p_i^1 \ln p_j^1](1 - 1/\prod_{i=1}^{I} p_i^{1\beta i}) \qquad (3.77)$$

True Cost of Living indices can be useful when making comparisons between household profiles which differ with respect to their welfare level. Using the equations (3.76) and (3.77 **)** different TCOLs, and in this way different incidence measures, can be computed, for different welfare levels and household types, in order to assess the distributive effects of environmental policies which imply price changes.

3.6 Demand elasticities

Due to the crucial relevance of own price, cross-price and income elasticities, this paragraph will go into detail of their computation from a demand system and other related issues. In particular, it will be divided in two parts: the first one will analyse the empirical and technical issues linked to elasticities estimation, whereas the second one will develop some considerations on the elasticity values and their differentiation.

The first problem is a theoretical one. The derivation of Hicksian demand from the cost (expenditure) function is an application of the envelope theorem. A very important theoretical property of Hicksian demand functions is that the matrix of price derivatives (Slutsky matrix), S_{ij}, is a symmetric negative semi-definite matrix. This property is a necessary condition for the recovery of preferences from demand and constitutes the basis of all consumer welfare analysis. This is referred to as integrability of demand, because it is about integrating back to preferences from demand functions. Of course, since we do not observe Hicksian demand functions (being utility not observable), the application of the integral envelope theorem to recover the expenditure function is not straightforward. We observe Marshallian demands, which depend on prices and expenditure. Then, we must first recover Hicksian demands from Marshallian demands and this requires the removal of the income effects from Marshallian demand; the Slutsky equation is used for this purpose. This tells us that the slope of the Marshallian demand will be steeper (flatter) than the slope of the Hicksian demand curve, as the derivative of w_i (p,x) with respect to x is negative (positive), or as good *i* is inferior (normal).

The Slutsky or substitution matrix is computed through the following expression

$$\frac{\partial h_i(p,u)}{\partial p_j} = \frac{\partial q_i(p,x)}{\partial p_j} + \frac{\partial q_i(p,x)}{\partial x} q_j(p,x) \qquad (3.78)$$

The estimates of interest in empirical demand studies are income elasticities and price elasticities, and they are likely to be non-linear functions of the econometric parameters from the demand system estimation. Given the importance of elasticities, it is useful to be able to express the Slutsky equation in terms of elasticities. This is done by multiplying both sides of (3.78) by $p_i p_j/x$. Then, let multiply the left hand side and the first term on the right hand side by q_i/q_i and multiply the second term on the right hand side by $q_i x/q_i x$. After this, equation (3.78) becomes

$$s_i e_{ij}^{C*} = s_i e_{ij}^{C} + s_i s_j e_i \qquad (3.79)$$

$$\Rightarrow \quad e_{ij}^{C*} = e_{ij}^{C} + s_j e_i$$

Formulas of this type are useful because many functional forms that are used in empirical demand studies are specified in log forms, yielding elasticities more easily than derivatives. For example, Deaton and Muellbauer present of the first functional form used in empirical studies for demand function estimation. It was one, the logarithmic demand function:

$$\ln w_i = \alpha_i + e_i \ln x + \sum_j e_{ij}^{C} \ln p_j \qquad (3.80)$$

When it is expressed in terms of compensated cross-price elasticities, e_{ij}^{C*}, the authors name this model Stone re-parameterized. Rewriting $e_{ij}^{C*} = e_{ij}^{C} + s_j e_i$ and substituting into (3.80 **)**, we obtain

$$\ln w_i = \alpha_i + e_i(\ln x - \sum_j s_j \ln p_j) + \sum_j e_{ij}^{C*} \ln p_j \qquad (3.81)$$

In the specification of functional forms, it is usually recognized that a term like $\sum_j s_j \ln p_j$ is an expression for a price index that can be constructed from the available data (see Paragraph 3.5). So one can construct this price index, *P*, and use it to deflate expenditure *x* to specify the model in terms of log real expenditure, *ln (x/P)*.

Another kind of problem, linked to empirical analysis, is that the complexity of empirically adequate specifications makes the interpretation of raw demand system parameters difficult. It could therefore be useful to report estimated income elasticities at various point of the data, for instance at the mean and quartiles of total expenditure *x* (Lewbel, 1997). I will follow this suggestion computing price and income elasticity for different household profiles (whose identification reflects different expenditure classes), with the aim of examining the potential asymmetries in adapting capacities to price changes, and consequently the connected risk of carbon tax regressivity.

The cost for a household of environmental policy measures depends to a large extent on substitution

possibilities. It is sometimes held that environmental policy imposes unequal burdens, because people in upper-income brackets have more options to adapt, for example by purchasing a less polluting car. Johnstone and Alavalapati (1998) observe that higher income households will tend to have a higher price elasticity for heating fuels. Such patterns are further aggravated by potential market failures, reinforcing the regressivity of environmental policy: if there are insulation measures with high returns, low-income households could not be able to borrow to the same extent as other types of households. It is therefore of interest in a distributional study to examine the price-sensitivity differentiation across income-groups. On the contrary, economists have traditionally assumed that price elasticities are the same for everyone. From the simplest possible demand structure, that is a demand curve linear in price and income (and other characteristics), it follows that the price elasticity decreases with income (as long as higher income increases demand). Intuitively, this seems a reasonable characterization of consumer behaviour in general: the greater our income, the less price-elastic is our demand.

A drawback with the linear demand curve is that it is not quite consistent with demand theory, even though it is an often used approximation. Using demand curves that are consistent with economic theory, one can show that price elasticity, income elasticity and substitution elasticity are closely linked (in the two-good case, price elasticity is a weighted sum of the income and substitution elasticities, the weights being the budget shares). Under certain assumptions, the variation of the price elasticity mainly comes from variations in the elasticity of substitution, and this enables to interpret higher price elasticity as an indicator of a higher elasticity of substitution. A third way to approach possible varying elasticities is via a theory developed by Frisch (1965). A key parameter in this theory is what is called the Frisch parameter, which represents the elasticity of the marginal utility of income. Frisch famously argued that this parameter has values of about -10 for the very poor ranging all the way up to -0.1 for the richest part of the population. According to Frisch, the price elasticity varies inversely with the Frisch parameter: for goods with constant budget shares, price elasticity become lower, as we move from higher to lower income.

Empirical evidence about this issue is relatively scant. Cornwell and Creedy (1996), in their analysis of carbon taxation in Australia, find that the lower income earners have relatively lower price elasticities compared with higher income earners. Sipes and Mendelsohn (2001) suggest, on the other hand, that higher income decreases price elasticity for gasoline consumption. West (2004) studies policy instruments for vehicle pollution control: examining price responsiveness by income deciles, she finds that lower income households reduce miles travelled to a larger extent than wealthier households, and they have higher price elasticities. This result is *inter alia* due to the fact that lower income households do not own cars to the same extent of higher income ones. The study by Brännlund and Nordström (2004) on the distributional impacts of carbon taxation finds very small differences between price elasticities across income groups. Their results are, to some extent, a consequence of the empirical model used. In conclusion, neither theory nor empirics allow a robust conclusion about how price elasticities vary across income groups in the case of environmental goods.

To conclude, I think it can be interesting to develop some general observations on the link between elasticity and taxation. High price elasticity of demand is desirable, when the market-based policy tools are used purely as incentive instruments, with the aim of achieving a large quantity response (for instance, the reduction of the use of a particular harmful substance). Very elastic demand would, however, lead to the erosion of the tax base and not allow substantial revenue recycling. Goods with lower price elasticities serve such purpose better, as the tax base is more stable while still having a significant positive environmental impact; typical examples are energy and transport products. The size of price elasticities in energy and transport sectors has been estimated in a number of studies by various econometric methods (OECD, 2006). This evidence confirms that demand for energy, as a whole, tends to be rather inelastic in the short-run (ranging between -0.13 and -0.26), but that long-run elasticities are considerably higher (-0.37 to –0.46). Price elasticities are not necessarily of the same magnitude for all energy products: for instance, own-price elasticities for petrol seem to be higher than for residential electricity. Moreover, long-run elasticities seem to clearly exceed short-run elasticities, in particular in the case of petrol. High long-run elasticities imply that a tax reform could lead to an environmental improvement on a permanent basis.

Chapter 4

4.1 Data description

For the demand system estimation I used data from the Italian National Statistical Institute (ISTAT), in particular, a sample extracted from the *Indagine sui Consumi delle Famiglie* hereinafter referred to as the Survey on Household Expenditure[33]. It surveys consumptions for a wide variety of goods and for a number of households which varies from one year to another, but amounts to around 25000 units per year. It provides also information on the level and structure of monthly expenditure, and on households characteristics, such as number of members and their standard of living. The expenditure is collected relating to groups and class of expenditure, to geographical distribution and to households characteristics. Data provided by ISTAT cannot be defined as a panel, because interviewed households are not the same from one month to another nor from one year to another. The record was not exactly the same from one year to another and the harmonization between different records has demanded an effort when constructing the sample; it was also necessary to convert from lire (years up to 2002) to Euro (following years).

The paragraph is divided in two sub-paragraphs. The first will describe consumption data and sample extraction, along with the related assumptions; on the other hand, the second sub-paragraph will propose a brief overview of the prices which were used in the demand system estimation.

4.1.1 Descriptive analysis

ISTAT collects household expenditure referring to a large amount of goods, diversified into different macro-categories; it was therefore clearly necessary to aggregate goods in order to perform demand system estimation. Each choice I have made regarding sample extraction reflects the specific problem I want to examine; first, I focused my attention on household current expenditure, excluding durable goods from the sample. Six goods were identified: food (w1), heating fuels (w2), electricity (w3), transport fuels (w4), public transport (w5), and a residual good which contains all the other current consumption expenditures (w6). Summing up the expenditure shares over these six goods, total expenditure can be obtained.

I chose to work on aggregate data because of the relevant presence of zero expenditure values for several kinds of expenditures: aggregating data clearly avoids the problem of

[33] I want to thank the Faculty of Economics of Università di Siena for having provided the *Indagine sui consumi delle famiglie* 1997-2005 from which I have extracted the sample used in demand system estimation.

zero expenditure values which often characterize individual data. The initial sample for each year examined consisted of a number of observations in the range 19000-25000; after the construction of subgroups, the frequency of the households in each subgroup changes from a minimum of 13 to a maximum of 169.

With regard to the households included in the analysis, some were excluded because not significant to the scope of the incidence evaluation of a carbon tax. More specifically, families with more than 4 members were dropped. This choice can be explained by representativeness issues: this type of families represents a small percentage in the original sample, so not so relevant. As I said before, also reasons of significance have driven sample extraction: the presence of scale economies is considered to be well represented by a sample which includes households with up to four members.

Households were divided into 18 subgroups, 6 of which based on their composition and 3 based on the geographical area of residence (namely, the North, Centre or South macro-regions). In order to do so, I examined different hypothesis and I chose the one which shows major differentiation in fuels, heating fuels and electricity expenditure patterns. I decided to divide households into six groups according to the number of members and age:

Famtipo1= single adult (years >=25 and < 65)

Famtipo2= two adults

Famtipo3= up to four adults

Famtipo4= two adults and 1or 2 children (up to 14 years)

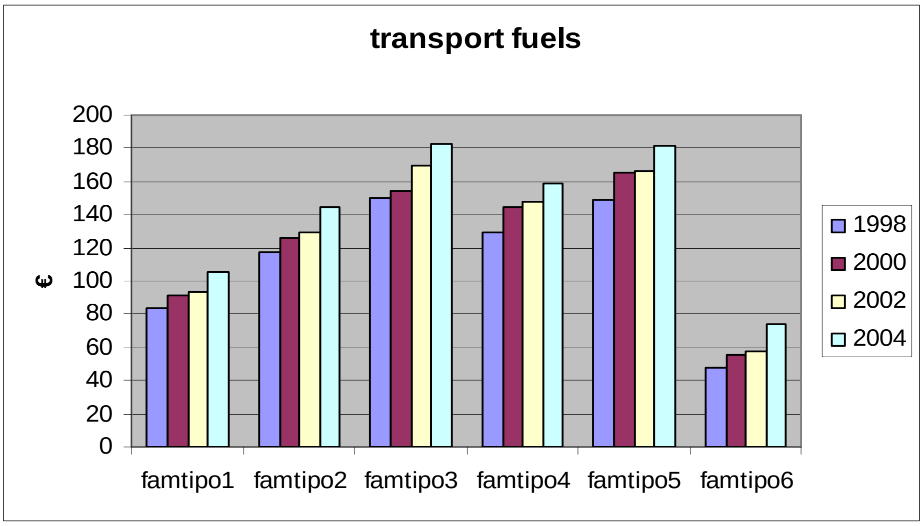
Famtipo5= two adults and 1or 2 young people (years>14 and <25)

Famtipo6= two elderly people

Examining the expenditure levels for each of relevant good, some interesting patterns can be noted[34].

[34] I have chosen four year among the eight examined only for reason linked to graph presentation.

Figure 4.1 – Transport fuels expenditure level by famtipo



For transport fuels (Figure 4.1), elderly people (famtipo6) have a very low expenditure level as well as one-adult households (famtipo1). Households with two adults (famtipo2) have an average expenditure level; expenditure becomes high both for households with three or four adults (famtipo3) and for households with two adults and one or two young people (famtipo5). Also households with two adults and one or two children (famtipo4) have medium-high expenditure level. Having children produces a positive effect on transport fuels expenditure, which becomes more relevant when children grow up and begin to drive motorcycles or cars. So, transport fuels consumption increases proportionally with household size, but it also depends on households composition.

Figure 4.2 – Transport fuels expenditure level by year

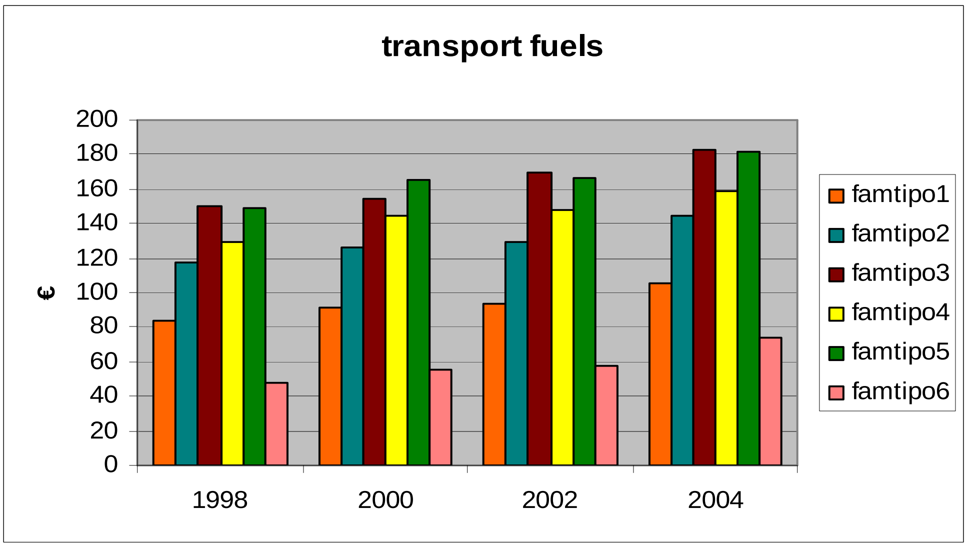
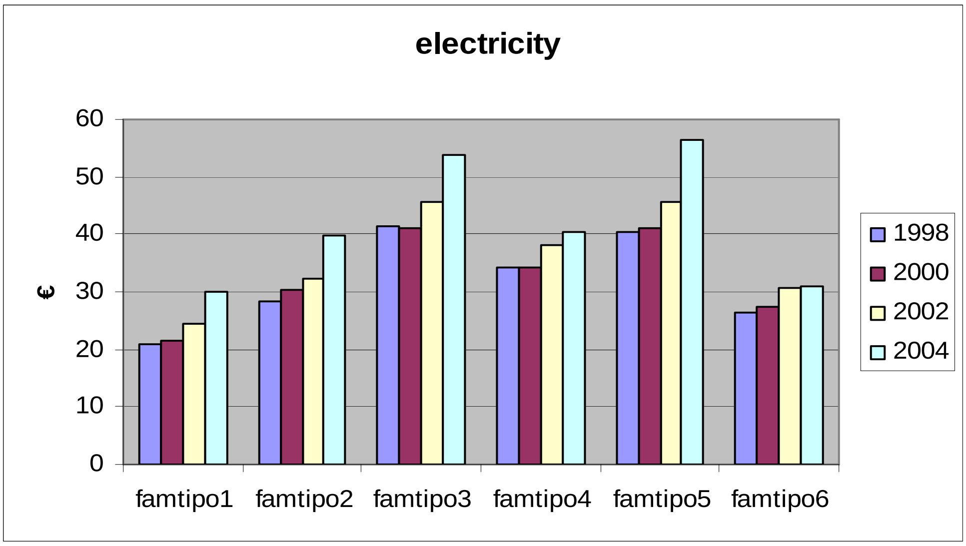


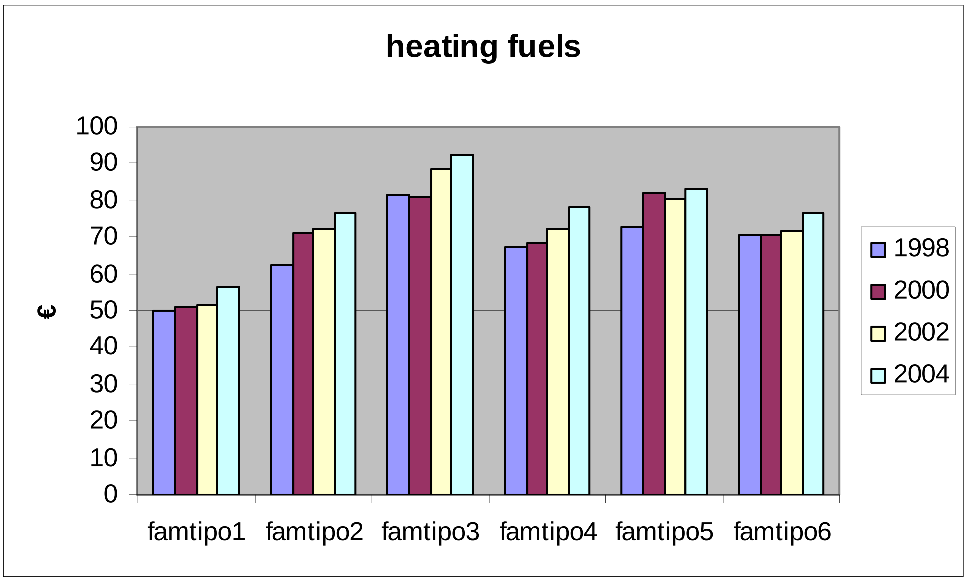
Figure 4.2 shows more clearly the households expenditure differentiation in every year: it could be said that the differentiation remains unchanged across different years of the sample.

Figure 4.3 - Electricity expenditure level by famtipo



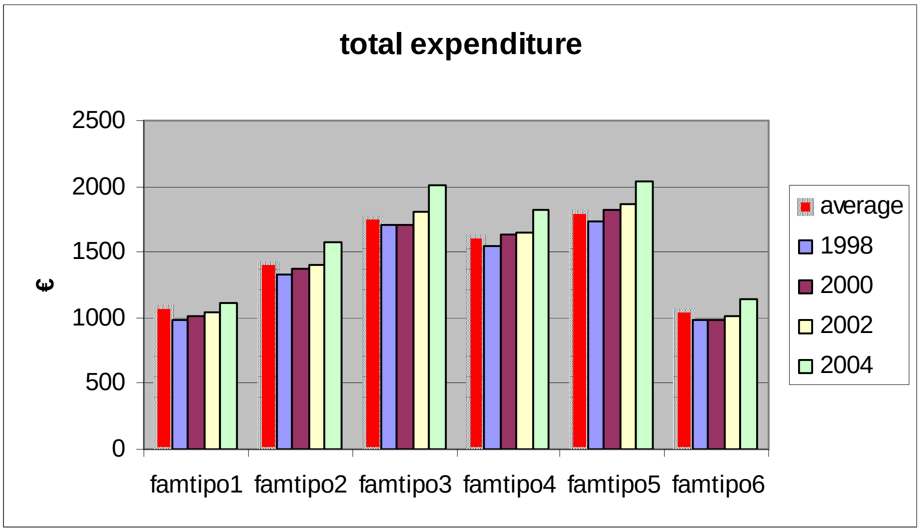
As far as electricity is concerned, single adults have the lower expenditure level, followed by elderly people. Two-adult households have a low expenditure level, whereas three/four adults and two adults with one or two young people have a high expenditure level. Two adults with one or two children households have a medium-high expenditure level. Then, in the case of electricity, consumption increases proportionally to household size. It could be interesting trying to link these expenditure levels with durable goods possession and utilization (for instance, computer and air conditioned), information collected by *Indagine sui consumi delle famiglie*.

Figure 4.4 - Heating fuels expenditure level by famtipo



Finally, quite different trends are detected by examining heating fuels. In particular, elderly people have a higher expenditure level if compared with other goods. Households with one or two children also have a high expenditure level. One-adult households, instead, have a low expenditure level. Two-adult households show a medium-high heating fuels expenditure, whereas households with three or four adults have a high expenditure level. This household type has in all cases the higher expenditure level. Graphs similar to Figure 4.2 show that the trend is almost unchanged across all the examined years for electricity and heating fuels.

Figure 4.5 – Total expenditure by famtipo



With Figure 4.5 I want to show as the chosen division into six household profiles approximates a division into expenditure classes: households with elderly people (famtipo6) have the lowest expenditure level, followed by single member households (famtipo1). Two-adult households (famtipo2) have a medium-low monthly expenditure level whereas households with children expenditure level is medium-high. Finally, households up to four adults (famtipo3) and with young people (famtipo4) have the highest total expenditure level (Table 4.1). The pattern described remains constant over the different years examined.

Table 4.1 – Expenditure shares and total expenditure (in Euro) for the whole sample and household profile

Variable	*Mean*	*Standard Deviation*	*Min*	*Max*	*Household profile (mean values)*					
					1	*2*	*3*	*4*	*5*	*6*
w1	0.297	0.047	0.173	0.455	0.267	0.285	0.296	0.285	0.284	0.364
w2	0.050	0.018	0.011	0.147	0.048	0.049	0.047	0.051	0.043	0.066
w3	0.026	0.005	0.013	0.047	0.026	0.025	0.027	0.023	0.026	0.029
w4	0.088	0.017	0.030	0.152	0.088	0.092	0.095	0.090	0.092	0.063
w5	0.008	0.005	0.001	0.041	0.008	0.073	0.009	0.006	0.014	0.007
w6	0.528	0.050	0.326	0.679	0.552	0.536	0.524	0.549	0.537	0.469
exp	1414.6	381.3	642.1	2747.0	1023.9	1353.5	1692.4	1601.1	1779.4	1037.1

The distinction chosen is also related to the possibility of further examining revenue reutilization: the number of adults belonging to a family is important if a lump sum based on the number of adults is hypothesized. On the contrary, having elderly people in an isolated group would help when the carbon tax revenue is used to reduce labour taxation. The household profiles chosen are coherent with categories defined by ISTAT (even if ISTAT categories have a higher differentiation degree): in this way, using specific coefficients, information on the whole population can be obtained and welfare aggregate measures can be computed.

The North, South and Centre could have differences in public transport supply, which is intended to be more efficient in the North with respect to the South: then taxing fuels (private transport) could have different effects on household consumption depending on geographical areas. Furthermore, the North, South and Centre have certainly important differences in heating fuels request. For these reasons, I distinguished share expenditures considering the information associated to the season; in this way, distinguishing between household type, macro-region and season, I obtained 216 different subgroups for each examined year.

Figure 4.6 – Expenditure share by macro-region

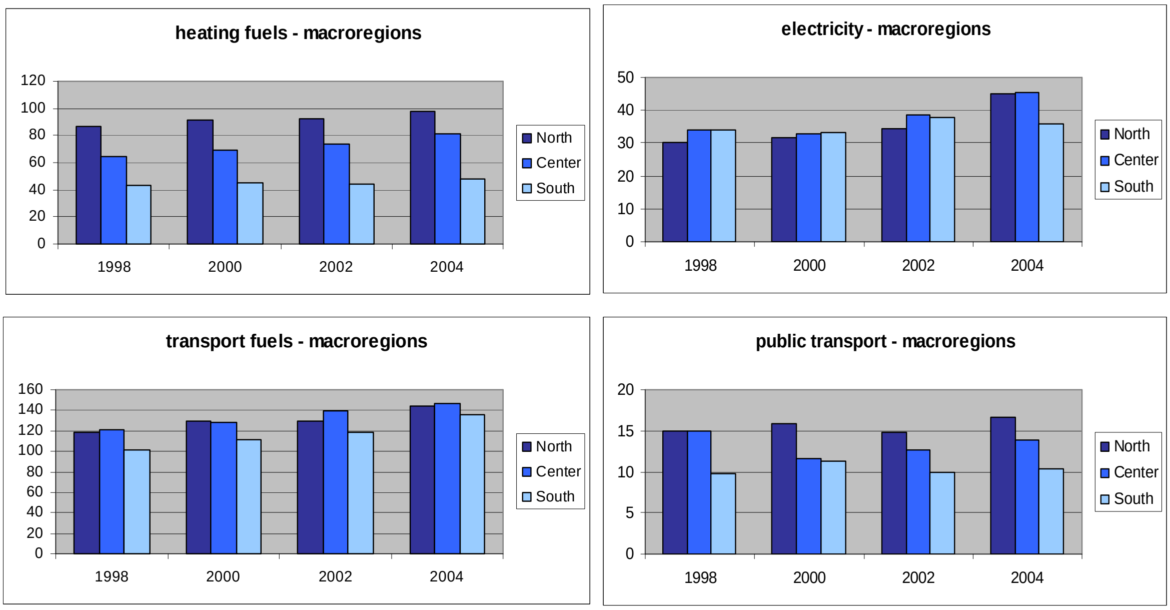


Figure 4.6 shows the differentiation for macro-regions of the expenditure share in heating fuels, electricity, transport fuels and public transport: they represent the goods included in the demand system on which carbon taxation will potentially impact. While for electricity and transport fuels consumption does not significantly differ, heating fuels expenditure share has a marked geographical trend: it is higher in the North, takes medium values in the Centre and is strictly lower in the South. Also public transport demand appears to be differentiated, having lower values in the South, where public transport development is still not comparable to that reached in the North and Centre. It is precisely this pattern that shows the opportunities linked to the development of an approach which takes into account the differentiation induced by the macro-region of residence, namely a demographic translated demand system.

4.1.2 Prices

With regard to the prices used to perform the demand system estimation, I extracted them from the Consumer Price Index (1998=100), also published by ISTAT. I used the *Indice nazionale dei prezzi al consumo per l'intera collettività* (Consumer price index for the whole nation, NIC) which monitors sale prices every month in all the Italian provinces. NIC is divided into 12 expenditure categories[35], entering each one in the aggregate national index with a specific weight, which reflects the relative importance on the concerned good on total consumption. For food prices I used directly price indices collected by ISTAT; on

[35] The expenditure categories are represented by: food and beverages, alcohol and tobacco, clothing, housing and energy, furniture, health, transport, communication, recreation, education, hotels and public services, and other goods and services.

the other hand, I aggregated some of them (computing the arithmetic mean) in order to obtain the aggregate prices of the other goods which constitute my demand system. In particular, I constructed other good and services prices in this way, by aggregating the following ISTAT expenditure categories: clothing, furniture, health, communication, recreation, education, hotels and public services, and other goods and services. For the other goods, namely heating fuels, electricity, transport fuels and public transport individual (elementary good) prices were used[36]. For heating fuels, transport fuels and public transport, I needed to aggregate individual prices to construct the price of the aggregate good included in my demand system. To this purpose, I used the coefficients provided by ISTAT which express the relative weight of each good constituting the index corresponding to the expenditure category. Finally, I assumed that all households in the sample face the same prices for each aggregate good: prices not vary longitudinally, having not been computed as implicit prices.

4.2 The empirical models and their results

This paragraph will propose an overview of the empirical and methodological issues related to the demand system estimation performed.

The errors are assumed to be jointly normal, independent across households and time periods, but correlated across goods. This model of the errors is what Pollak and Wales (1992) refer to as the standard stochastic specification for demand systems. An advantage of normality is that the errors in all equations can be jointly normal while still maintaining the adding up constraint. The restriction that budget shares sum to one is imposed by dropping one equation from the system, and jointly estimating the other equations using Maximum Likelihood. Joint normality of the errors ensures that the resulting estimates will not depend on which equation is dropped.

I have estimated both an AIDS and a QAIDS in order to indentify the preferred functional form (on the basis of statistical significance criteria) and to compare their results: in fact, very often a functional form is chosen and estimated without testing other specification and the derived results are not compared with alternative ones. For a more detailed description of the two theoretical models see Paragraph 3.3.4 and 3.3.5 . Since in both cases the models structure implies non-linearity in parameters, I have chosen not to limit my empirical work to the estimation of the approximated linear version (employing the Stone

[36] For the price series on province and monthly basis I thank the Ufficio Prezzi of ISTAT for having provided the data used in the demand system estimation.

Index, see equation (3.36)) and I have performed a non-linear estimation using Maximum Likelihood. To detect the preferred functional form, I have tested the significance of the quadratic specification with a Wald test on the joint significance of quadratic terms. The Chi-squared value (97.49) enables the null hypothesis according to which quadratic terms equal zero to be rejected at a 0.001 statistical significance level.

As far as theoretical restrictions are concerned, it should be noted that each equation is a linear combination of the others. Therefore, to avoid singularity of the variance-covariance matrix of errors, one of the equations needs to be left out of the estimation. I did not estimated the equation related to other goods, and its parameters were recovered using the adding-up constraints. Even if demand system theory implies homogeneity and symmetry constraints (see equation 3.39) beyond their verification, I thought it was useful to test them on the sample used: at this purpose I performed Likelihood Ratio tests computing the restricted and unrestricted models. Then, I estimated the unrestricted simultaneous equations system, namely not imposing homogeneity or symmetry: indicating with L1 the Log-Likelihood value of this estimation, it equals 31543.8 . I then estimated the demand system imposing symmetry: L2, the Log-Likelihood value of this estimation, equals 31232.0 . Finally, I estimated the demand system imposing both homogeneity and symmetry: the value of Log-Likelihood (L3) amounts in this case to 31204.9. The test statistics are constructed as standard Likelihood Ratio tests and under the null hypothesis are distributed as Chi-squared with degrees of freedom equal to the number or restrictions imposed. Table 4.2 shows the results for the null hypothesis represented by symmetry, homogeneity (given symmetry) and symmetry and homogeneity jointly, in the case of QAIDS demographic translated. The null hypothesis was always rejected at the 5% statistical significance level and the same holds when tests are performed for the AIDS demographic translated.

Table 4.2 – Homogeneity and symmetry tests

	Symmetry 2x(L1-L2)	**Homogeneity** 2x(L2-L3)	**Symmetry and homogeneity** 2x(L1-L3)
Log Likelihood Ratio	623.5	54.1	677.7
Degrees of freedom	10	5	15
Chi-squared	18.3 (95%)	11.1 (95%)	37.6 (95%)

I also tested homogeneity on the single equations composing the demand system, using an F-test, where the null hypothesis corresponded to $\sum_j \gamma_{ij} = 0$. Under the null, the test statistic is distributed as a Chi-squared with degrees of freedom equal to the number or restrictions imposed, and the null hypothesis was not rejected only for the fourth equation, corresponding to transport fuels. Irrespective of these results, I imposed symmetry and homogeneity conditions so that the estimated demand system was coherent with consumer theory (Rizzi and Balli, 2002; Labandeira et al., 2006).

The demand system to be estimated was also tested for total expenditure endogeneity (among others, Tiezzi, 2005; Labandeira et al., 2006) in prices, household type, macro-region and season– namely, in all the independent variables included in the model – in order to discover if a treatment of endogeneity (or separability) of total expenditure was needed (Keen, 1986; Hausman et al., 1995). To that end, an Hausman-Wu test was performed: the test statistic is constructed as a Likelihood Ratio test, then in a similar way than the tests performed for homogeneity and symmetry. First, an auxiliary regression was estimated, in which total expenditure was regressed on all the other exogenous variables in the model; then, the unrestricted model was estimated, by including the residuals of the auxiliary regression as explanatory variable in each equation of the simultaneous system. In this case, the restriction is represented by exogeneity, namely imposing equal to zero the coefficients of the residuals in each expenditure share equation. Finally, the test was computed, making the difference between the Log-Likelihood values of the unrestricted and restricted model; also in this case, the tests commented refer to the QAIDS demographic translated: they were computed also for the AIDS demographic translated and the same results hold. As in the case of homogeneity and symmetry, the degrees of freedom equal the number of restrictions imposed: then, in this case, the Chi-squared threshold value is 11.1 at 95% statistical significance level and the Log Likelihood Ratio is represented by $2 \times (L_r - L_{nr}) = 2 \times (31458.5 - 31204.9) = 253.6$, where L_r and L_{nr} stand for the Log Likelihood values respectively of the restricted and unrestricted model. Given these values, the null hypothesis of exogeneity was rejected and total expenditure turned out to be endogenous. For this reason, Ordinary Leat Squares provide inconsistent estimates due to the existence of contemporaneous correlation between the error terms and total expenditure. This can be solved by instrumenting total expenditure with the other independent variables used in the estimation, namely prices and all the dummy variables. Since the model is non-linear in parameters, I had to use a non-linear instrumenting variables technique. The estimator for both the AIDS and QAIDS was modified by implementing a Full Information Maximum Likelihood (FIML) algorithm in Stata. To this aim, the variance-covariance matrix was enlarged including the error terms related to the auxiliary regression for the instrumented variable, and with this procedure Maximum

Likelihood estimates were obtained from the non-linear simultaneous equations model. Alternatively, I could have applied an iterative procedure with starting values taken from a first stage estimation of a linear version of the model, using these initial estimates to obtain the non-linear ones through an iterative method until convergence was achieved (Labandeira et al. 2006; Blundell and Robin, 1999).

In a first stage of my empirical work, I also estimated AIDS on a national basis, using national prices and not distinguishing subgroups for the macro-region, but the number of observation was limited (in fact, the QAIDS did not converged) and the results clearly improved when distinguishing for the macro-region (see Appendix I for the parameters and their statistical significance). For this reason the elasticities belonging to linear national model will not be commented in Paragraph 4.3.

The sample used for the estimation when distinguishing between macro-regions consisted of 1944 observations (6 households profiles over 12 month for 9 years in 3 macro-regions). Using *h* to indicate the household type, *r* the macro-region, *m* the month and *y* the year, the data were organized as a sample $\Phi(m,r,h,y)$ by lining up monthly data ($m=1$-12) on each macro-region ($r=1$-3) and household type ($h=1$-6) for each year ($y=1$-9) in vectors of 1944 observations.

A demographic translated demand system was estimated (equation (3.52)), by adding translating intercepts a_{ih} represented by the equation

$$demo_i = \sum_h a_{ih} d_h \qquad (4.1)$$

where *demo* assumes a different value for every good *i* and every household type *h*. Translating intercepts satisfy the adding-up conditions according to the following equation

$$\sum_i a_{in} = 0 \qquad (4.2)$$

that it to say they sum to zero when household type *h* is fixed. I included six dummy variables d_1-d_6 that classify the household type although to avoid perfect collinearity, I dropped a variable (Greene, 1997). Since prices are differentiated for the three different geographical areas and some difference in energy products demand may exist, I also included translating intercepts which distinguished macro-regions. I also estimated three translating intercepts for each expenditure share equation that specified the season, believing that it could have an impact on households' demand: for example, heating fuels expenditure share is certainly significantly higher in winter than in the other seasons. Also an annual time trend was included in the expenditure share equations in order to detect the presence of specific period effects in the demand of the six aggregated goods; relative coefficients were significant in all cases, except for the demand for food (Appendix I , Table II and III).

The values of prices and expenditures were transformed into logarithms because of the demand system structure (see equation (3.31)). All the variables were normalised as differences with regard to their sample means. Due to the adding-up restriction, I have estimated only five equations and I have obtained the parameters of the sixth equation as a linear combination of the coefficients of the first five equations (see (3.38)).

For the AIDS the elements of the Slutsky matrix are given by the expression (3.2)

$$S_{ij} = \frac{x}{p_i p_j}\left[\gamma_{ij} + w_i w_j - \delta_{ij} w_i + \beta_i \beta_j \ln\left(\frac{x}{P}\right)\right]$$

In order to guarantee that the matrix of substitution effects is globally negative semi-definite the solution $\gamma_{ij}=0$ and $\beta_i=0 \;\; \forall\, i, j$ has to be excluded, because it reduces the system to a constant share model and then it is not appealing. Given that the substitution terms are approximately equal to $\gamma_{ij} + w_i w_j - \delta_{ij} w_i$ and that the expression $w_i w_j - \delta_{ij} w_i$ is negative semi-definite as long as budget shares are positive, Moschini (1998) points out that the desired curvature property will be satisfied if the matrix γ_{ij} is negative semi-definite. In this way the Slutsky matrix is negative semi-definite for all price and income levels but "too much concavity" is imposed on the model (Diewert and Wales, 1987), which loses its flexibility properties. For this reason, Moschini (1998) limits his scope to maintaining the curvature property locally.

Typically, the sample mean is chosen as the point for maintaining concavity because it represents the point with the highest sample information. Assuming that $\alpha_0=0$ and scaling data so that $p_i=x=0$ at the sample mean, in this point $w_1=\alpha_1$. Then, the substitution terms matrix at the mean point, θ_{ij}, can be written as

$$\theta_{ij} = \gamma_{ij} + \alpha_i \alpha_j - \delta_{ij}\alpha_i \qquad (4.3)$$

For concavity at the desired point to hold, the matrix θ_{ij} must be negative semi-definite and this condition can be ensured by reparameterizing it with the Cholesky decomposition (Lau, 1978); then, the AIDS has to be rewritten in terms of θ_{ij}. Diewert and Wales (1987) adopted a version of this decomposition according to which a necessary and sufficient condition for the matrix θ_{ij} to be negative semi-definite is that it can be written as $\theta_{ij}=-T'T$ where $T=[\tau_{ij}]$ is an upper triangular matrix of dimension $n-1$. Afterwards, as I have described in Paragraph 3.2.3, it can be necessary to restrict the rank to a number $K<(n-1)$:

here the rank of the T matrix was reduced from 5 to 3 by setting $\tau_{ij}=0$ for all $i>K$. In this way, the positive eigenvalues are excluded and the negativity condition is satisfied by construction. Since the number of τ_{ij} parameters is reduced from 15 to 12, the price coefficients θ_{ij} are estimated with less information: for this reason, such a restricted locally concave model is called Semiflexible Almost Ideal Demand System (Moschini, 1998). I followed exactly this approach in order to guarantee the curvature (negativity) condition.

4.3 Elasticities

I computed own and cross-price elasticities using the demographic translated version both of AIDS and QAIDS[37]. Here, I will focus on a discussion of the QAIDS elasticities because of the statistical significance of the quadratic specification[38]. The translating intercepts contribute to the computation of elasticities by entering in the estimated expenditure shares as in equation (3.52). I find out that at the sample mean they are coherent for all the examined goods: for example, the substitutability among private and public transport always holds, even if the absolute value of the elasticity changes with the translating intercepts. The Marshallian elasticities were computed by using the expression (3.33 **)**; I also computed compensated or Hicksian elasticities (expression (3.34)) and the theoretical property according to which they should be lower than their corresponding uncompensated figures was verified. In what follows I will only discuss Marshallian elasticities; furthermore, the elasticities I will discuss starting from here are those given by QAIDS demographic translated system. They were computed at the sample mean and as average values for each household profile.

Table 4.3 should be read in this way: for the *n* goods included in the demand system, the values in the columns represent the effect of a price change of good *i* on the demand of all the other goods (including itself); conversely, the rows contain the effects on the demand of the good *j* induced by changes in its own and other goods price.

[37] It could be useful and interesting compare the results I have obtained in terms of estimated elasticities with those synthesized by the meta-analysises described in Paragraph 2.4.1. Aniway, it should be remembered that the elasticities included in the meta-analysis refer only to fuels.

[38] AIDS elasticities can be found in Appendix II, which also includes the standard errors and the statistical significance for the elasticities discussed in this paragraph.

Table 4.3 – Average elasticities

	food	*heating fuels*	*electricity*	*transport fuels*	*public transport*	*other goods*
food	**-0.260**	0.026	-0.086	0.020	0.019	-0.225
	(0.041)	*(0.035)*	*(0.020)*	*(0.030)*	*(0.011)*	*(0.048)*
heating fuels	-0.073	**-1.204**	0.406	0.188	-0.326	0.046
	(0.209)	*(0.165)*	*(0.067)*	*(0.163)*	*(0.066)*	*(0.250)*
electricity	-0.959	0.813	**-1.093**	-0.546	0.621	1.286
	(0.221)	*(0.127)*	*(0.108)*	*(0.121)*	*(0.093)*	*(0.269)*
transport fuels	-0.015	0.131	-0.170	**-0.544**	0.085	-0.268
	(0.098)	*(0.092)*	*(0.036)*	*(0.092)*	*(0.036)*	*(0.117)*
public transport	0.395	-1.836	1.812	0.821	**-0.790**	-1.725
	(0.380)	*(0.371)*	*(0.275)*	*(0.119)*	*(0.207)*	*(0.528)*
other goods	-0.366	0.002	0.042	-0.092	-0.028	**-0.869**
	(0.027)	*(0.023)*	*(0.013)*	*(0.019)*	*(0.009)*	*(0.125)*

The own price elasticities (computed in the sample average) show a variation in consumption which is more than proportional to the price change for heating fuels and electricity. Heating fuels demand is the most price elastic (-1.204), showing high sensitivity to price changes and this finding is consistent with the value obtained by Tiezzi (2005), who estimated a very similar demand system. Electricity demand also appears to be very price elastic and this is surprising given the electricity connotation of necessary good. This is likely to reflect the presence of a high part of electricity demand linked to "luxury utilization" (such as air conditioning and some electrical appliances) and then the existence of a high margin for energy saving. Public transport has a high own-price elasticity (-0.790), differently from the very low elasticity computed by Tiezzi (-0.031); on the other hand, transport fuels demand is less price-elastic (-0.544).

Cross-price elasticities contain meaningful information on the tax impacts on consumption consumption patterns. In particular, the second, third and fourth columns of the table refer to the goods on which I will simulate the carbon tax impacts.

The change in heating fuels demand due to a change in the price of electricity is positive (0.406) and the two goods appear to be substitutes. Then, when heating fuel price increases, there is a strong substitution effect which operates through changes in domestic appliances equipment, enhancing the spread of electric appliances. This result is relatively new in the energy demand literature because the demand for these two goods has rarely been separated. Demand for electricity roughly shows a similar figure with regard to cross-price elasticities with heating fuels: a high substitution effect holds (0.813). In order to explain the very high own-price elasticities obtained for heating fuels and electricity, a modified demand system was estimated where electricity and heating fuels were aggregated. In this way it be seen that for the aggregate good (represented by heating fuels and electricity) the own-price elasticity is coherent with the necessary good connotation of electricity and heating. The estimated elasticities are shown in Table 4.4.

Table 4.4 – Average elasticities of the modified demand system

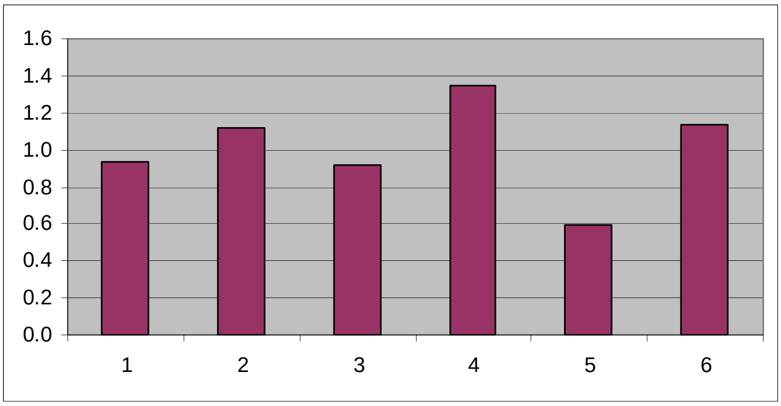
	food	***heating fuels + electricity***	***transport fuels***	***public transport***	***other goods***
food	**-0.343** *(0.060)*	0.076 *(0.032)*	0.029 *(0.030)*	0.029 *(0.033)*	-0.515 *(0.021)*
heating fuels + electricity	0.286 *(0.127)*	**-0.634** *(0.137)*	-0.488 *(0.041)*	-0.026 *(0.068)*	0.099 *(0.183)*
transport fuels	-0.025 *(0.102)*	-0.449 *(0.035)*	**-0.371** *(0.068)*	0.028 *(0.040)*	-0.629 *(0.051)*
public transport	0.709 *(1.090)*	-0.279 *(0.567)*	0.234 *(0.028)*	**-0.676** *(0.204)*	1.171 *(0.340)*
other goods	-0.418 *(0.011)*	-0.016 *(0.026)*	0.123 *(0.071)*	0.041 *(0.018)*	**-0.713** *(0.039)*

Continuing our analysis of Table 4.3, the consumption of transport fuels is lightly affected when heating fuels, electricity and public transport prices change (respectively, cross-price elasticities equal to 0.131, -0.170, 0.085). Taking into consideration public transport demand, the cross-price elasticity with transport fuels (0.821) shows that public transport represents a relevant substitute for private transport: when the transport fuels price changes, there is an important behavioural response on public transport consumption. The presence of a substitutability relation between private and public transport represents an important basis for carbon tax implementation to be successful. This pattern will be examined distinguishing different household profiles (Figure 4.7). In this case – and also for heating fuels – distinguishing households on the basis of the geographical area of residence seems worth to be examined. I have computed the elasticities in the average values for each macro-region, but they do not differ substantially (in the range of +/–0.05): then, only the expenditure share on heating fuels shows a pronounced differentiation between macro-regions (see Figure 4.6).

A first analysis of average elasticities enables to say that, although carbon tax may be effective in reducing the consumption of the polluting goods, it is not likely to affect the consumption pattern significantly. In fact, extracting them from Table 4.3, the cross-price elasticities related to price changes in heating and transport fuels are represented respectively by the vectors (0.026, 0.813, 0.131, -1.836, 0.002) and (0.020, 0.188, -0.546, 0.801, -0.092) which do not imply relevant impacts, except for the effect on public transport produced by price changes in heating fuels. Tiezzi (2005) estimated indirect impacts even more reduced.

Since my simulation analysis take into consideration an augmentation of private transport price, studying its cross-price elasticity with transport fuels is relevant if one is interested to the relative price of private and public transport. Public transport demand has a pronounced variability of cross-price elasticity with transport fuels if the household type changes (Figure 4.7).

Figure 4.7 – Cross-price private-public transport elasticities (famtipo)



The relation of substitutability always holds and public transport demand appears to be in all cases very sensitive to transport fuels price changes. In particular, households with children (household type 4) show a strong substitution effect towards transport options which are an alternative to private transport when it becomes more expensive. On the contrary, the substitution effect is weaker for households with young people (type 5) showing that, in this case, the alternative of public transport is less desirable when private transport costs increase perhaps because of the presence of consumption habits that are more difficult to modify and the availability of more than one vehicle in the household. Probably for the same reasons the substitution effect applies to a lower extent also to household type 1 and 3 (respectively corresponding to single-adult and up to four adults households). To summarize, households with children, couples without children and elderly people seem to be more disposed to shift from private to public transport when transport fuels price increases.

Regarding the differences in household profiles elasticities, the number of household members certainly constitutes an important explanatory variable of consumption and it is likely to be linked to the size of the house and then to the consumption of electricity and heating. Furthermore, the number of household members is clearly relevant when examining transport services consumption; as I will highlight in what follows, this characteristic has a different effect on transport fuels and public transport demand. Besides, consumption of energy goods could be related to the age of the head of the household in two ways: cultural reasons may influence preferences, and age could provide some insight on the characteristics of the house and the stock of its appliances, such as the heating system (Labandeira et al., 2006).

Focusing on heating fuels demand, the legislation developed for the implementation of Law 10/91 has reduced energy consumption in new buildings by 10% compared with 1990 levels. The decrees issued by the Ministry of Industry on 24 April 2001 also had an important role, setting the national quantitative objectives for energy savings together with quantitative objectives for increasing the energy efficiency of final uses. Measures involving the labelling of home appliances, as well as more efficient electrical devices in general, also play an important role in reducing the consumption of electricity in buildings. This demonstrates the relevance of durable goods equipment: for example, higher income households, probably with a higher education level, are likely to have more expensive and efficient appliances and better insulated houses (Labandeira et al., 2006). Some household profiles could have reduced possibilities (that is to say lower elasticities) of accessing some energy goods – or durable goods connected, which favour energy savings – and thus to substitute away when prices change.

As for the average income elasticities of demand (Table 4.5), surprisingly heating fuels and public transport turn out to be luxury goods (1.262 and 1.322 respectively) whereas the demand for electricity and transport fuels increases less than proportionally to income. An important point is represented by the fact that electricity, as expected, appears to be a necessary good; this could demonstrate that the fact that the "luxury demand" of electricity – mainly linked to air conditioning – does not constitute the prevailing component with regard to "necessary electricity demand", linked to cooking and lighting.

Table 4.5 – Average income elasticities

food	0.506 *(0.014)*
heating fuels	1.262 *(0.054)*
electricity	0.477 *(0.024)*
transport fuels	0.780 *(0.022)*
public transport	1.322 *(0.076)*
other goods	1.311 *(0.010)*

The luxury good connotation of heating fuels probably reflects a still not universal spreading of this device: for this reason, the sample or the methodological approach used could not completely model the complexity of heating fuels demand[39]. Heating fuels turn out to be a luxury good also in other cases, for example represented by Labandeira et al. (2006) and Tiezzi (2005), who found an income elasticity of domestic fuels equal to 1.523. In particular, some problems can arise with observed expenditure on heating: in fact very often households share collective central heating and this implies that their expenditure share on this good is not directly related to individual household consumption, but rather to the average for some households (Labandeira et al., 2006). Public transport, on the other hand, is a luxury good in the measure that very often public transport connections are better when the household live in central locations (compared with the suburbs): income increases could then be associated with improvements in the possibilities to use public transport. Another issue which could have contributed to this result is represented by the fact that expenditure for holidays could be included in this aggregate good (travelling with public transport).

Also in this case it appears to be useful to show the income elasticities estimated through the modified demand system, in which heating fuels and electricity are aggregated into a single good (Table 4.6).

Table 4.6 – Average income elasticities of the modified system

food	0.723 *(0.012)*
heating fuels + electricity	0.764 *(0.022)*
transport fuels	1.140 *(0.017)*
public transport	1.541 *(0.050)*
other goods	1.157 *(0.007)*

Table 4.7 shows the income elasticities for each household type: the pattern already described at general level always holds. Considering this table, households with elderly people are globally the less reactive to income changes: the income elasticities belonging to this group, except for electricity, are always below the average (Table 4.5).

[39] The proportion of heated homes out of the inhabited homes has remained practically unchanged from 1990 to 1999 (approximately 89%), though there is a growing tendency to use independent heating systems (+33.1%) rather than centralised systems (-15.8%) or single devices (-4.5%). Breaking down final energy consumption for domestic heating in 1999 by type of heating system, 14% regarded individual systems, 63% autonomous systems and 23% centralised systems (Ministry of Environment and Territory, 2002).

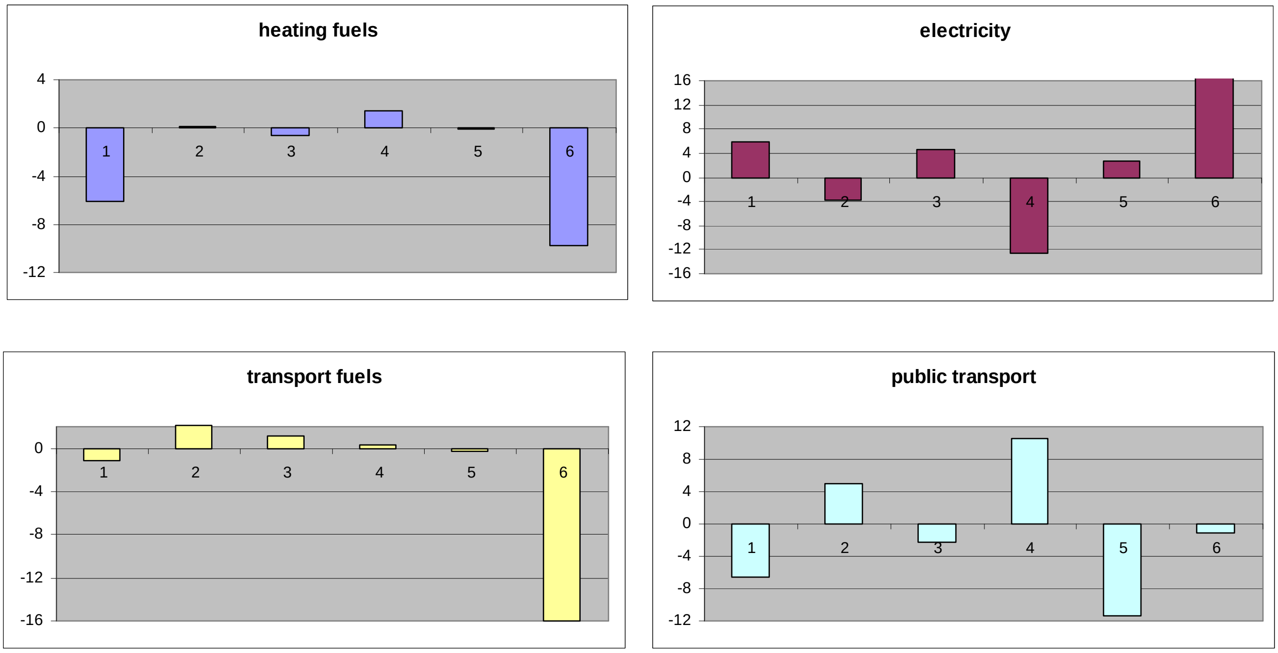
Table 4.7 – Income elasticities by famtipo

	1	*2*	*3*	*4*	*5*	*6*
heating fuels	1.186 *(0.069)*	1.264 *(0.055)*	1.254 *(0.059)*	1.280 *(0.061)*	1.260 *(0.067)*	1.139 *(0.049)*
electricity	0.505 *(0.029)*	0.459 *(0.025)*	0.499 *(0.024)*	0.417 *(0.027)*	0.490 *(0.026)*	0.556 *(0.026)*
transport fuels	0.771 *(0.024)*	0.796 *(0.020)*	0.789 *(0.021)*	0.782 *(0.021)*	0.778 *(0.022)*	0.655 *(0.036)*
public transport	1.236 *(0.093)*	1.388 *(0.092)*	1.292 *(0.077)*	1.462 *(0.115)*	1.171 *(0.049)*	1.306 *(0.116)*

Heating fuels are in all cases a normal good but income elasticities are higher in case of households with children (1.280). Income elasticity for electricity demand seems to have an increasing pattern linked to the number and age of household members. Income elasticity is, in fact, higher for household with elderly people (type 6) and household with up to four adults and young people (types 4 and 5). Perhaps this last point reflects the higher relative importance that goods and services that make a high use of electricity, such as computers and internet connections, have in the mentioned household types. Also the demand for transport fuels increases less than proportionally to income, but it does not have relevant tendencies for different household types, except being lower for household type 6. This further confirms the absence of regressivity of the taxation directed to this group of goods. In fact, if income elasticity had assumed very different values for each household profile – and then for different expenditure levels – the behavioural response would likely have been different and carbon taxation would likely have had regressive impacts. Public transport turns out to be a luxury good in all cases, in particular for household profiles 4 and 2 (income elasticities equal to 1.462 and 1.388). To summarize, we can say that the main pattern of income elasticities remains almost constant even if household profile changes.

The graphs contained in Figure 4.8 show the percentage variation with respect to the average elasticity, for each household profile and each good of interest. The different tendencies if household profile changes are here more visible; only in the case of transport fuels there is not any relevant difference, except for household type 6. Both in the case of heating fuels and transport fuels the income elasticities for household type 6 are below the average, showing that the demand is less elastic with respect to income, maybe due to the fact that elderly people are often retired and their income endowment is atypical.

Figure 4.8 – The percentage variation of income elasticity by good



Some potential explanations, for the different examined goods, are given by:

1) heating fuels (average elasticity equal to 1.262): income elasticity is lower than the average for household type 6, then the age of households component plays a relevant role in influencing demand, making heating fuels "more necessary".

2) electricity (average elasticity equal to 0.477): the demand is less elastic than average for household type 2 and 4; in particular, for household type 4, the connotation of normal good is marked. On the other hand, for household type 6 the demand appears to be more reactive to income changes.

3) transport fuels (average elasticity equal to 0.780): a common trend exists, with the exception of household type 6, which represents – as in the case of all the other goods with exception of electricity – an outlier: the necessary connotation of transport fuels, as in the case of the other goods, is more pronounced.

4) public transport (average elasticity equal to 1.322): the demand for public transport – and then the habit to use it – seems to differently react to income according to household type. The presence of children makes the demand for public transport more income-elastic, stressing the connotation of luxury good. On the other hand, in the case of household type 5, the variation with respect to the average is negative, showing a more inelastic demand and then habits more difficult to modify, even in presence of income changes.

Table 4.8 – Expenditure share versus elasticity by famtipo

a. heating fuels			
	own-price	*w*	*income*
1	-1.166	5%	1.186
2	-1.147	5.1%	1.264
3	-1.167	4.7%	1.254
4	-1.198	4.4%	1.280
5	-1.217	4.3%	1.260
6	-1.009	6.6%	1.139

b. electricity			
	own-price	*w*	*income*
1	-1.084	2.4%	0.505
2	-1.107	2.3%	0.459
3	-1.058	2.5%	0.499
4	-1.168	2.2%	0.417
5	-1.078	2.5%	0.490
6	-1.005	2.8%	0.556

c. transport fuels			
	own-price	*w*	*income*
1	-0.502	8.8%	0.771
2	-0.499	8.9%	0.796
3	-0.496	8.9%	0.789
4	-0.480	8.6%	0.782
5	-0.486	8.7%	0.778
6	-0.325	6%	0.655

d. public transport			
	own-price	*w*	*income*
1	-0.778	4.7%	1.236
2	-0.735	4.8%	1.388
3	-0.784	5%	1.292
4	-0.678	4.1%	1.462
5	-0.858	5%	1.171
6	-0.723	3%	1.306

Table 4.8a shows that household type 6 has the highest expenditure share and the lowest income and own-price elasticities. On the other hand, household types 4 and 5 have low expenditure shares and their own-price elasticities are high. With respect to the income elasticities, they follow the expenditure shares pattern and it could be said that electricity demand become less elastic when household members number increases. In the case of electricity demand (Table 4.8b) household type 6 has the greatest expenditure share and also the greatest income elasticity; on the other hand, the own-price elasticity is the lowest, indicating that other household types have better substitution possibilities. The pattern of transport fuels (Table 4.8b c) is very different: household type 6 has the lowest expenditure share and also the lowest own-price and income elasticity. The other household types have very similar expenditure shares and elasticities. Also in the case of public transport (Table 4.8Table 4.d) household type 6 has the lowest expenditure share and the elasticities are among the lower ones. In the case of household type 4 the expenditure share is relatively low and the own price elasticity is the lowest. Finally, household types 3 and 5 have the same expenditure share, but the first has a higher income elasticity whereas the second a higher own-price elasticity.

Price responses – and then the way people react to policy changes – enable some initial assessments to be made: price elasticities for heating fuels, electricity and transport fuels are high (Table 4.3) and this represents a crucial factor for the environmental effectiveness of a tax reform. Then introducing carbon taxation in Italy could be a powerful tool for meeting Kyoto targets; in particular, the sensitivity of transport fuels demand to price changes confirms that transport is a key sector for Italian environmental policy. I want to highlight the role of cross-price elasticities for transport fuels and public transport: transport fuels demand is so price-elastic (-0.544) also because of the availability of alternative transport options. In fact, West and Williams (2004) find that the demand for gasoline is more inelastic (elasticities in the range -0.5, -0.7, except for the top quintile of the income distribution) and this may be due to the fact that in the USA distances are much greater and private transport cannot always be substituted by for public transport. (Tiezzi, 2005). Moreover, substitutability between private and public transport seems worth examining by differentiating between the macro-regions: in fact, different efficiency levels in public transport could emerge (have different implications for the demand responses). Computing the elasticities in the sample average for each macro-region shows that the impacts on public transport deriving from private transport price changes are greater in the South (0.989) whereas they are lower in the Centre (0.853) and in the North (0.831). This demonstrates how great opportunities exist for public transport development in the South.

4.4 True Cost of Living Indices and welfare measures

After the description of demand elasticities, this paragraph will deal with the welfare and incidence analysis; in order to give a comprehensive understanding of the different step I followed, it will be divided in three sub-paragraphs. Paragraph 4.4.1 will describe the methodological approach associated to True Cost of Living indices and incidence measures estimation, and it should be read considering that its theoretical complement is constituted by Paragraph 3.5. In Paragraph 4.4.2 the taxation scenarios simulated will be described, while Paragraph 4.4.3 will comment the results, comparing welfare measures across different macro-regions, welfare levels and scenarios.

4.4.1 The methodological approach

True Cost of Living index computation is a relatively easy task once demand system estimation has been performed: in fact, these indices are expressed in terms of cost functions, whose parameters represent the output of demand models computation. They have another advantage, linked to the computation of welfare measures: they allow to compute compensating and equivalent variation with a similar procedure, and in this way the comparison between the values obtained can be made.

For a detailed description of TCOLs computation and welfare measures derivation in the case of an AIDS see Paragraph 3.5. In order to assess the different implications linked to the functional form choice I have computed TCOLs with both AIDS and QAIDS parameters. To my knowledge it is the first time TCOLs are computed for a QAIDS; for this reason, I need to derive the parametrization of a TCOLs when using the QAIDS cost function.

Starting from the QAIDS indirect utility function (equation (3.41)) and solving it for the log of the expenditure level *x* we obtain the cost function for the QAIDS system

$$\ln x = \ln c(p,u) = \ln a(p) + b(p)\left(\frac{1}{1/u - \lambda(p)}\right) \tag{4.4}$$

where $\lambda(p) = \sum_i \lambda_i \ln p_i$. Given this cost function, we can derive the expression for TCOLs computation for a QAIDS

$$\begin{aligned}\ln P(p^1, p^0, u) &= \ln c(p^1, u) - \ln c(p^0, u) = \ln a(p^1) + b(p^1)\left(\frac{1}{1/u - \lambda(p^1)}\right) + \ln a(p^0) + b(p^0)\left(\frac{1}{1/u - \lambda(p^0)}\right) = \\ &= \ln a(p^1) + b(p^1)\left(\frac{1}{1/u - \lambda(p^1)}\right) - u\end{aligned} \tag{4.5}$$

The difference between cost functions reduces to the last expression since, when prices are normalized to unity in the starting period, the price functions *a(p), b(p)* and *λ(p)* are all equal to one in period zero.

In order to compute the utility reference level *u* as in the equation (3.75), the QAIDS indirect utility function has to be employed. Then, for compensating variation, where the utility reference level is represented by the initial period utility level, we have

$$\ln P = \ln a(p^1) + b(p^1)\left(\frac{1}{1/\ln x_0 - \lambda(p^1)}\right) - \ln x_0 \tag{4.6}$$

Conversely, for equivalent variation, where the final period utility level represents the reference level, the expression is more complicated

$$\ln P = \ln a(p^1) + b(p^1)\left(\frac{1}{1/u^1 - \lambda(p^1)}\right) - u^1 \tag{4.7}$$

In fact, in this case the price functions are different from one and the utility level does not reduce to ln*x*. Clearly it could be checked that when the *λ(p)* is null both equations (4.6) and (4.7) are equal to the TCOLs equation in case of AIDS, respectively in the case of compensating and equivalent variation.

Concretely, in order to compute TCOLs several steps were followed. First, different welfare levels were identified and this was done based on representativeness criteria and searching to assure a numeric balance between different groups. Five welfare (expenditure) levels were identified, represented by: low income (level 1), medium-low income (level 2), medium income (level 3), medium-high income (level 4) and high income (level 5). For this purpose threshold values in terms of total monthly expenditure were identified

$$\begin{array}{ll} \ln x \le x_1 & x_1 = 0.5 \times \ln x \\ x_1 < \ln x \le x_2 & x_2 = 0.8 \times \ln x \\ x_2 < \ln x \le x_3 & x_3 = 1.2 \times \ln x \\ x_3 < \ln x \le x_4 & x_4 = 1.6 \times \ln x \\ \ln x > x_4 & \end{array} \tag{4.8}$$

In this way the threshold values change (increase) in the sample period and are specific to household profile. For instance, for household type 2 – the two-adult household, on which equivalent scales are defined – the thresholds are represented by: EUR 680 (*x1*), EUR 1088 (*x2*), EUR 1904 (*x3*), EUR 2449 (*x4*). These thresholds are related to compensating variation computation, which requires the normalization of monthly total expenditure to the year 1998 (the year before carbon taxation was introduced), used as reference utility level. The method to identify welfare levels does not change in the case of equivalent variation except for the normalization of total expenditure, which is done to the final year of the simulation, employed as reference utility level. Table 4.9 shows the numerousness of each welfare level for household type 2 in all the examined years: it could be seen that there is some variability from one year to another. For the sake of brevity, only the numerousness for household type 2 is shown; Table 4. focuses on this particular household profile because with reference to it the equivalence scales were defined.

Table 4.9 – Welfare level numerousness for household type two

	year							
level	***1997***	***1998***	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***
1	320	195	211	219	213	275	258	236
2	420	506	468	513	556	617	637	517
3	507	649	595	695	705	774	812	657
4	372	431	413	467	409	541	510	443
5	539	494	475	528	528	583	617	547
total	***2158***	***2275***	***2162***	***2422***	***2411***	***2790***	***2834***	***2400***

Table 4.10 contains the numerousness (in percentage terms) of each expenditure level distinguishing for the household profile: it is in line with expectations, for example level 1 numerousness is relatively higher for single-adult households and households with elderly people.

Table 4.10 – Welfare level numerousness (percentage on the total)

	household type					
	1	***2***	***3***	***4***	***5***	***6***
level 1	13.2	9.9	9.5	7.6	8.9	12.7
level 2	21.1	21.8	20.8	20.9	20.3	23.2
level 3	26.5	27.7	29.1	30.6	29.1	25.6
level 4	16.3	18.4	18.7	19.3	19.4	16.3
level 5	22.9	22.2	21.8	21.5	22.3	22.3
total	***100***	***100***	***100***	***100***	***100***	***100***

After having defined welfare levels, prices were normalized to unit in the initial period, identified with 1998, when the carbon tax had not been adopted. Then, following Tiezzi (2005), the difference between the TCOLs in two scenarios was computed, a scenario without carbon taxation (A) and another in which carbon taxation – in its different forms (see Paragraph 4.4.2) – was introduced (B). Finally, in order to compute TCOLs the expenditure levels needed to be made comparable: for this purpose, the equivalent expenditure was computed by using an equivalence scale estimated by Perali (1999). I had to adjust them to be applicable to the households profiles used in my estimation: in fact, in some cases Perali (1999) differentiated household profiles even more and then I needed to compute an average equivalence scale. The equivalence scales used in my estimation are defined with reference to the household profile "couple without children": then, in terms of adult-equivalent, the equivalence scale for this household profile is 2 (using the household types included in my empirical model, the couple without children is represented by the second household profile). With regard to other household profiles, the equivalence scale used is represented by: 1.62 (single-adult households), 2.53 (up to four adults households), 2.495 (households with children), 2.45 (households with young people), 1.04 (two elderly people households). This means that, for instance, a household with young people needs 2.45 times the expenditure of the two-adult household in order to enjoy the same welfare level. Adopting the equivalence scales described, all the welfare measures computed and commented in the following could be expressed in equivalent expenditure terms.

4.4.2 The different taxation scenarios

The main taxation scenario (B1) simulated refers to the carbon tax introduced with the Budget Law for 1999 (see Paragraph 1.8.1): for this reason, the price series of energy products starts to differ from 2000. Unione Petrolifera has provided fuels and heating fuels prices, broken down into industrial price and excise components: on this basis, it has been possible to construct the price series for the scenario under which the carbon tax is introduced and not frozen up after the first year. In particular, excise augmentation was distributed on seven years, up to 2005, in line with DPCM 15/1/1999. The carbon tax prices series was computed for every transport fuel, and the prices were then aggregated using ISTAT weighting coefficients. During this phase I used data provided by Unione Petrolifera and in this way I could take into consideration the distance of the real excise from the objective level. Then, the prices which include the carbon tax were merged to the sample with households divided in expenditure levels. In Table 4.11 the excise augmentation pattern is shown: the total increase needed to achieve the 2005 objective level was equally distributed on seven years.

Table 4.11 – Expected excises under scenario B1 (EUR/litre)

	1999	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Unleaded fuel	0.539	0.522	0.524	0.542	0.542	0.559	0.563
Unleaded fuel (carbon tax)	0.537	0.546	0.556	0.565	0.575	0.584	0.594
Diesel	0.400	0.383	0.385	0.403	0.403	0.403	0.411
Diesel (carbon tax)	0.402	0.413	0.424	0.435	0.447	0.4583	0.469
LPG	0.156	0.146	0.147	0.157	0.156	0.157	0.157
LPG (carbon tax)	0.163	0.154	0.146	0.1383	0.130	0.121	0.113
Heating fuels	0.400	0.378	0.367	0.403	0.403	0.403	0.403
Heating fuels (carbon tax)	0.400	0.414	0.425	0.436	0.447	0.458	0.470

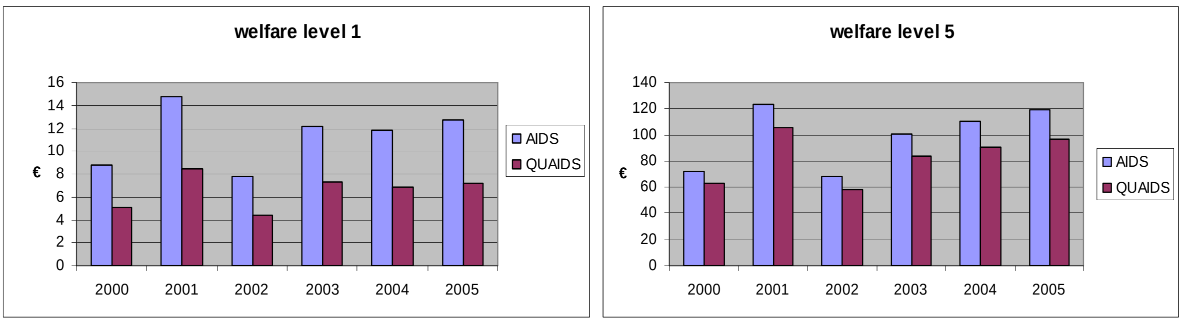
Three other scenarios were simulated, two of which are simple re-modulations of carbon taxation scenario B1, aimed investigating and detecting if excise augmentation of heating or transport fuels individually has regressive impacts. Then, under scenario B2 only prices of heating fuels were increased whereas under scenario B3 only prices of transport fuels. Scenario B4, on the other hand, simulated an intervention on electricity prices, following several experiences in the Nordic countries (see Paragraph 1.6). Since DPCM 15/1/1999 also introduced a gradual increase of the excise of energy products used for electricity generation, the consequent price increase was used to compute the augmentation of electricity prices. This augmentation was constructed considering that from 1999 to 2005 the Italian energy mix had changed: for this purpose, a weighted average of energy sources (steam coal, natural gas and heavy fuel oil) price increases was computed, where the weights were the annual shares in energy mix[40]. It should be mentioned that this scenario has several limitations: namely, it does not take into account electricity produced using renewable sources or the increased competitiveness of imported electricity (exempted from the tax).

These scenarios, even if not so distant from the main scenario B1 – as in scenario B2 and B3 – or simple in the way they model energy market – as in B3 – aim to show that my methodological approach allows different options of ecological tax reforms to be compared.

4.4.3 The results

As I anticipated in Paragraph 4.4.1, I estimated TCOLs, compensating and equivalent variations both with AIDS and QAIDS parameters, in order to detect differences between the two functional forms. The linear functional form adopted with AIDS always estimates greater welfare impacts with respect to the quadratic functional form. Here, by way of an example, I include only the graph related to compensating variation for the lowest and the highest welfare level (respectively 1 and 5) in the macro-region North, computed for all the examined years (Figure 4.9). Given this overestimation and the statistical significance of the quadratic specification, in what follows I will only discuss welfare impacts from the QAIDS estimation.

Figure 4.9 – AIDS versus QAIDS (Euro 1998)



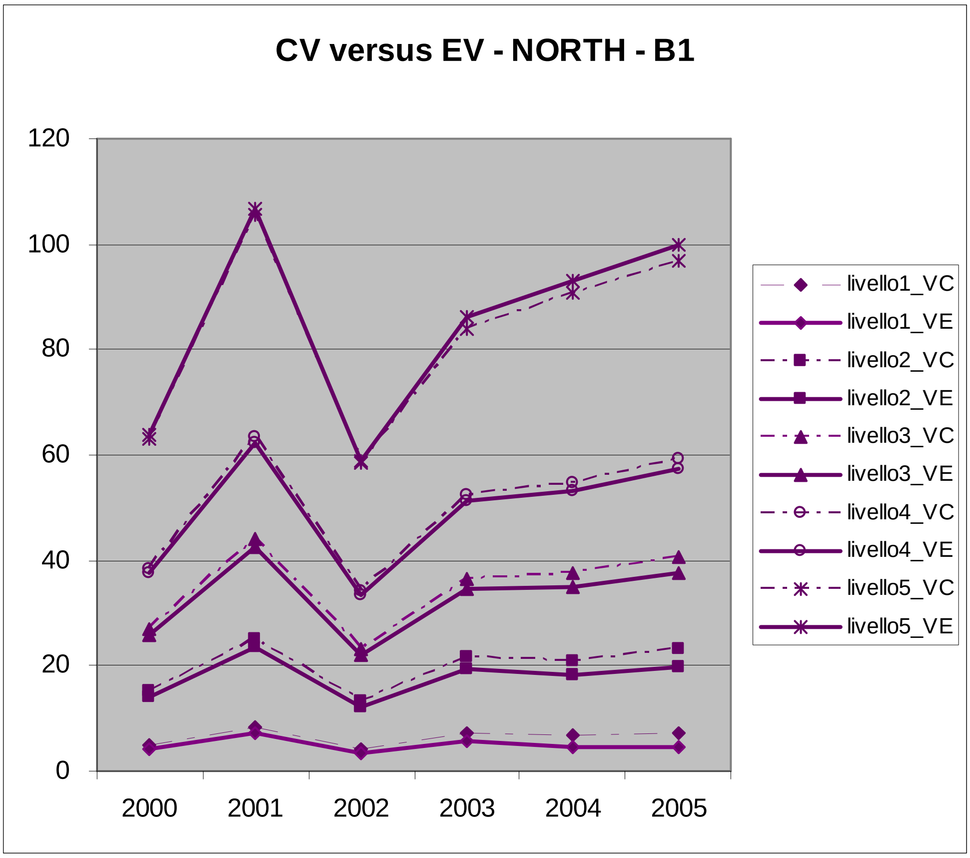
In this paragraph compensating and equivalent variation will be commented both in absolute values and as percentage of total expenditure. In fact, the analysis of compensating and equivalent variation in absolute values is useful in order to investigate the direct impact of carbon taxation and the possibility to compensate specific expenditure classes or household profiles. On the other hand, only the examination of compensating and equivalent variation as percentage of total expenditure allows to identify potential

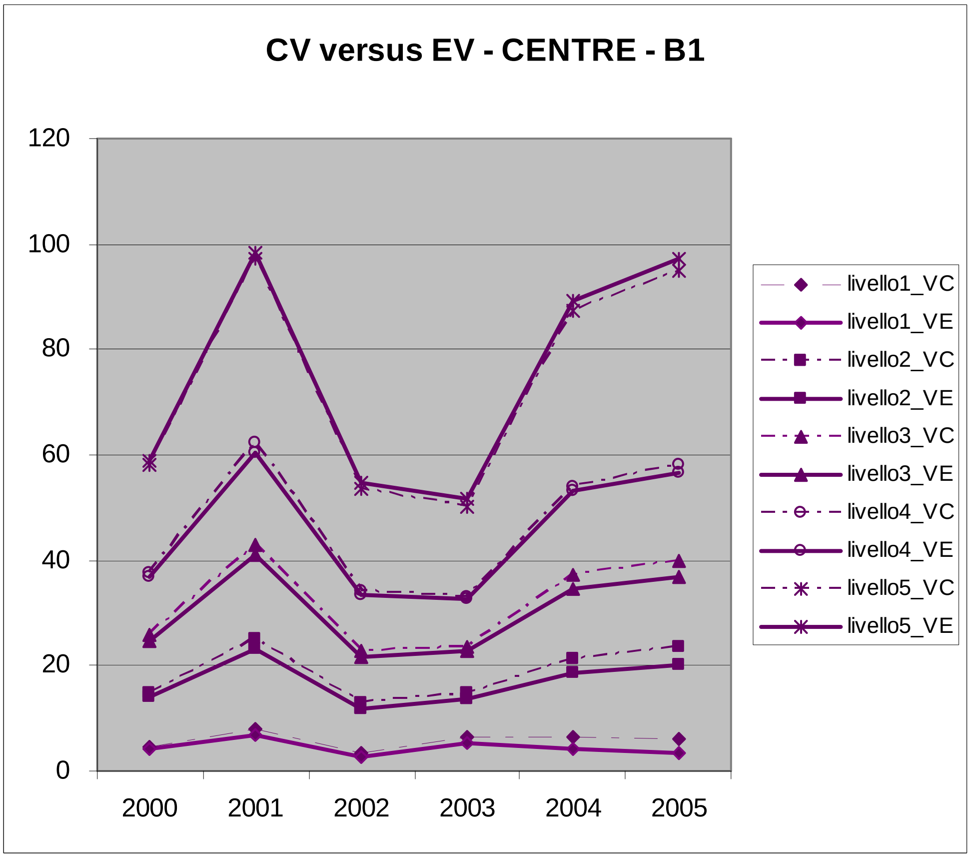
[40] The impact of the carbon taxation on electricity prices has been computed employing as weight the part of electricity tariff which reflects the generation (fuel) cost, as provided by AEEG (2003; 2005).

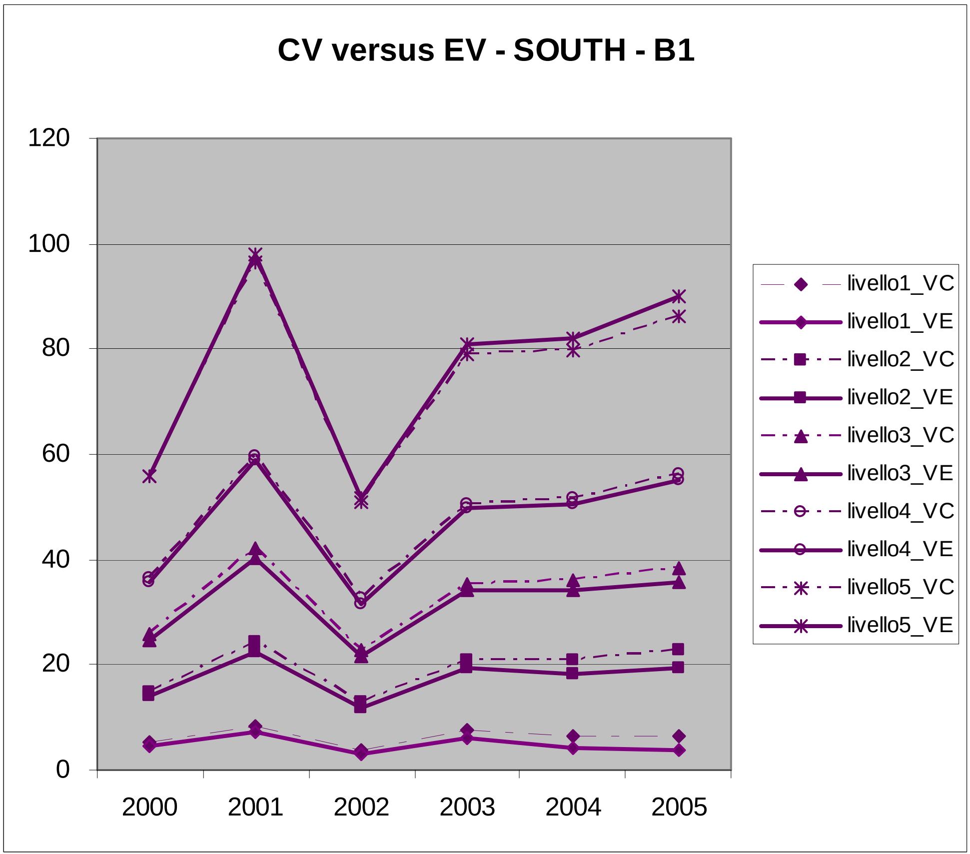
regressive impacts of the taxation scenarios simulated. Furthermore, the absolute values of CV and EV represent an annual welfare impact, whereas the values in percentage terms are referred to monthly total expenditure.

In the following graphs (Figure 4.10), Compensating Variation (CV) and Equivalent Variation (EV) computed under scenario B1 are compared for the macro-regions North, Centre and South (see also Appendix III, Table I).

Figure 4.10 – CV versus EV under scenario B1 (Euro 1998)




CV versus EV - CENTRE - B1
120
100
80
60
40
20
0
2000
2001
2002
2003
2004
2005
livello1_VC
livello1_VE
livello2_VC
livello2_VE
livello3_VC
livello3_VE
livello4_VC
livello4_VE
livello5_VC
livello5_VE


CV versus EV - SOUTH - B1
120
100
80
60
40
20
0
2000
2001
2002
2003
2004
2005
livello1_VC
livello1_VE
livello2_VC
livello2_VE
livello3_VC
livello3_VE
livello4_VC
livello4_VE
livello5_VC
livello5_VE

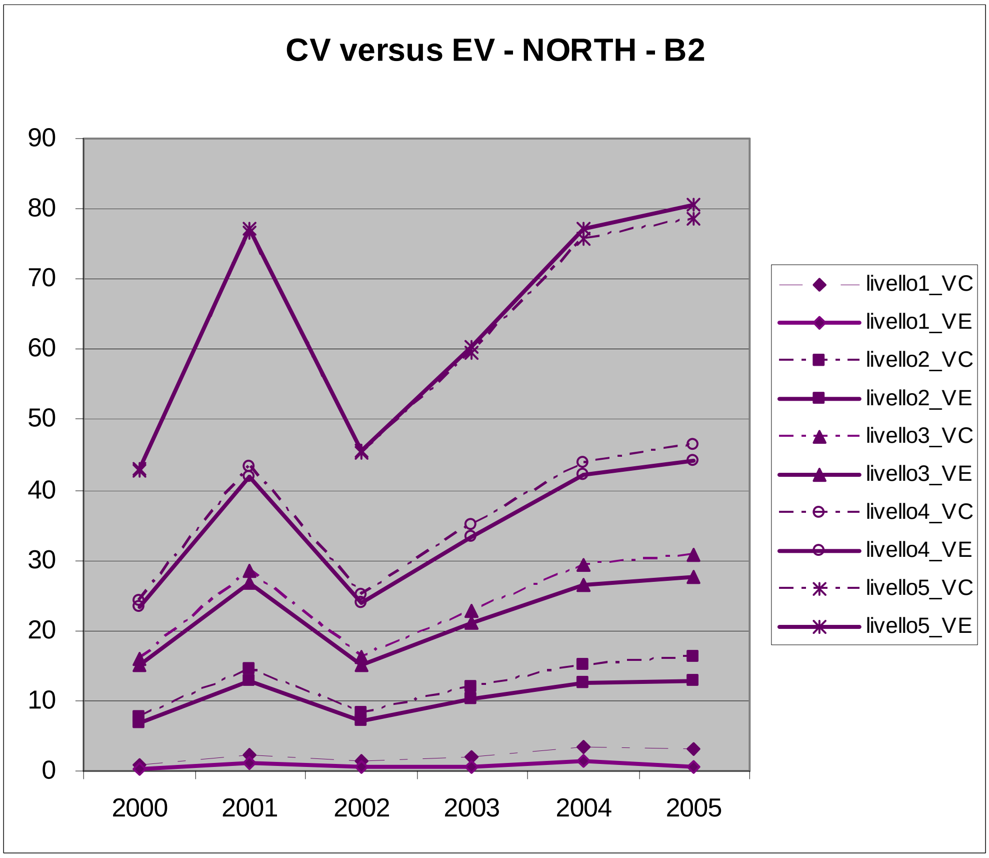
In the North, the highest welfare impacts are observed, especially concerning expenditure level 5; CV and EV values are relatively lower in the Centre in the period 2002-2003. Beyond this, the three macro-regions show a common trend. The particular trend observed in 2001-2002, according to which welfare impacts are very higher in the first year and lower in the following, would require further investigations. Since the excise augmentation is equally distributed and strictly increasing and the consumption of the taxed products shows a regular pattern in the years examined, then the trend is likely to be due to specific factors or omitted variables. The specificity of 2001 could be attributable to a change in the composition of the aggregate goods on which carbon taxation was simulated: a modification in the relative weights of the individual goods in them is likely to have occurred. Furthermore, 2001 could have been characterized by adverse climate conditions, which could have influenced the taxed products demand, making it more inelastic. Probably the introduction of Euro in 2002 has also played a role in inverting the trend observed for the previous year.

Second, it can be seen that EV is always lower than CV, except for the expenditure level 5. In particular, the difference between these welfare measures decreases when the expenditure level increases: compensating variation is on average 25% greater than equivalent variation for level 1, 10% for level 2, 5% for level 3 and 2% for level 4; on the opposite, equivalent variation is on average 2% greater than compensating variation for level 5 (Appendix III, Table I). This is coherent with the standard economic theory according to which the willingness to pay for avoiding a price increase is lower than the willingness to accept compensation. The specific pattern observed for richer households could confirm the hypothesis of environment as a luxury good with which – when the welfare level is very high – a willingness to pay that is higher than a willingness to accept compensation is associated.

Finally, the graphs included in Figure 4.10 highlight the differences between macro-regions, showing that in the North both compensating and equivalent variations are higher, representing more important welfare impacts. The impacts in the South are in second position according to their relevance whereas the impacts in the Centre are more measured. In particular, compensating variation in the Centre is on average 9% lower than in the North (level 1 and 5 both lower than 12%) and in the South it is lower than 5% (level 4 and 5 respectively lower than 4% and 10%). This could be due to a differentiation in the consumption structure and the presence of different substitution opportunities, linked for instance to public transport supply; for more detail on the differentiation among macro-regions see Figure 4.14, while for an analysis in aggregate terms see Paragraph 4.5.

Similarly to Figure 4.10, Figure 4.11 shows the comparison among CV and EV under scenario B2, under which only heating fuels are taxed: the difference detected in the previous graphs are observed also in this case. I present only the graph for the North because the trend remains unchanged in the other macro-regions; the amount of compensating and equivalent variation however shows some differentiation among macro-regions which is worth mentioning (see Appendix III, Table I). Compensating variation in the Centre is on average 12% lower than in the North (in particular, for level 1 and 5 it is respectively 18% and 14% lower), whereas in the South 4% lower (in particular, for level 5 it is 11% lower). Also the percentage variation of EV among macro-regions shows a similar pattern.

Figure 4.11 – CV versus EV under scenario B2 (Euro 1998)

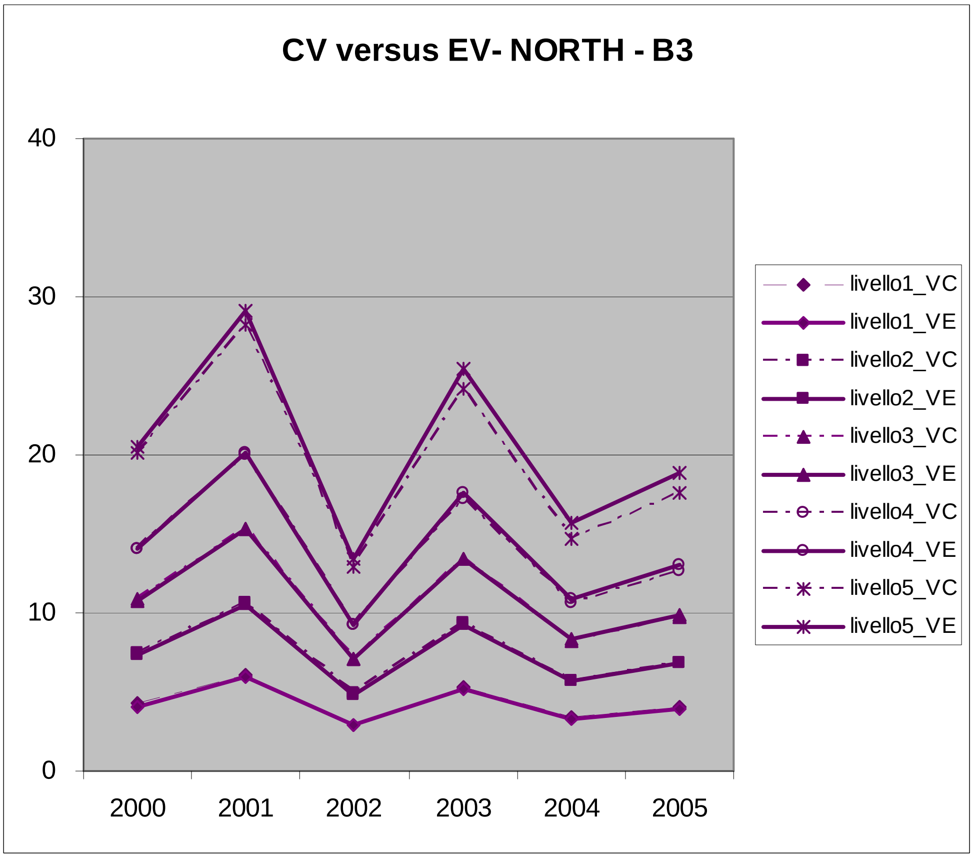


As expected – since only one kind of energy products is taxed – welfare impacts under scenario B2 are less relevant than in scenario B1: this suggests that a comparison among scenarios can be interesting (see Figure 4.15).

With regard to scenario B3, Figure 4.12 compares the absolute values of compensating and equivalent variation in the macro-region North. Compensating variation in the Centre is on average 1% greater than in the North, whereas in the South 3.5% greater, in particular with respect to level 1 and level 5 which experiment respectively welfare effects 3% and 4% higher. Also in this case the trend observed in the percentage variation of EV among macro-regions remains coherent.

Even if, as in scenario B2, carbon taxation is only levied on one type of energy product, taxing heating fuels produces higher welfare impacts than taxing fuels. The percentage variation of welfare among the different simulated scenario can be computed: on average, in the North scenario B2 affects welfare 38% less than scenario B1 (it is interesting to note that the difference becomes less marked when the expenditure level increases: 67% less for the lowest expenditure level and 24% less for the highest) whereas scenario B3 affects it 60% less (on the contrary, in this case, the difference becomes more marked when the expenditure level increases: 33% less for the lowest expenditure level and 76% less for the highest). The Centre represents the macro-region where the differentiation of welfare impacts among the different scenarios is more pronounced (B2 affects welfare 41% less than scenario B1 and scenario B3 63% less) whereas the South shows a differentiation among scenarios very similar to the North. In both macro-regions the increasing or decreasing pattern observed in the differentiation among welfare levels remains unchanged.

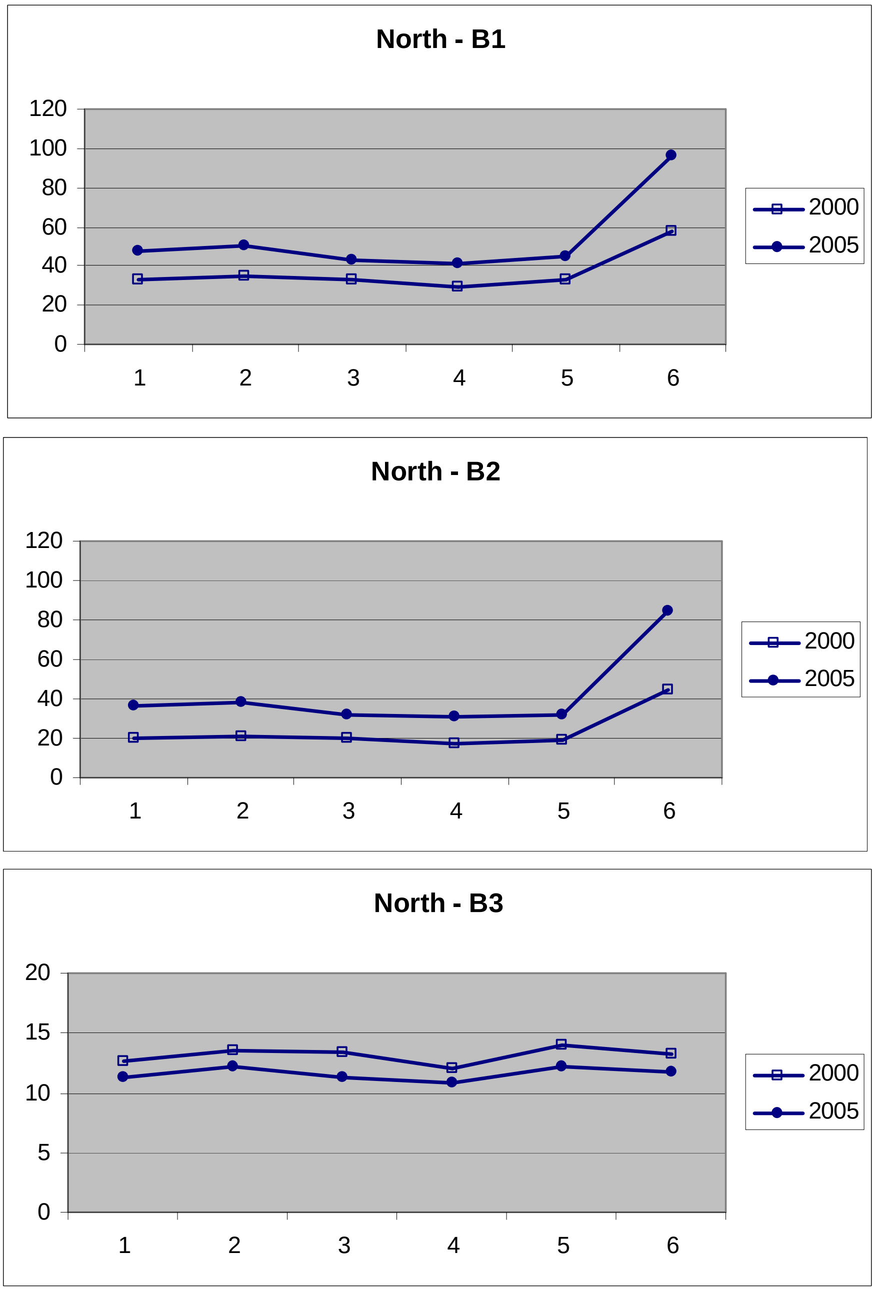
Figure 4.12 – CV versus EV under scenario B3 (Euro 1998)



As far as scenario B4 is concerned, I will defer its analysis to the end of the paragraph: due to its scarce relevance in terms of price increases – and then of welfare effects – it would have been difficult to compare it with the other carbon taxation scenarios.

Figure 4.13 demonstrates that the annual impact does not show relevant changes for different household profiles except for household type 6; I have put in the graphs only for macro-region North, because the other macro-regions do not show relevant differences. The aim of this figure is to show the differentiation of the welfare losses in monetary terms produced by the different taxation scenarios simulated: welfare effects can be directly compared among different household profiles because they are expressed in equivalent expenditure terms, since equivalence scales were employed. If we examine the three different scenarios, we discovers that the component that determines a heavy tax burden on households with elderly people is represented by heating fuels. With regard to this point, I want to specify again that in the South the impacts of scenario B2 are slightly lower, demonstrating that the consumption of heating fuels is relatively less relevant in this macro-region. It is worth to be mentioned that annual compensating variation is not always included between 2000 and 2005 values: for instance, in 2002 welfare impacts are lower than in 2000, whereas in 2001 higher than 2005 both for B1 and B3.

Figure 4.13 – Comparison between scenarios B1, B2, B3 (famtipo, Euro 1998)



In order to assess the problem of carbon taxation potential regressivity, the burden of compensating variation on total expenditure has to be computed. Relatively to scenario B1, the analysis of the percentage variation of welfare effects with respect to level 1 shows that the ranking between macro-regions is Centre, North and South, except in 2003, when the intensity is greater in the North, followed by the South and Centre. On the other hand, scenario B2 implies a percentage variation in welfare impacts higher in the North, followed by the South and Centre; under scenario B3 the percentage variation of welfare effects with respect to level 1 is greater in the South with respect to the North and Centre (Figure 4.14).

After these considerations and the description of the differentiation among the absolute values of compensating variation among macro-regions (Figure 4.10-4.12), Table 4.12 shows the burden of compensating variation on total expenditure for the taxation scenarios B1, B2, B3. The average national welfare impacts are expressed in percentage of total monthly expenditure in order to investigate the regressivity of the different scenarios simulated.

Table 4.12 – Average national welfare impacts in percentage of total monthly expenditure

	Scenario B1					
	2000	***2001***	***2002***	***2003***	***2004***	***2005***
level1	0.197	0.307	0.151	0.257	0.208	0.213
level2	0.338	0.541	0.283	0.413	0.403	0.434
level3	0.393	0.629	0.336	0.462	0.479	0.513
level4	0.407	0.653	0.352	0.471	0.498	0.536
level5	0.384	0.616	0.334	0.431	0.468	0.497
	Scenario B2					
	2000	***2001***	***2002***	***2003***	***2004***	***2005***
level1	0.131	0.176	0.144	0.166	0.195	0.181
level2	0.169	0.304	0.176	0.219	0.289	0.301
level3	0.230	0.401	0.231	0.276	0.370	0.384
level4	0.253	0.439	0.255	0.299	0.397	0.416
level5	0.255	0.438	0.254	0.290	0.385	0.398
	Scenario B3					
	2000	***2001***	***2002***	***2003***	***2004***	***2005***
level1	0.164	0.228	0.106	0.190	0.112	0.130
level2	0.168	0.235	0.107	0.192	0.113	0.132
level3	0.162	0.225	0.103	0.185	0.108	0.127
level4	0.153	0.211	0.096	0.171	0.100	0.118
level5	0.128	0.175	0.079	0.139	0.081	0.097

The potential regressivity of the carbon tax introduced with the Budget Law for 1999 (scenario B1) can be rejected, consistent with the results obtained by Tiezzi (2005), even if taxation burden decreases from the medium-high (level 4) to the high (level 5) welfare level in all the years examined. With the exception of this result, Table 4.12 shows that the compensating variation as percentage of total expenditure increases with the welfare level. The presence of regressive impacts can also be excluded for taxation scenario B2; on the other hand, taxation scenario B3 turns out to be regressive since compensating variation in percentage terms decreases when welfare level increases.

Examining the percentage variation in welfare impacts with reference to level 1 can help in identifying particular phenomena or years which alleviate or exacerbate the carbon taxation distributive effects. On average, the non-regressivity of scenario B1 is confirmed, even if the welfare impacts for the highest welfare level are relatively lower: with respect to level 1, welfare impacts are 82% higher for level 2, 113% for level 3, 121% for level 4 and 107% for level 5. 2001 turns out to be a particular year: the progressive distribution of welfare impacts is less marked (76% higher for level 2, 105% for level 3, 112% for level 4 and 100% for level 5); this phenomena could be due to specific climatic conditions which make the demand inelastic for all the expenditure levels.

Under scenario B2, welfare impacts are obviously reduced in terms of percentage of total expenditure (Table 4.12) and for this reason also the absolute values of percentage variations with reference to level 1 are reduced. However, also in this case the non-regressivity can be confirmed: with respect to level 1, welfare impacts are 45% higher for level 2, 89% for level 3, 105% for level 4 and 102% for level 5. The specificity of year 2001 previously highlighted could be ascribable to heating fuels demand: in fact, in this period, scenario B2 produces greater percentage variations in welfare impacts (63% higher for level 2, 128% for level 3, 150% for level 4 and 5); then, this pattern is therefore likely to be due to the severity of winter.

By computing the percentage variation of welfare impacts in scenario B3, the regressivity of this scenario clearly emerges: with respect to level 1, welfare impacts are 2% higher for level 2 and 2% lower for level 3, 9% for level 4 and 25% for level 5. In this case welfare impacts distribution does not substantially differ from one year to another, demonstrating a higher level of independence of fuels demand from exogenous factors.

Table 4.13 is aimed to show the annual welfare loss in year 2000 as a percentage of total expenditure distinguishing both household type and welfare level. Contrary to what has been found in other similar studies (Smith, 2000; Symons et al., 1998; Cornwell and Creedy, 1996), the tax burden is progressively distributed across households at different welfare levels. It can be observed that the tax burden predominantly affects households with up to four adults whereas it decreases for families with young people and, in particular, families with children. This result can be linked to car ownership (Tiezzi, 2005): for households consisting only of adults the cars owned –and then fuels consumption – are likely to increase with the number of members, which is clearly not the case in households with children; households with young people probably have an intermediate pattern compared with the previously examined households.

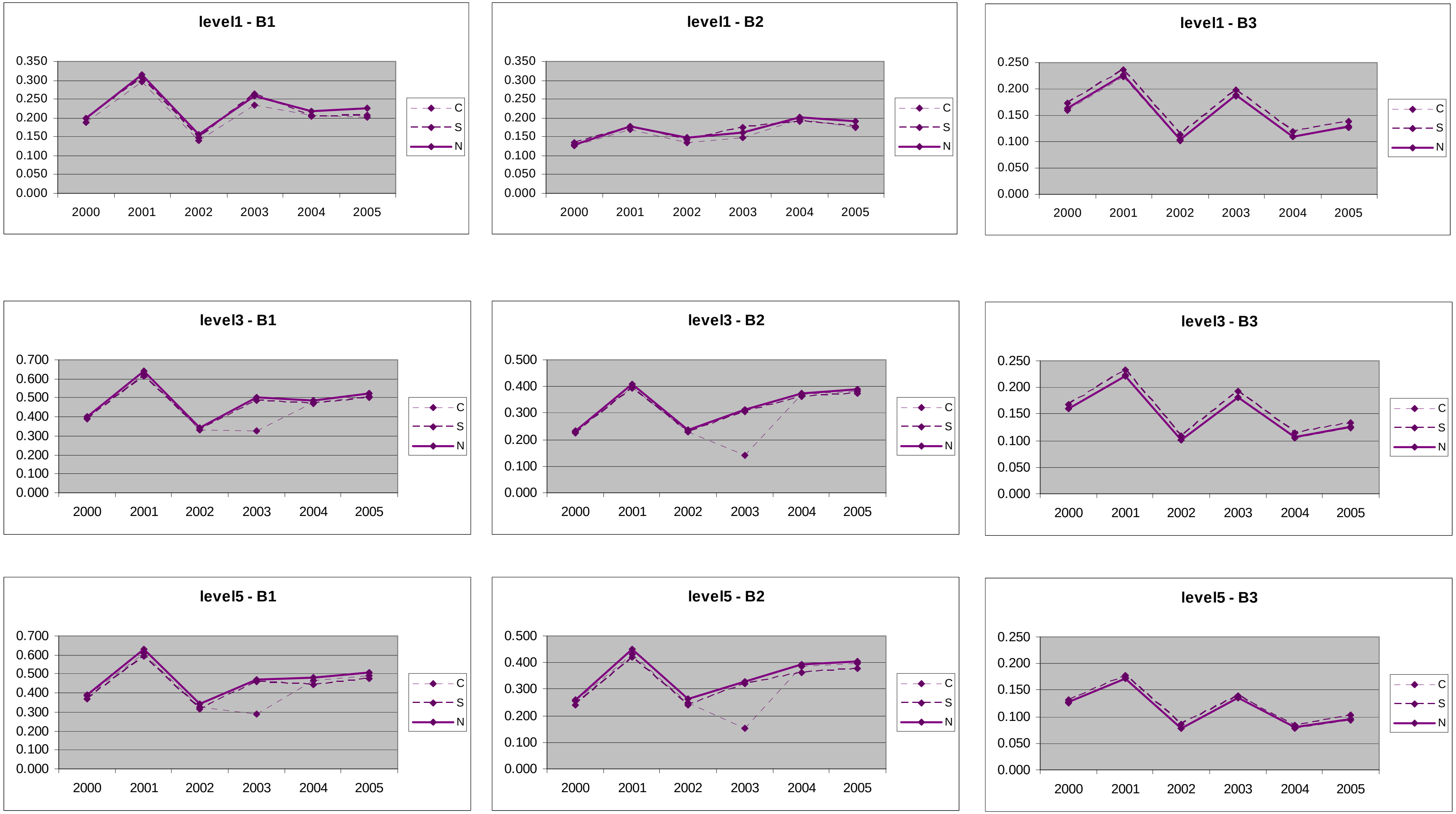
Table 4.13 – National welfare impacts as percentage of total expenditure in year 2000 (scenario B1)

	level1	***level2***	***level3***	***level4***	***level5***
famtipo1	0.106	0.298	0.385	0.428	0.437
famtipo2	0.212	0.346	0.404	0.423	0.401
famtipo3	0.263	0.369	0.404	0.405	0.355
famtipo4	0.245	0.340	0.380	0.384	0.342
famtipo5	0.257	0.352	0.380	0.376	0.322
famtipo6	0.152	0.329	0.421	0.463	0.473

Figure 4.14 highlights the differentiation between different regions of compensating variation expressed as percentage of total expenditure. I have chosen to present only three welfare levels since in this way the comparison is made easier without loosing in significance. It is when examining scenarios B2 and B3 that relevant differences among regions arise. The pattern followed by B2 welfare effects is similar to the one that arises in scenario B1; in the North, more important impacts can be observed with regard to heating fuels taxation, probably due to climate effects (in fact, the order of the remaining macro-regions is Centre followed by the South with respect to the magnitude of welfare impacts). The relative higher importance of heating fuels in the North is also confirmed by the values of the parameters associated with the regional translating intercepts (see Appendix I, Table III). In fact, they enter with a negative value in the estimation of heating fuels expenditure share in the Centre and South (and in this case the coefficient is higher in absolute value) and with a positive value in the North (the intercept associated to this macro-region is not included in the Table II and Table III in Appendix I because they were obtained through the adding-up constraint).

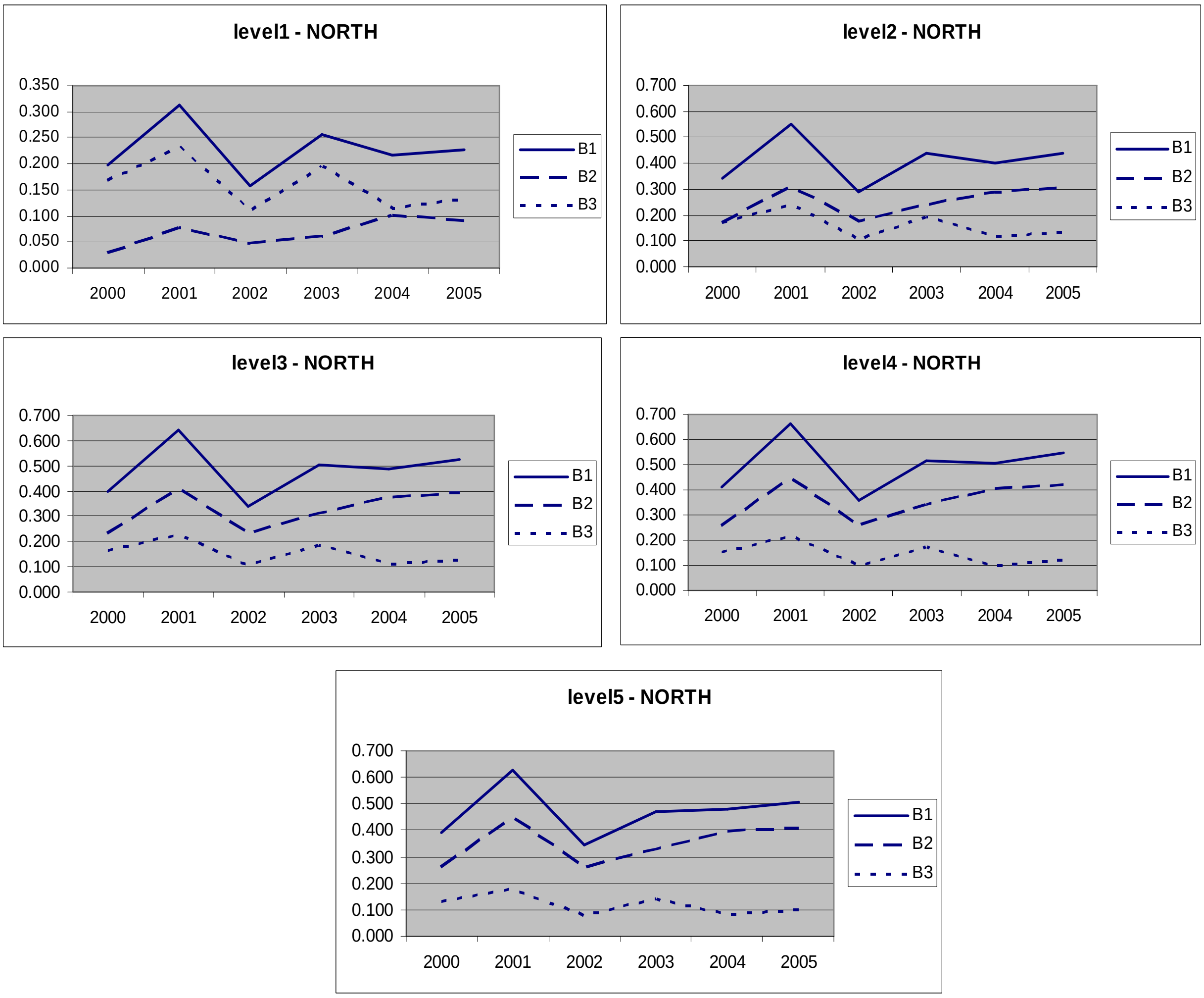
Differently, pattern B3 is very different from scenarios B1 and B2: welfare impacts are higher in the South and this could be due to the fact that – with the exception of some isolated examples – public transport is less efficient in this macro-region. Scenario B3 implies reduced welfare impacts when comparing them with welfare impacts related to scenario B2. Even if the own-price elasticity of transport fuels is lower than that of heating fuels (Table 4.3) – and this is likely to imply higher welfare impacts when the first energy product is taxed – the adaptation and substitution measures are probably more immediate for transport fuels (namely, orienting consumption towards public transport rather than changing heating devices in order to use electricity in its place). With regard to scenario B1, there is not a relevant difference in the compensating variation burden among medium and high welfare level (and also considering the medium-high which is not presented in the graphs). The same holds in taxation scenario B2; on the contrary, the regressivity of scenario B3 is confirmed.

Figure 4.14 – Comparison between scenarios B1, B2, B3 (welfare levels and macro-regions)



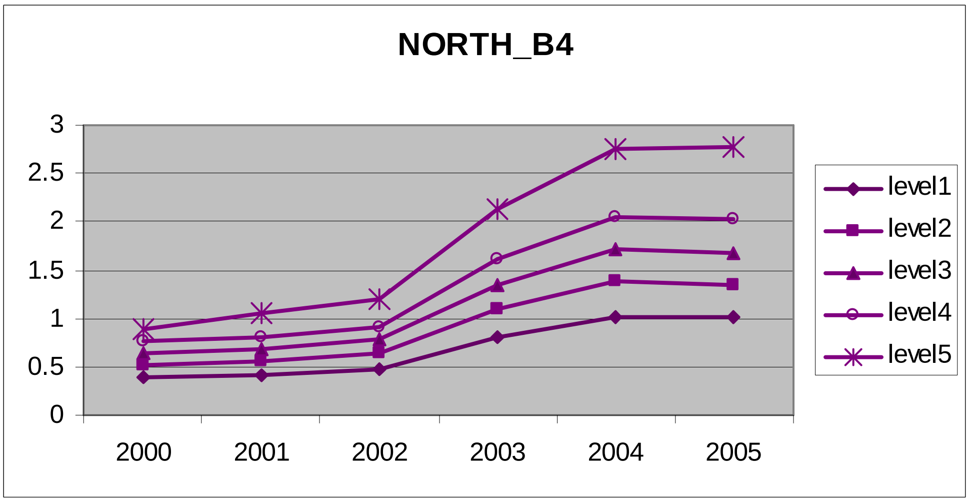
In Figure 4.15 the differences among scenarios B1, B2 and B3 are shown, expressing compensating variation as percentage of total expenditure; I have decided to make this comparison only for the macro-region North after having checked that the observed trend remains unchanged for the other macro-regions. The graph included in the figure represent further confirmation of non-regressivity of carbon taxation in Italy. An important difference is represented by the fact that for level 1 scenario B3 produces higher welfare impacts than scenario B2, whereas for all the other expenditure levels the ranking is B1, B2, B3. This could be due to a transport fuels demand linked to necessary displacements, which can highly be replaced by public transport utilization. Also in this case it could be observed that a high similarity holds in the compensating variation burden between medium, medium-high and high welfare levels.

Figure 4.15 – Comparison between scenarios B1, B2, B3 (welfare levels)



In the following I will briefly comment the taxation scenario related to electricity price augmentation: As I already mentioned, scenario B4 was separated from the other because of its particularly low welfare impacts.

Figure 4.16 – Scenario B4 (Euro 1998)



From Figure 4.16 it clear that the carbon taxation implemented under scenario B4 would be equally distributed and it would therefore represent a type of proportional taxation. This is probably due to the fact that electricity is a necessary good and households in all welfare levels are likely to enjoy its use in a similar proportion, beyond their total expenditure level.

Finally, I have checked for the presence of a seasonal trend in the welfare effects, namely compensating and equivalent variation values, but this it not the case in all scenarios, even if the translating intercept are statistically significant (see Appendix I, Table II and III).

4.5 Aggregation and raised revenue

This paragraph will take into consideration both the computation of the aggregate compensating and equivalent variation and the estimation of the revenue raised by carbon taxation. For this reason Paragraph 4.5 is divided in two parts: the first part will deal with the computation of aggregate welfare measures, whereas the second one will be related to the description of the method adopted to compute raised revenue. Finally, the results developed with these separate approaches will be connected and commented.

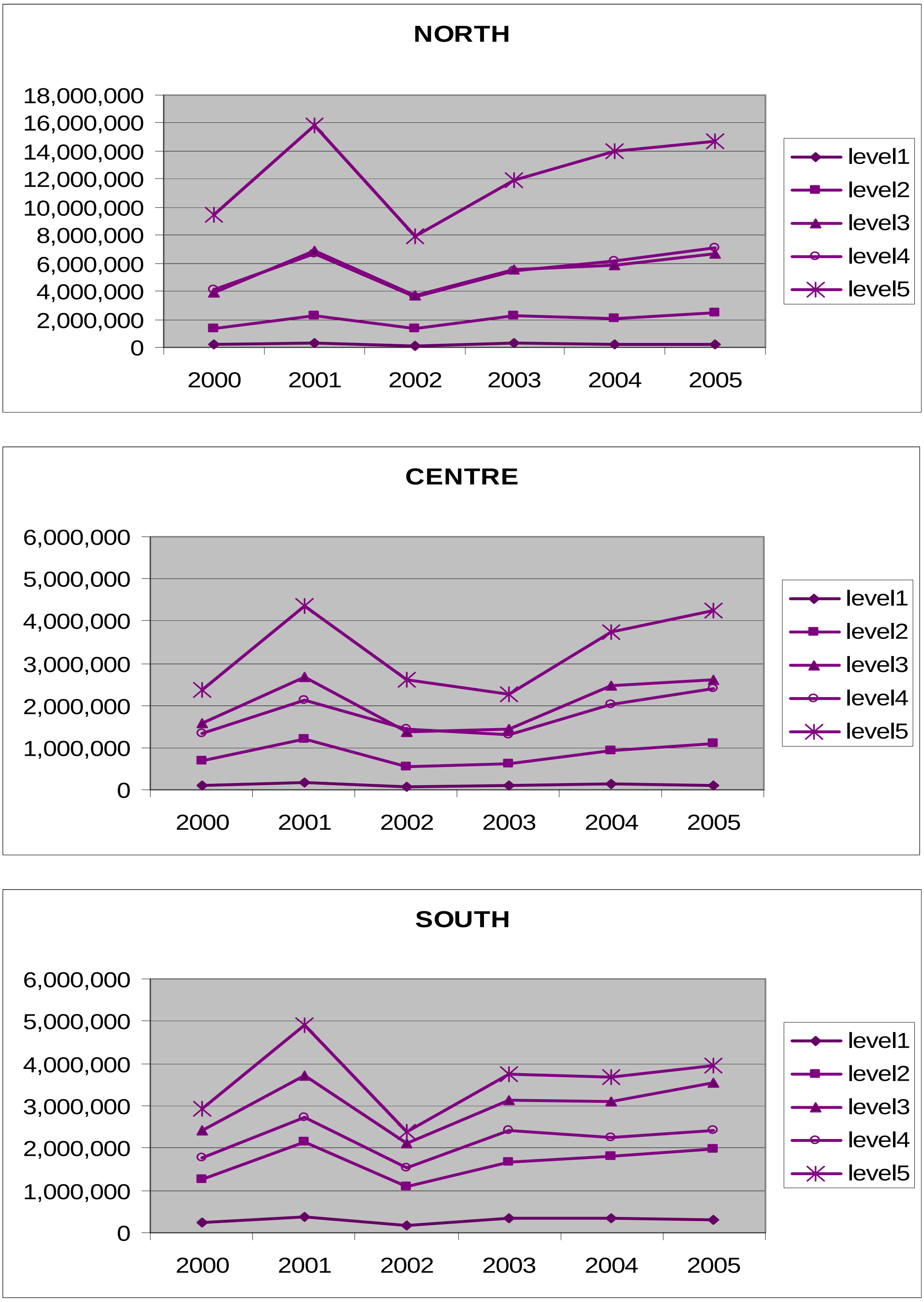
In the Survey on Household Expenditure, ISTAT also includes a coefficient for every record in the database which allows the individual data to be converted to the existing population: these coefficients indicate how many households with characteristic analogous to the one interviewed there are in Italy in the specific year that the Survey on Household

Expenditure concerns. I used these coefficients once CV and EV had been computed in order to obtain their aggregate values.
When I constructed the sample used in the demand system estimation, I have excluded the household types which did not correspond to any of the chosen categories (household 1-6, see Paragraph 4.1). Examining the percentage of households included in my sample on the total of italian households I have checked that the loss of significance is around 40%. Another point that has to be specified is related to the fact that I did not consider the revenue raised from primary, industrial and tertiary sectors when carbon tax is introduced because I have not adopted an approach that allows it to be computed such as an input-output or equilibrium approach (bottom-up or top-down). These issues have to be considered when comparing the revenue raised values obtained from my simulation with the effective revenue variation for 1999. Already in Paragraph 1.8.1 some considerations were made on the amount of additional revenue raised by carbon taxation.
With regard to this point, it is also important to observe that the raised revenue hypothesis included in the Technical Appendix of DPCM 15/1/1999 was a projection (Table 1.15), in which there was no distinction between the contribution of the residential sector and the primary, industrial and tertiary sectors. Moreover, these projections were calculated assuming no behavioural responses to carbon tax introduction: then, the hypothesis of constant consumption levels is likely to imply greater estimates of raised revenue with respect to those presented in the following.
My final intention was to compare welfare impacts with revenue raised and, on this basis, investigate the potential of compensating some categories of consumers if the welfare impacts turned out to be regressive or too high to be acceptable (with reference to some threshold level identified by public authorities and policy makers). For this reasons, I computed the aggregate welfare measures and the revenue raised only for the taxation scenario B1, which modelled the carbon tax introduced in Italy with the 1999 Budget Law. In general, this approach allows the revenue raised by different taxation scenarios to be computed and compared and this can be useful for widening policy makers information basis.
An important feature of the aggregation method adopted is represented by the possibility of analysing the contribution of all the households included in each welfare level and examining the relevance of carbon tax impact also at aggregate level through the aggregate compensating or equivalent variation. In other words, the results obtained for each expenditure level of the extracted sample can be converted to the existing population, and,

in this way, carbon tax impacts be weighted for the numerousness of households in each expenditure level. The results shown in Figure 4.17 enable to evaluate the burden of carbon taxation on each welfare (expenditure) level; on this basis, specific compensative intervention could be modulated.

In what follows I will only comment on the aggregate compensating variation since the difference highlighted in Paragraph 4.4 between this welfare measure and the equivalent variation remains unchanged also at aggregate level.

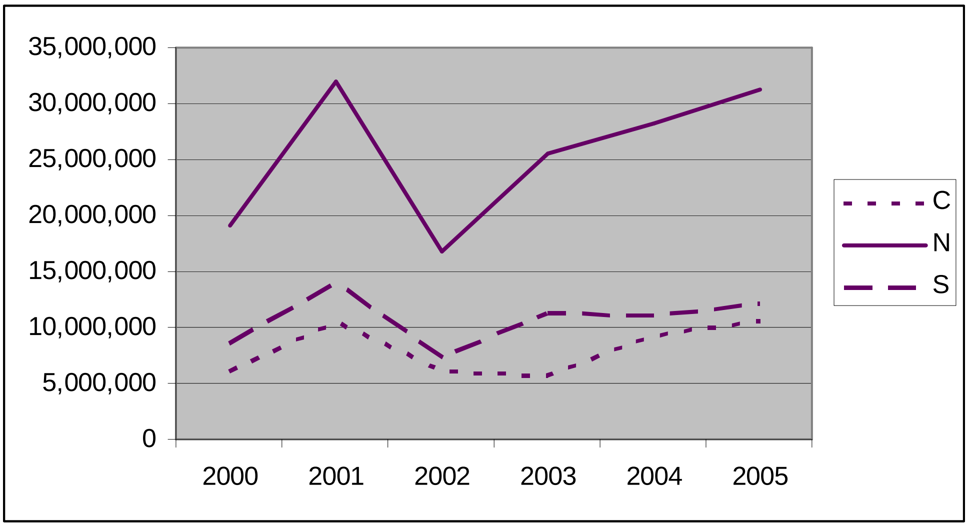
Figure 4.17 – Aggregate compensating variation (welfare levels, Euro 1998)



According to the results of my estimation, carbon taxation introduced in Italy in 1999 – and frozen in 2000 – would have had welfare impacts increasing with expenditure class also at aggregate level (Figure 4.17). At aggregate level, taxation burden in the Centre is on average 62% lower than the burden in the North (respectively, 50% and 73% lower for level 1 and level 5), and in the South it is 33% lower (while for level 5 the burden is 70% lower, for level 1 it is 25% higher with respect to the North). In the South, and to a lesser extent in the Centre, the welfare impacts at aggregate level appear to be more relevant for expenditure level 3 than for expenditure level 4; in the North, the aggregate welfare impacts for these expenditure levels are almost coincident. This is likely to be due to a more relevant numerousness of expenditure level 3, which is more marked in the South and Centre macro-regions (see Table 4.10 for welfare levels numerousness). Moreover, the computation of compensating variation converting the sample used to the existing population makes even more evident how welfare impacts in the North are more pronounced, both for the lower and higher expenditure classes. The high population density of the macro-region North emphasizes the trend already detected at not aggregate level: then, it could be said that in the North the welfare impacts are greater, maybe due to a generally higher expenditure pattern, and to compute them taking into consideration the total of households makes them even more relevant.

Figure 4.18 shows the aggregate compensating variation for the expenditure classes summed all together. The graph clearly is useful to investigate the macro-regional differentiation of welfare impacts: this is not only due to the fact that the North is more populated but because its consumption of energy products is higher. This could be considered further confirmation of the absence of adverse distributive effects of carbon taxation when its impacts are examined on macro-regional level.

Figure 4.18 – Aggregate compensating variation (macro-regions, Euro 1998)



In the following table (Table 4.14), the aggregate compensating variation (welfare losses) are shown, for each expenditure level and household profile: for each year included in the simulation, the total welfare loss was computed, and also for each expenditure level and household profile across the years examined. In the last column, the cumulate welfare loss for expenditure level or household type value is expressed as a share of the total in order to highlight differences in the distribution of taxation welfare impacts. With regard to the expenditure levels, it can be seen d that the carbon taxation simulated under scenario B1 implies welfare losses which are progressively distributed. Examining the household profiles, at aggregate level the welfare loss of single-adult and two-adult households is almost the same whereas the corresponding aggregate compensating variation for household profiles 3 (up to four adults) and 5 (with young people) is surprisingly lower. For three/four adult households, the annual welfare loss goes from EUR 2.8 million (1998 exchange rate, Euro 1998) in 2000 to EUR 3.5 million in 2005, at the target level of taxation; conversely, for households with young people the annual welfare loss amounts to EUR 4.6 million in 2000 and to EUR 5.6 million in 2005. On the contrary, the aggregate compensating variation appears to be particularly high for elderly people households (profile 6) and for households with children (profile 4): for household profile 6, the aggregate compensating variation equals EUR 6.9 million in 2000 and EUR 15.1 million in 2005, while for household profile 4, it amounts to EUR 7.6 and 10.1 million respectively. This differentiation in annual welfare loss could be due to a different numerousness of three/four adult households and households with young people if compared with households with elderly people and children.

Table 4.14 – Aggregate compensating variations (welfare losses) at national level (million/Euro 1998)

	2000	***2001***	***2002***	***2003***	***2004***	***2005***	***total***	***% on the total***
level1	0.496	0.854	0.372	0.728	0.691	0.644	3.786	1.4
level2	3.297	5.606	2.958	4.574	4.821	5.523	26.779	10.1
level3	7.956	13.274	7.186	10.133	11.365	12.866	62.779	23.7
level4	7.258	11.583	6.562	9.164	10.443	11.928	56.938	21.5
level5	14.744	25.031	12.855	18.040	21.462	22.931	115.062	43.4
total	**33.751**	**56.348**	**29.932**	**42.639**	**48.782**	**53.892**	**265.344**	**100**
famtipo1	5.584	9.308	5.040	7.580	7.992	10.100	45.604	17.2
famtipo2	6.295	10.100	5.220	7.493	7.887	9.481	46.477	17.5
famtipo3	2.809	4.934	2.688	3.764	4.040	3.488	21.723	8.2
famtipo4	7.582	12.100	6.344	8.846	9.096	10.100	54.068	20.4
famtipo5	4.588	7.007	3.689	5.385	5.066	5.623	31.358	11.8
famtipo6	6.893	12.900	6.950	9.571	14.700	15.100	66.114	24.9

In order to estimate carbon taxation's raised revenue, a simple method has been adopted represented by computing the total differential of quantity in real terms, indicated with *Q(w, p)*, with respect to prices and the expenditure share of energy products. In fact, computing raised revenue requires having values in real terms at disposal: for this purpose, the quantity consumed of heating and transport fuels was derived by dividing real expenditure by the price in real terms, for every year included in the taxation scenario. Then, the total differential was computed, according to the expression (4.9)

$$\Delta Q = \frac{x \times \Delta w}{p} - \frac{x \times w}{p^2} \Delta p \tag{4.9}$$

$$\Delta Q_{tax} = \frac{x \Delta w}{p_{notax}} - \frac{x \times w_{notax}}{p_{notax}^2} \Delta p$$

where x represents total expenditure, w the expenditure share on heating or transport fuels and p their price; Δw was computed by using the estimated own-price elasticity for heating and transport fuels. Once the quantity consumed has been derived, the revenue raised by the carbon tax was computed using the following equation

$$G(Q,t) = Q \times t \tag{4.10}$$

where t is the excise rate corresponding to B1 taxation scenario. Then, the variation in raised revenue determined by the carbon tax can be computed by using the total revenue differential

$$\Delta G_{tax} = t \times \Delta Q_{tax} + Q \times \Delta t \tag{4.11}$$

I developed an approach in terms of revenue variation because carbon taxation in Italy modified the existing excise rates on energy products and it did not introduce excise rates *ex novo*. Clearly, in order to obtain the national revenue raised, the aggregate consumed quantity should be computed using ISTAT coefficients as in aggregate welfare measures. Also in this case the choices made when constructing the sample imply a representativeness loss; but I would like to point out that reconstructing consumed quantity in this way (and not importing it from external sources) avoids problems of non-comparability with aggregate welfare impacts derived by demand system estimation. The following figure shows the raised revenue from each macro-region included in the sample, namely North, Centre and South. In every year of the analysis, the North represents the macro-region from which the raised revenue is the greatest. The South follows the North, in terms of raised revenue in all the examined years except 2003, when the amount of revenue raised from the Centre is higher.

Figure 4.19 – The carbon tax raised revenue (Euro 1998)

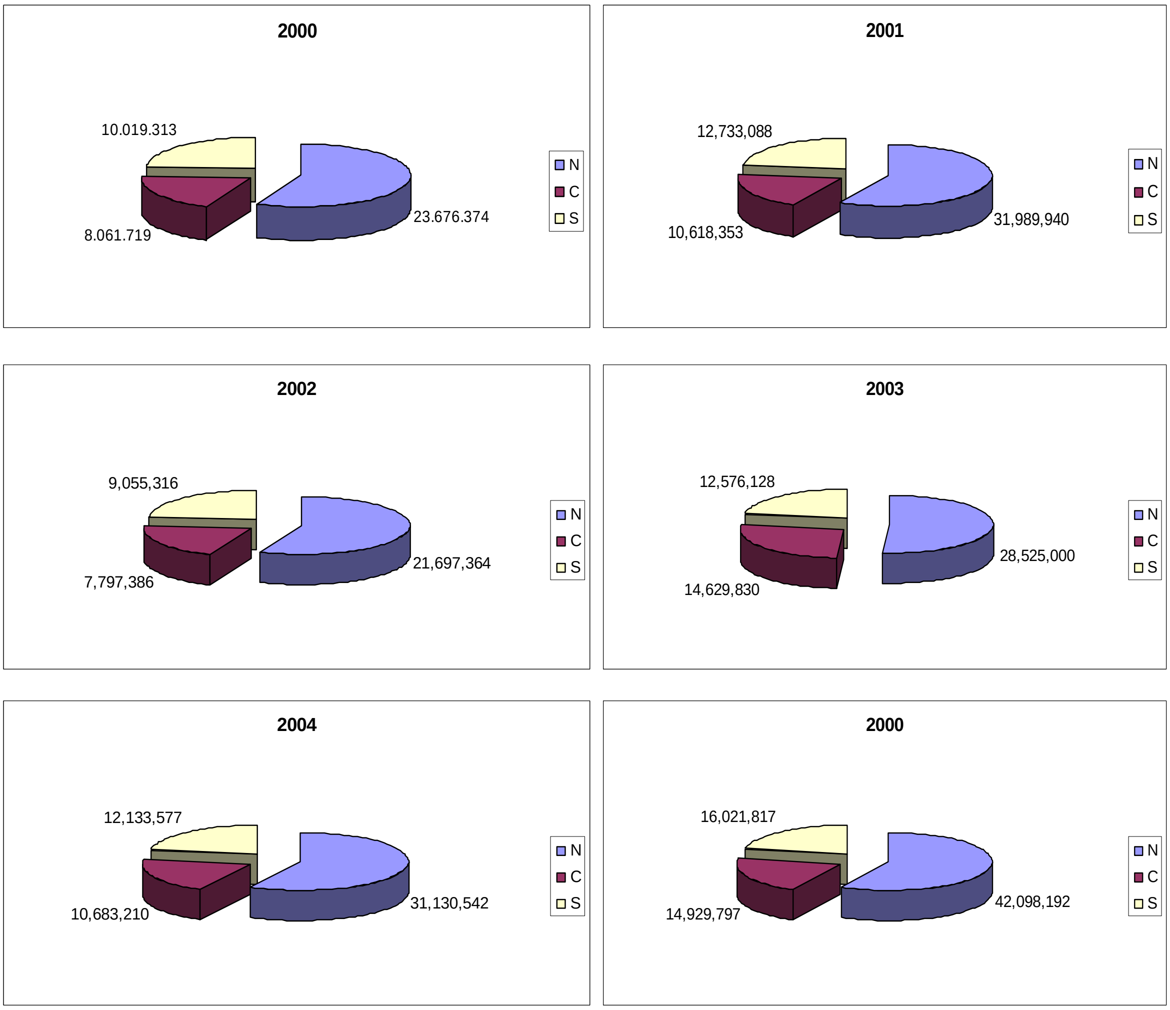


Table 4.15 shows, for the initial and final year of the carbon taxation scenario B1, the raised revenue from each expenditure level, both in monetary and in percentage terms. I believe that this table is particularly important when evaluating the potential regressivity of aggregate distributive impacts. In fact, the table contains also two columns with the number and the percentage of households corresponding to each expenditure level: looking at the two columns in percentage terms, it can be seen that they follow a similar trend and that at aggregate level, carbon taxation impacts seem to be not adversely distributed. The only difference in the trend followed by raised revenue and the number of household percentages is represented by the contribution of the expenditure level 2 and 5: the first level contribution in terms of revenue raised is lower than its significance in number of household terms, the second one is higher. Then, carbon taxation impacts at aggregate

level appears to have a pro-poor distribution which particularly favours the medium-low income class.

Table 4.15 – Raised revenue and household numerousness (welfare levels, Euro 1998)

		Raised revenue	% of the total	Number of households	% of the total
2000	level 1	1,449,376	3	1,183,304	9
	level 2	5,703,021	14	2,644,914	21
	level 3	11,592,396	28	3,669,529	29
	level 4	8,982,399	22	2,306,935	18
	level 5	14,030,213	34	2,879,000	23
	Total	41,757,405	100	12,683,681	100
2005	level 1	2,553,974	3	1,236,145	9
	level 2	11,190,370	15	2,926,045	22
	level 3	20,706,728	28	3,898,135	29
	level 4	16,035,435	22	2,471,012	18
	level 5	22,563,300	31	2,890,398	22
	Total	73,049,807	100	13,421,736	100

Table 4.16 includes the excess burden produced by carbon taxation under scenario B1, computed according to the equation (2.1). The quantity consumed needed in order to calculate the excess burden has been obtained using the same procedure adopted in raised revenue computation (see equations (4.10)). Once more, it can be assessed that carbon taxation would not produce adversely distributed welfare effects, expressing them in terms of excess burden. In Appendix III, Table II shows the excess burden for macro-region.

Table 4.16 – Annual excess burden at national level (Euro 1998)

	2000	2001	2002	2003	2004	2005
level1	2.8	5.3	2.0	4.5	3.5	3.4
level2	11.0	18.9	9.5	15.0	15.7	17.1
level3	20.6	34.8	17.8	26.4	29.7	31.7
level4	30.7	51.6	27.1	39.0	44.6	48.3
level5	51.4	88.3	47.6	64.4	76.3	81.5

This paragraph confirms that the simulated carbon taxation scenario B1 is not regressive. If regressivity occurred – or if the impacts on some specific social categories were particularly high in relative terms – the analysis developed would have made light on the possibility of using the revenue collected to implement compensation mechanisms.

Furthermore, the analysis carried on in this paragraph demonstrates how a method initially conceived to estimate micro-economic effects can also be used to develop macro-economic projections. In fact, the welfare measure computation is relatively straightforward once a demand system has been estimated whereas their comparison with revenue raised estimation (always based on demand system's output) has been rarely developed in literature, even if connecting these approaches can turn out to be very interesting.

4.6 Conclusions and future research developments

The analysis of carbon taxation impacts, not only on the distributional side, is particularly scarce in Italy, even if this topic is crucial to the development of Post Kyoto policy strategies. My work gives several contributions to the existing literature on the topic. Two different demand systems have been estimated, AIDS and QAIDS, and the related results, in terms of welfare impacts, have been briefly compared. The estimation has been performed by defining three macro-regions and six household profiles and translating the demand system so that this differentiation can be taken into consideration. Then, price and demand elasticities have been estimated: they represent a valuable output because they can be employed by other studies in which the energy sector can be analysed more widely. Four different scenarios have been simulated and the main taxation scenario (B1) models the carbon tax introduced in Italy with the Budget Law for 1999: the years in the sample extracted from the Survey on Household Expenditure are those for which progressive excise rate augmentation was planned. Using True Cost of Living Indices, two different welfare measures, represented by compensating and equivalent variation, have been calculated. Some considerations on raised revenue have been made, showing how demand system estimation can be used for public finance projections and evaluations.

The empirical work has demonstrated the environmental effectiveness of introducing an ecological tax reform such as carbon taxation in Italy, given the high price elasticities of energy products. Furthermore, public transport has turned out to represent a key sector when trying to mitigate environmental impacts of transport fuels consumption (high cross-price elasticities with transport fuels): increasing investments could be an important strategy to be associated with carbon taxation in order to mitigate its effects.

The examination of elasticities computed for the different household profiles has shown the importance of distinguishing household characteristics: in this way, a differentiation of behavioural responses according to the demographic profile can emerge. Moreover, incidence analysis has demonstrated the existence of differentiated welfare impacts among macro-regions. Since the amount of additional revenue raised by carbon taxation is always greater than the aggregated welfare impact, this trend sustains the possibility of implementing compensation mechanism directed to particularly affected household profiles or geographical areas.

Finally, carbon taxation does not embed regressive impacts; this confirms the findings obtained in a previous study by Tiezzi (2005): the introduction of carbon taxation in Italy does not imply regressive impacts when evaluating them both on the welfare (expenditure) levels that I have chosen and on aggregate level. If we consider that in 2000 the carbon tax had been frozen in part because of its potential regressive impacts, this issue has not been confirmed by my empirical model. The other main cause which had led to carbon tax freezing was linked to inflation concerns and the increasing trend of oil prices: this issue has become increasingly more relevant given current oil prices. Regard to this point, an input-output or an equilibrium approach (bottom-up or top-down) would help to disentangle the effect produced by two different sources of augmentation in energy product prices: the augmentation due to oil price increasing trends from the augmentation due to carbon taxation. In fact, with such approaches all the complexity of the economic system can be modelled (in our case, with a particular focus on the energy sector), the assumptions of complete translation on consumers relaxed and the effects of international oil price trend taken into account.

The possibility of combining demand analysis with an input-output or general equilibrium approach represents only one extension of the empirical work I have performed. Clearly, many extensions are possible and I will give here a brief overview: some represent refinements of the analysis conducted, other are substantial changes in the approach. The first group of extensions includes the possibility of computing welfare measures for a specific sample such as households that own a vehicle (Smith, 2000) or household location (Labandeira et al., 2006). Furthermore, the behavioural responses estimated can be used to compute the consumed quantity change and then, with converting factors, obtain the polluting emissions reduction consequent from the specific policy simulated. The chosen approach can be improved by performing an analysis of individual data, that is to say to estimate a demand system not based on aggregate observations. I have chosen to work on average expenditures, distinguishing the household profile, in order to avoid the problem of zero consumption of one or more of the items considered which often arise when working on individual expenditures. The first estimation procedures for censored consumer demand systems were developed by Heien and Wessels (1990); Yen, Lin and Smallwood (2003) and Yen and Lin (2006) provide useful literature review on estimation procedures for censored demand systems. In particular, different approaches to facing the issued linked to corner solutions (zero consumption) in demand system estimation are represented by the efficient Generalized Maximum Entropy procedure developed by Golan, Perlo and Shen (2001), the consistent but less efficient approaches such as Perali and Chavas (2000) multi-step procedure and Shonkweiler and Yen (1999) Two-Step estimator, which involves probit estimation in the first step and a selectivity-augmented equation system in the second step. In the probit estimation, the quantity consumed of each good in the demand system can be regressed on total expenditure and dummies for household characteristics and geographical location. In this way, demographical characteristics could be included in demand system to be estimated on individual data and a model such as EASI, developed by Lewbel and Pendakur (2008), can be employed.

Other relevant issues could be represented by linking this approach with general equilibrium models (Giraudet and Quirion, 2008) or bottom-up models, and also by using the information provided by this method in the context of collective decision-making theory. The first issue is connected to the approach previously mentioned (concerning the oil price trend) which implies the possibility of joining the analysis focused on consumption with a model that investigates the supply side of energy sector. MARKAL (acronym for Market Allocation) is a widely applied bottom-up family of models which deals with both the energy supply and demand side of the energy system. It provides policy makers and planners in the public and private sector with extensive detail on energy producing and consuming technologies, and it contributes to the understanding of the interplay between the macro-economy and energy use. In these models, the demand for energy services may be disaggregated by sector (residential, manufacturing, transportation, and commercial) and specific functions within a sector (e.g., residential heating, lighting, hot water, etc.); the user defines technology costs, technical characteristics, and energy service demands. As a result of this integrated approach, supply-side technologies are matched to energy services demands; the specification of new technologies, which are less energy or carbon-intensive, allows to explore the effects of these choices on total system costs, changes in fuel mix, and the levels of greenhouse gases emissions. Therefore, MARKAL models are highly useful in understanding the role of technology in carbon mitigation efforts and other energy system planning settings. A variety of different constraints may be applied to the least-cost solution; with regard to this point, there has been much speculation about the interaction between technology policies and energy price instruments such as carbon taxes or carbon permits.

The second issue is linked to the opportunity to connect this empirical analysis to the collective decision making theory, in particular using the output of the demand system estimation as input in majority voters models: this can be done both directly, as in elasticities, or indirectly, as in welfare impacts. Cremer et al. (2004a; 2004b) analyse the issue of political support for tax levied on an externality-generating good. In their approach, environmental taxes are determined by majority voting, given a refund rule that specifies the proportions of the tax revenue that is redistributed to wage earners and capital owners. Environmental policy is a very interesting issue to explore from a political economy perspective, and an important aspect of the problem is represented by its political feasibility: the adoption of any environmental policy invariably entails losers and winners and this implies that policy makers are subject to a considerable amount of political pressure. The authors capture this element through a simplified model where environmental policy is chosen by direct majority voting, they postulate that rational individuals, before casting their vote, assess not only the purely environmental consequences, but also the distributional ones of alternative policies. In order to represent this choice, they introduce distributional concerns modelling an environmental policy that consists of two members, a tax and a budgetary (or refund) rule. In democracies, a voters' utility depends not just on the efficiency of a public decision (the effectiveness of a proposed policy to alleviate a market failure), but also on the impact of the policy on the voter's after-tax income. This suggests that the way the policy is financed plays a fundamental role in determining the political support for environmental taxation: so, the issue of revenue reutilization and compensation mechanisms seems worth to be further investigated (Callan et al., 2008).

To conclude, the analysis of environmental policies distributive impacts represents a crucial issue when evaluating their political acceptability and feasibility. Consequently, every approach based only on efficiency criteria risks to be biased and to provide policy-makers with insufficient or even biased information. Then, the different policy options to reduce environmental degradation policies need to be compared both on efficiency and distributional grounds, and on this basis the preferred intervention strategy has to be identified and developed. In this context, investigating the welfare impacts of carbon taxation appears to be particularly interesting due to the possibility from benefiting of a double dividend and the relevance of this policy instrument in the post Kyoto climate change policy. To support the economic relevance of the specific environmental policy I have decided to examine, Nordhaus (2007) criticizes the quantity based approach adopted under the Kyoto Protocol and promotes a harmonized carbon tax approach. In his view, the advantages of carbon taxation are represented by higher efficiency, accompanied by the ease in capturing revenue and the lower incidence of rent-seeking behaviour and distortionary effects. Regarding this last point, economists typically have focused on economic efficiency of environmental policies, even though there are usually important distributional implications as well. Depending upon the distribution of welfare impacts, policies may be regressive in the sense that their effects could be adversely distributed, namely be higher for lower income groups. In fields such as climate change and energy policies, where government intervention is needed since net benefits are positive and large across income groups, the potential regressivity may limit a policy's political and social appeal. Even if environmental policy is likely to impose adjustment costs, they are seldom quantified in distributional studies. The heterogeneity of firms and households implies that each has different possibilities to adjust to new policies: Hourcade (2001) argues strongly that the importance of this fact has not been sufficiently appreciated in the shaping of environmental policy. This study is an attempt to face this issue, concentrating on the introduction of carbon taxation and its distributive impacts on Italian households. I firmly believe that a priority in the process of shaping environmental policies should be represented by comprehensively evaluating their distributional impacts: not only because this is beneficial to the public debate and the general understanding of how environmental policy affects human welfare but because it constitutes a crucial point for ecological tax reform feasibility.

Appendix I

Table I - AIDS national

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
alpha1	0.420	0.015	27.910	0.000	0.391	0.450
alpha2	0.121	0.006	20.390	0.000	0.109	0.133
alpha3	0.033	0.001	24.750	0.000	0.030	0.036
alpha4	0.021	0.005	4.260	0.000	0.011	0.031
alpha5	0.004	0.005	0.840	0.402	-0.005	0.014
alpha6	0.400	0.014	27.640	0.000	0.372	0.429
beta1	-0.052	0.006	-8.890	0.000	-0.064	-0.041
beta2	-0.027	0.002	-11.880	0.000	-0.032	-0.023
beta3	-0.003	0.000	-7.530	0.000	-0.004	-0.003
beta4	0.024	0.002	12.460	0.000	0.020	0.028
beta5	0.018	0.002	9.570	0.000	0.014	0.022
beta6	0.041	0.006	7.250	0.000	0.030	0.052
tau11	-0.360	0.052	-6.900	0.000	-0.463	-0.258
tau12	0.188	0.038	4.900	0.000	0.113	0.264
tau13	0.127	0.023	5.450	0.000	0.081	0.172
tau14	0.025	0.038	0.660	0.506	-0.049	0.099
tau15	0.016	0.042	0.390	0.694	-0.065	0.098
tau22	-0.246	0.039	-6.370	0.000	-0.322	-0.170
tau23	0.125	0.030	4.110	0.000	0.066	0.185
tau24	0.054	0.034	1.590	0.113	-0.013	0.120
tau25	-0.157	0.031	-5.120	0.000	-0.217	-0.097
tau33	0.058	0.074	0.790	0.431	-0.087	0.204
tau34	-0.093	0.036	-2.540	0.011	-0.164	-0.021
tau35	0.085	0.077	1.110	0.267	-0.065	0.236

In all the different models estimated, the first equation concerns food, the second one heating fuels, the third electricity, the fourth transport fuels, the fifth public transport, and the last (omitted in order to avoid singularity problems) other goods and services.
Then, the parameter *alpha1* is related to food expenditure share, *alpha2* to heating fuels and so on; the same holds for parameters beta (see equation (3.32)).
Regarding *tau* parameters, they are employed for the computation of the elements of the Slutsky matrix (*theta* parameters) in the Semiflexible Almost Ideal Demand System, described in Paragraph 4.2: then, by way of example, *tau11* is used for the computation of *theta11*, *tau11* and *tau12* for the computation of *theta12*, entering in the food expenditure share.
The auxiliary regression coefficients have been omitted.

Table II - AIDS regional

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
alpha1	0.292	0.001	461.290	0.000	0.291	0.293
alpha2	0.051	0.000	127.010	0.000	0.050	0.052
alpha3	0.026	0.000	279.600	0.000	0.026	0.026
alpha4	0.088	0.000	314.820	0.000	0.088	0.089
alpha5	0.009	0.000	90.800	0.000	0.009	0.009
alpha6	0.534	0.001	685.270	0.000	0.532	0.535
alpham1	0.001	0.002	0.530	0.594	-0.002	0.004
alpham2	-0.003	0.002	-1.610	0.107	-0.006	0.001
alpham3	-0.002	0.002	-1.120	0.261	-0.005	0.001
alpham4	0.003	0.001	4.540	0.000	0.002	0.005
alpham5	-0.015	0.001	-19.680	0.000	-0.017	-0.014
alpham6	-0.018	0.001	-23.040	0.000	-0.019	-0.016
alpham7	0.000	0.000	1.510	0.132	0.000	0.001
alpham8	0.000	0.000	0.130	0.898	0.000	0.001
alpham9	0.000	0.000	-0.740	0.461	-0.001	0.000
alpham10	0.002	0.001	3.000	0.003	0.001	0.004
alpham11	0.003	0.001	4.010	0.000	0.002	0.005
alpham12	0.003	0.001	3.250	0.001	0.001	0.004
alpham13	0.000	0.000	1.070	0.283	0.000	0.001
alpham14	-0.002	0.000	-5.170	0.000	-0.002	-0.001
alpham15	0.001	0.000	2.660	0.008	0.000	0.001
alpham16	-0.007	0.002	-3.490	0.000	-0.012	-0.003
alpham17	0.016	0.002	7.530	0.000	0.012	0.020
alpham18	0.016	0.002	7.620	0.000	0.012	0.021
alphar1	0.016	0.001	10.870	0.000	0.013	0.019
alphar2	0.035	0.002	20.610	0.000	0.032	0.039
alphar3	-0.012	0.001	-18.520	0.000	-0.014	-0.011
alphar4	-0.028	0.001	-35.910	0.000	-0.029	-0.026
alphar5	0.002	0.000	8.770	0.000	0.002	0.002
alphar6	0.002	0.000	8.780	0.000	0.002	0.003
alphar7	0.009	0.001	12.040	0.000	0.007	0.010
alphar8	0.006	0.001	7.790	0.000	0.005	0.008
alphar9	-0.001	0.000	-3.400	0.001	-0.001	0.000
alphar10	-0.001	0.000	-4.570	0.000	-0.002	-0.001
alphar11	-0.013	0.002	-7.040	0.000	-0.017	-0.010
alphar12	-0.015	0.002	-6.740	0.000	-0.019	-0.010
alphad1	0.059	0.002	24.350	0.000	0.054	0.064
alphad2	0.101	0.003	34.560	0.000	0.096	0.107
alphad3	0.083	0.003	29.670	0.000	0.078	0.089
alphad4	0.098	0.003	31.720	0.000	0.092	0.104
alphad5	0.098	0.002	46.140	0.000	0.094	0.103
alphad6	-0.003	0.002	-2.290	0.022	-0.006	-0.001
alphad7	-0.009	0.002	-4.790	0.000	-0.012	-0.005
alphad8	-0.011	0.002	-5.970	0.000	-0.014	-0.007
alphad9	-0.014	0.002	-7.040	0.000	-0.017	-0.010
alphad10	0.018	0.001	13.270	0.000	0.015	0.020
alphad11	0.003	0.000	9.270	0.000	0.003	0.004
alphad12	0.008	0.000	18.850	0.000	0.007	0.009

alphad13	0.004	0.000	9.150	0.000	0.003	0.005
alphad14	0.008	0.000	17.880	0.000	0.007	0.009
alphad15	0.003	0.000	10.570	0.000	0.003	0.004
alphad16	0.005	0.001	4.670	0.000	0.003	0.007
alphad17	0.008	0.001	6.220	0.000	0.006	0.011
alphad18	0.003	0.001	2.240	0.025	0.000	0.005
alphad19	0.006	0.001	4.340	0.000	0.003	0.009
alphad20	-0.033	0.001	-34.510	0.000	-0.034	-0.031
alphad21	-0.003	0.000	-6.690	0.000	-0.003	-0.002
alphad22	-0.001	0.000	-3.170	0.002	-0.002	-0.001
alphad23	-0.004	0.000	-10.150	0.000	-0.005	-0.004
alphad24	0.004	0.000	8.480	0.000	0.003	0.005
alphad25	-0.002	0.000	-5.770	0.000	-0.003	-0.001
alphad26	-0.061	0.003	-20.560	0.000	-0.067	-0.055
alphad27	-0.107	0.004	-29.720	0.000	-0.114	-0.100
alphad28	-0.075	0.003	-21.660	0.000	-0.081	-0.068
alphad29	-0.102	0.004	-26.960	0.000	-0.109	-0.095
alphad30	-0.085	0.003	-32.420	0.000	-0.090	-0.080
beta1	-0.145	0.004	-36.160	0.000	-0.153	-0.137
beta2	0.017	0.003	6.590	0.000	0.012	0.022
beta3	-0.014	0.001	-24.300	0.000	-0.016	-0.013
beta4	-0.017	0.002	-9.760	0.000	-0.021	-0.014
beta5	0.004	0.001	5.500	0.000	0.002	0.005
beta6	0.157	0.005	31.720	0.000	0.147	0.166
tau11	-0.173	0.035	-4.930	0.000	-0.242	-0.104
tau12	0.090	0.066	1.360	0.174	-0.040	0.220
tau13	-0.131	0.030	-4.310	0.000	-0.190	-0.071
tau14	0.107	0.039	2.740	0.006	0.030	0.184
tau15	0.043	0.019	2.220	0.027	0.005	0.081
tau22	0.257	0.031	8.400	0.000	0.197	0.317
tau23	-0.042	0.035	-1.210	0.226	-0.111	0.026
tau24	-0.095	0.038	-2.530	0.012	-0.169	-0.021
tau25	0.048	0.017	2.880	0.004	0.015	0.080
tau33	-0.161	0.020	-7.960	0.000	-0.201	-0.121
tau34	-0.146	0.028	-5.240	0.000	-0.201	-0.091
tau35	0.058	0.011	5.300	0.000	0.037	0.080
t1	0.505	0.383	1.318	0.187	-0.261	1.270
t2	1.996	0.279	7.154	0.000	1.438	2.554
t3	1.159	0.236	4.904	0.000	0.687	1.632
t4	1.479	0.321	4.610	0.000	0.837	2.121
t5	-0.256	0.096	-2.661	0.008	-0.448	-0.064
t6	-3.505	0.462	-7.588	0.000	-4.428	-2.581
Auxiliary regression coefficients						
zeta1	1.281	0.269	4.760	0.000	0.753	1.809
zeta2	-0.976	0.184	-5.310	0.000	-1.336	-0.616
zeta3	0.728	0.123	5.910	0.000	0.486	0.969
zeta4	0.583	0.147	3.970	0.000	0.296	0.871
zeta5	-1.541	0.310	-4.970	0.000	-2.148	-0.933
zeta6	1.821	0.344	5.290	0.000	1.147	2.495
zeta7	-0.037	0.003	-11.370	0.000	-0.044	-0.031
dd2	0.279	0.012	23.290	0.000	0.256	0.303
dd3	0.517	0.016	32.880	0.000	0.486	0.547

dd4	0.407	0.015	27.130	0.000	0.378	0.437
dd5	0.554	0.016	35.690	0.000	0.524	0.585
dd6	-0.015	0.023	-0.640	0.524	-0.061	0.031
dm2	-0.031	0.011	-2.921	0.003	-0.052	-0.010
dm3	-0.029	0.009	-3.310	0.001	-0.047	-0.012
dm4	-0.037	0.008	-4.409	0.000	-0.054	-0.020
dr2	-0.076	0.008	-9.262	0.000	-0.092	-0.059
dr3	-0.187	0.013	-14.854	0.000	-0.213	-0.162

The coefficients *alpham* represent the translating intercepts for the season (*alpham1-3* are associated to food expenditure share, *alpham4-6* to heating fuels, …), *alphar* those for the macro-region (*alpham1-3* are associated to food expenditure share, *alpham4-6* to heating fuels, …) and *alphad* for the household profile (*alphad1-5* are associated to food expenditure share, *alpham4-6* to heating fuels, …). One season, macro-region and household type, for the different kind of translating intercepts, has been omitted in order to avoid perfect collinearity (Greene, 1997).

The parameters *t1-t6* are related to the annual time trend: *t1* refers to the food expenditure share, *t2* to the heating fuels one and so on.

In the auxiliary regression of total expenditure, *zeta7* is the constant, *zeta1-6* are the coefficients associated to prices (*zeta1* is related to food prices, *zeta2* to heating fuels prices, …), *dd2-dd6* to the household profiles (*dd2* is related to household type 2, *dd3* to household type 3, …), *dm2-dm4* to the season (*dm2* is related to spring, *dm3* to summer, …), *dr2-3* to the macro-region (*dr2* is related to Centre and *dr3* to South).

Table III - QAIDS regional

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
alpha1	0.293	0.001	344.620	0.000	0.291	0.294
alpha2	0.052	0.001	97.330	0.000	0.051	0.053
alpha3	0.026	0.000	206.070	0.000	0.025	0.026
alpha4	0.089	0.000	237.120	0.000	0.088	0.090
alpha5	0.009	0.000	69.320	0.000	0.009	0.010
alpha6	0.531	0.001	510.120	0.000	0.529	0.533
alpham1	0.001	0.002	0.320	0.745	-0.003	0.004
alpham2	-0.003	0.002	-1.960	0.050	-0.006	0.000
alpham3	-0.002	0.002	-1.540	0.124	-0.006	0.001
alpham4	0.004	0.001	5.410	0.000	0.002	0.005
alpham5	-0.015	0.001	-20.520	0.000	-0.016	-0.013
alpham6	-0.018	0.001	-24.560	0.000	-0.019	-0.016
alpham7	0.000	0.000	1.460	0.144	0.000	0.001
alpham8	0.000	0.000	-0.120	0.901	-0.001	0.000
alpham9	0.000	0.000	-0.720	0.471	-0.001	0.000
alpham10	0.003	0.001	3.690	0.000	0.001	0.004
alpham11	0.004	0.001	5.140	0.000	0.002	0.005
alpham12	0.003	0.001	3.960	0.000	0.001	0.004
alpham13	0.000	0.000	1.090	0.277	0.000	0.001
alpham14	-0.002	0.000	-5.740	0.000	-0.002	-0.001
alpham15	0.001	0.000	2.620	0.009	0.000	0.001
alpham16	-0.008	0.002	-3.900	0.000	-0.012	-0.004
alpham17	0.016	0.002	7.850	0.000	0.012	0.020
alpham18	0.017	0.002	8.320	0.000	0.013	0.021
alphar1	0.016	0.001	11.570	0.000	0.013	0.019
alphar2	0.034	0.002	21.050	0.000	0.031	0.037
alphar3	-0.011	0.001	-17.810	0.000	-0.013	-0.010
alphar4	-0.027	0.001	-36.410	0.000	-0.029	-0.026
alphar5	0.002	0.000	9.420	0.000	0.002	0.003
alphar6	0.001	0.000	5.160	0.000	0.001	0.002
alphar7	0.008	0.001	12.450	0.000	0.007	0.009
alphar8	0.005	0.001	7.170	0.000	0.004	0.007
alphar9	-0.001	0.000	-4.480	0.000	-0.002	-0.001
alphar10	-0.001	0.000	-3.660	0.000	-0.002	0.000
alphar11	-0.014	0.002	-7.870	0.000	-0.017	-0.010
alphar12	-0.013	0.002	-6.230	0.000	-0.017	-0.009
alphad1	0.058	0.002	23.330	0.000	0.053	0.063
alphad2	0.101	0.003	34.570	0.000	0.096	0.107
alphad3	0.083	0.003	29.400	0.000	0.077	0.088
alphad4	0.098	0.003	31.740	0.000	0.092	0.104
alphad5	0.098	0.002	46.140	0.000	0.094	0.103
alphad6	-0.005	0.002	-3.120	0.002	-0.008	-0.002
alphad7	-0.009	0.002	-4.820	0.000	-0.013	-0.005
alphad8	-0.011	0.002	-6.340	0.000	-0.015	-0.008
alphad9	-0.013	0.002	-6.820	0.000	-0.017	-0.009
alphad10	0.018	0.001	13.270	0.000	0.015	0.020
alphad11	0.004	0.000	9.740	0.000	0.003	0.004
alphad12	0.008	0.000	18.940	0.000	0.007	0.009

alphad13	0.004	0.000	9.460	0.000	0.003	0.005
alphad14	0.008	0.000	17.740	0.000	0.007	0.009
alphad15	0.003	0.000	10.620	0.000	0.003	0.004
alphad16	0.004	0.001	3.810	0.000	0.002	0.006
alphad17	0.008	0.001	6.250	0.000	0.006	0.011
alphad18	0.002	0.001	1.930	0.054	0.000	0.005
alphad19	0.006	0.001	4.540	0.000	0.004	0.009
alphad20	-0.033	0.001	-34.620	0.000	-0.034	-0.031
alphad21	-0.003	0.000	-7.160	0.000	-0.004	-0.002
alphad22	-0.001	0.000	-3.200	0.001	-0.002	-0.001
alphad23	-0.005	0.000	-10.410	0.000	-0.005	-0.004
alphad24	0.004	0.000	8.630	0.000	0.003	0.005
alphad25	-0.002	0.000	-5.810	0.000	-0.003	-0.001
alphad26	-0.058	0.003	-19.060	0.000	-0.064	-0.052
alphad27	-0.107	0.004	-29.840	0.000	-0.114	-0.100
alphad28	-0.073	0.003	-21.220	0.000	-0.080	-0.066
alphad29	-0.103	0.004	-27.260	0.000	-0.110	-0.096
alphad30	-0.085	0.003	-32.500	0.000	-0.090	-0.080
beta1	-0.147	0.004	-34.140	0.000	-0.155	-0.138
beta2	0.013	0.003	4.870	0.000	0.008	0.019
beta3	-0.014	0.001	-21.780	0.000	-0.015	-0.013
beta4	-0.019	0.002	-10.220	0.000	-0.023	-0.016
beta5	0.003	0.001	4.250	0.000	0.002	0.004
beta6	0.164	0.005	31.090	0.000	0.154	0.174
tau11	0.173	0.035	4.920	0.000	0.104	0.242
tau12	-0.089	0.066	-1.350	0.178	-0.219	0.040
tau13	0.126	0.030	4.170	0.000	0.067	0.185
tau14	-0.110	0.039	-2.830	0.005	-0.187	-0.034
tau15	-0.041	0.019	-2.120	0.034	-0.079	-0.003
tau22	0.257	0.030	8.460	0.000	0.197	0.316
tau23	-0.042	0.034	-1.250	0.212	-0.108	0.024
tau24	-0.098	0.038	-2.540	0.011	-0.173	-0.022
tau25	0.047	0.016	2.860	0.004	0.015	0.079
tau33	-0.161	0.020	-8.230	0.000	-0.199	-0.123
tau34	-0.143	0.029	-5.020	0.000	-0.199	-0.087
tau35	0.058	0.011	5.220	0.000	0.036	0.080
lambda1	-0.010	0.008	-1.170	0.242	-0.026	0.006
lambda2	-0.019	0.005	-3.610	0.000	-0.029	-0.009
lambda3	0.003	0.001	2.890	0.004	0.001	0.006
lambda4	-0.011	0.004	-2.990	0.003	-0.018	-0.004
lambda5	-0.003	0.001	-2.660	0.008	-0.006	-0.001
lambda1	-0.010	0.008	-1.170	0.242	-0.026	0.006
t1	-0.250	0.583	-0.430	0.667	-1.393	0.892
t2	2.330	0.428	5.450	0.000	1.492	3.168
t3	0.926	0.143	6.450	0.000	0.644	1.207
t4	1.656	0.289	5.730	0.000	1.090	2.222
t5	-0.383	0.155	-2.470	0.013	-0.687	-0.080
t6	-4.278	0.737	-5.810	0.000	-5.722	-2.833
Auxiliary regression coefficients						
zeta1	1.325	0.198	6.700	0.000	0.937	1.712
zeta2	-0.274	0.132	-2.070	0.038	-0.533	-0.015
zeta3	0.495	0.094	5.280	0.000	0.311	0.679

zeta4	0.084	0.098	0.860	0.389	-0.107	0.276
zeta5	-1.399	0.245	-5.71	0.000	-1.889	-0.909
zeta6	1.896	0.262	7.237	0.000	1.372	2.420
zeta7	-0.038	0.003	-11.860	0.000	-0.044	-0.031
dd2	0.283	0.011	25.840	0.000	0.262	0.305
dd3	0.502	0.011	45.610	0.000	0.480	0.523
dd4	0.453	0.011	41.280	0.000	0.431	0.474
dd5	0.553	0.011	50.390	0.000	0.532	0.575
dd6	0.009	0.011	0.850	0.397	-0.012	0.031
dm2	-0.026	0.009	-3.060	0.002	-0.043	-0.009
dm3	-0.026	0.009	-2.970	0.003	-0.044	-0.009
dm4	-0.043	0.009	-4.880	0.000	-0.060	-0.026
dr2	-0.066	0.007	-8.790	0.000	-0.080	-0.051
dr3	-0.205	0.012	-17.670	0.000	-0.228	-0.183

Lambda1-5 represent the coefficients associated to the quadratic terms.

Table IV - QAIDS modified

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
alpha1	0.294	0.001	291.560	0.000	0.292	0.296
alpha2	0.075	0.000	164.450	0.000	0.074	0.076
alpha3	0.089	0.000	218.240	0.000	0.088	0.090
alpha4	0.009	0.000	75.540	0.000	0.009	0.010
alpha5	0.532	0.001	495.880	0.000	0.530	0.535
beta1	-0.082	0.004	-22.320	0.000	-0.090	-0.075
beta2	-0.018	0.002	-10.710	0.000	-0.021	-0.015
beta3	0.012	0.001	8.300	0.000	0.009	0.015
beta4	0.005	0.000	10.790	0.000	0.004	0.006
beta5	0.083	0.004	21.140	0.000	0.075	0.091
tau11	-0.192	0.047	-4.110	0.000	-0.283	-0.100
tau12	0.201	0.027	7.330	0.000	0.148	0.255
tau13	0.144	0.025	5.870	0.000	0.096	0.192
tau14	0.056	0.049	1.120	0.261	-0.041	0.153
tau15	0.051	0.055	0.930	0.354	-0.056	0.158
tau22	0.059	0.037	1.590	0.112	-0.014	0.133
tau23	-0.192	0.023	-8.410	0.000	-0.237	-0.147
tau24	0.150	0.070	2.142	0.032	0.010	0.290
tau25	-0.161	0.094	-1.712	0.086	-0.349	0.027
tau33	-0.192	0.047	-4.110	0.000	-0.283	-0.100
tau34	0.201	0.027	7.330	0.000	0.148	0.255
tau35	0.144	0.025	5.870	0.000	0.096	0.192
lambda1	-0.013	0.012	0.280	0.782	-0.021	0.028
lambda2	0.007	0.001	6.030	0.000	0.005	0.010
lambda3	-0.019	0.005	-4.560	0.000	-0.030	-0.012
lambda4	0.006	0.001	4.520	0.000	0.004	0.009
lambda5	-0.018	0.004	-4.556	0.000	-0.026	-0.010

The auxiliary regression coefficients have been omitted.
In this model there are five equations since heating fuels and electricity have been aggregated, but otherwise Table IV can be read as the previous ones.

Appendix II

Table I - Average elasticities in QAIDS regional

		Coef.	Std. Err	z	P>|z|	[95% Conf. Interval]	
marshallian							
	ela11	-0.26	0.041	-6.32	0.000	-0.34	-0.179
	ela12	0.026	0.035	0.73	0.467	-0.043	0.095
	ela13	-0.086	0.02	-4.37	0.000	-0.124	-0.047
	ela14	0.02	0.03	0.67	0.5	-0.038	0.078
	ela15	0.019	0.011	1.68	0.092	-0.003	0.041
	ela16	-0.225	0.048	-4.66	0.000	-0.32	-0.131
	ela21	-0.073	0.209	-0.35	0.727	-0.483	0.337
	ela22	-1.204	0.165	-7.29	0.000	-1.534	-0.874
	ela23	0.406	0.067	6.09	0.000	0.275	0.537
	ela24	0.188	0.163	1.15	0.249	-0.132	0.508
	ela25	-0.326	0.066	-4.94	0.000	-0.455	-0.196
	ela26	0.046	0.25	0.18	0.855	-0.444	0.535
	ela31	-0.959	0.221	-4.34	0.000	-1.392	-0.526
	ela32	0.813	0.127	6.41	0.000	0.565	1.062
	ela33	-1.693	0.108	-10.12	0.000	-1.309	-0.877
	ela34	-0.546	0.121	-4.52	0.000	-0.782	-0.309
	ela35	0.621	0.093	6.67	0.000	0.439	0.804
	ela36	1.286	0.269	4.77	0.000	0.758	1.814
	ela41	-0.015	0.098	-0.15	0.877	-0.208	0.178
	ela42	0.131	0.092	1.42	0.156	-0.05	0.311
	ela43	-0.17	0.036	-4.74	0.000	-0.24	-0.1
	ela44	-0.543	0.092	-5.88	0.000	-0.724	-0.362
	ela45	0.087	0.036	2.42	0.015	0.017	0.158
	ela46	-0.271	0.117	-2.32	0.02	-0.5	-0.042
	ela51	0.395	0.38	1.04	0.298	-0.349	1.139
	ela52	-1.836	0.371	-4.95	0.000	-2.562	-1.109
	ela53	1.812	0.275	6.58	0.000	1.273	2.351
	ela54	0.821	0.119	3.89	0.000	3.99	0.000
	ela55	-0.79	0.207	-3.81	0.000	-1.195	-0.384
	ela56	-1.725	0.528	-3.27	0.001	-2.761	-0.69
	ela61	-0.366	0.027	-13.68	0.000	-0.418	-0.314
	ela62	0.002	0.023	0.08	0.934	-0.044	0.048
	ela63	0.042	0.013	3.15	0.002	0.016	0.068
	ela64	-0.093	0.019	-4.76	0.000	-0.131	-0.055
	ela65	-0.029	0.009	-3.27	0.001	-0.046	-0.012
income							
	ela1	0.506	0.014	34.89	0.000	0.477	0.534
	ela2	1.262	0.054	23.35	0.000	1.156	1.368
	ela3	0.477	0.024	19.84	0.000	0.43	0.524
	ela4	0.78	0.022	36.3	0.000	0.738	0.823
	ela5	1.322	0.076	17.36	0.000	1.173	1.471
	ela6	1.311	0.01	130.97	0.000	1.291	1.33
hicksian							
	ela11	-0.109	0.041	-2.68	0.007	-0.189	-0.029
	ela12	0.051	0.035	1.45	0.148	-0.018	0.12

	ela13	-0.072	0.02	-3.69	0.000	-0.111	-0.034
	ela14	0.065	0.029	2.2	0.028	0.007	0.123
	ela15	0.024	0.011	2.08	0.038	0.001	0.046
	ela16	0.042	0.047	0.89	0.375	-0.051	0.135
	ela21	0.302	0.209	1.44	0.149	-0.108	0.712
	ela22	-1.44	0.205	-7.01	0.000	-1.843	-1.038
	ela23	0.439	0.067	6.59	0.000	0.309	0.57
	ela24	0.3	0.163	1.84	0.066	-0.019	0.62
	ela25	-0.314	0.066	-4.76	0.000	-0.444	-0.185
	ela26	0.712	0.246	2.89	0.004	0.23	1.194
	ela31	-0.817	0.221	-3.69	0.000	-1.251	-0.383
	ela32	0.837	0.127	6.59	0.000	0.588	1.086
	ela33	-1.681	0.098	-17.14	0.000	-1.873	-1.489
	ela34	-0.503	0.121	-4.17	0.000	-0.74	-0.266
	ela35	0.626	0.093	6.72	0.000	0.443	0.808
	ela36	1.538	0.268	5.74	0.000	1.013	2.064
	ela41	0.217	0.098	2.2	0.028	0.024	0.41
	ela42	0.17	0.092	1.84	0.066	-0.011	0.35
	ela43	-0.149	0.036	-4.17	0.000	-0.219	-0.079
	ela44	-0.473	0.092	-5.13	0.000	-0.654	-0.292
	ela45	0.094	0.036	2.62	0.009	0.024	0.165
	ela46	0.141	0.116	1.22	0.221	-0.085	0.368
	ela51	0.788	0.379	2.08	0.038	0.045	1.531
	ela52	-1.769	0.371	-4.76	0.000	-2.497	-1.041
	ela53	1.847	0.275	6.72	0.000	1.308	2.386
	ela54	0.938	0.358	2.62	0.009	0.236	1.64
	ela55	-0.778	0.207	-3.75	0.000	-1.184	-0.372
	ela56	-1.027	0.525	-1.95	0.051	-2.057	0.003
	ela61	0.024	0.027	0.89	0.373	-0.029	0.076
	ela62	0.068	0.023	2.9	0.004	0.022	0.114
	ela63	0.077	0.013	5.74	0.000	0.051	0.103
	ela64	0.024	0.019	1.23	0.22	-0.014	0.062
	ela65	-0.017	0.009	-1.95	0.051	-0.035	0

Table II - Average elasticities in AIDS regional

		Coef.	Std. Err	z	P>|z|	[95% Conf. Interval]	
marshallian							
	ela11	-0.263	0.041	-6.380	0.000	-0.344	-0.182
	ela12	0.027	0.035	0.780	0.438	-0.042	0.096
	ela13	-0.089	0.020	-4.530	0.000	-0.128	-0.050
	ela14	0.019	0.029	0.630	0.529	-0.039	0.076
	ela15	0.021	0.011	1.800	0.072	-0.002	0.043
	ela16	-0.227	0.049	-4.660	0.000	-0.322	-0.131
	ela21	-0.082	0.209	-0.390	0.695	-0.492	0.328
	ela22	-1.532	0.204	-7.500	0.000	-1.932	-1.132
	ela23	0.416	0.067	6.260	0.000	0.286	0.547
	ela24	0.177	0.162	1.090	0.276	-0.141	0.495
	ela25	-0.332	0.066	-5.050	0.000	-0.461	-0.203
	ela26	-1.684	0.295	-5.700	0.000	-2.262	-1.105
	ela31	0.020	0.250	0.080	0.936	-0.469	0.509
	ela32	-0.987	0.221	-4.460	0.000	-1.421	-0.553

	ela33	0.838	0.127	6.610	0.000	0.590	1.086
	ela34	-1.730	0.098	-17.740	0.000	-1.921	-1.539
	ela35	-0.553	0.121	-4.580	0.000	-0.789	-0.316
	ela36	0.641	0.093	6.920	0.000	0.460	0.822
	ela41	1.337	0.269	4.970	0.000	0.810	1.864
	ela42	-0.025	0.098	-0.250	0.801	-0.218	0.168
	ela43	0.126	0.092	1.380	0.167	-0.053	0.306
	ela44	-0.173	0.036	-4.830	0.000	-0.243	-0.103
	ela45	-0.547	0.092	-5.950	0.000	-0.727	-0.367
	ela46	0.088	0.036	2.450	0.014	0.018	0.158
	ela51	-0.274	0.117	-2.350	0.019	-0.503	-0.045
	ela52	0.422	0.381	1.110	0.269	-0.325	1.169
	ela53	-1.873	0.370	-5.070	0.000	-2.598	-1.149
	ela54	1.868	0.274	6.830	0.000	1.331	2.404
	ela55	0.824	0.358	2.300	0.021	0.122	1.526
	ela56	-0.843	0.206	-4.100	0.000	-1.246	-0.439
	ela61	-1.790	0.530	-3.380	0.001	-2.828	-0.752
	ela62	-0.361	0.027	-13.370	0.000	-0.414	-0.308
	ela63	0.004	0.023	0.160	0.873	-0.042	0.050
	ela64	0.044	0.013	3.330	0.001	0.018	0.071
	ela65	-0.090	0.019	-4.620	0.000	-0.128	-0.052
income							
	ela1	0.512	0.013	37.980	0.000	0.486	0.539
	ela2	1.333	0.050	26.420	0.000	1.234	1.431
	ela3	0.453	0.022	20.160	0.000	0.409	0.498
	ela4	0.804	0.020	40.090	0.000	0.765	0.844
	ela5	1.393	0.071	19.480	0.000	1.253	1.533
	ela6	1.296	0.009	138.750	0.000	1.278	1.315

Table III - Average elasticities in QAIDS modified

		Coef.	Std. Err	z	P>|z|	[95% Conf. Interval]	
marshallian							
	ela11	-0.343	0.06	-5.69	0.000	-0.461	-0.225
	ela12	0.076	0.032	2.36	0.018	0.013	0.139
	ela13	0.029	0.03	0.98	0.327	-0.029	0.088
	ela14	0.029	0.033	0.87	0.382	-0.036	0.095
	ela15	-0.515	0.021	-24.43	0.000	-0.556	-0.474
	ela16	0.286	0.127	2.26	0.024	0.037	0.534
	ela21	-0.634	0.137	-4.63	0.000	-0.902	-0.365
	ela22	-0.488	0.041	-11.97	0.000	-0.568	-0.408
	ela23	-0.026	0.068	-0.39	0.698	-0.16	0.107
	ela24	0.099	0.183	0.54	0.59	-0.26	0.457
	ela25	-0.025	0.102	-0.24	0.808	-0.224	0.174
	ela26	-0.449	0.035	-12.79	0.000	-0.518	-0.38
	ela31	-0.371	0.068	-5.45	0.000	-0.504	-0.237
	ela32	0.028	0.04	0.71	0.48	-0.05	0.105
	ela33	-0.629	0.051	-12.333	0.000	-0.731	-0.527
	ela34	0.709	1.09	0.65	0.516	-1.428	2.846
	ela35	-0.279	0.567	-0.49	0.622	-1.391	0.832
	ela36	0.234	0.028	8.357	0.000	0.178	0.29

	ela41	-0.676	0.204	-3.313	0.001	-1.084	-0.268
	ela42	1.171	0.34	3.444	0.001	0.491	1.851
	ela43	-0.418	0.011	-36.82	0.000	-0.44	-0.395
	ela44	-0.016	0.026	-0.6	0.548	-0.067	0.035
	ela45	0.123	0.071	1.732	0.083	-0.019	0.265
	ela46	0.041	0.018	2.29	0.022	0.006	0.076
	ela51	-0.713	0.039	-18.282	0.000	-0.791	-0.635
	ela52	-0.343	0.06	-5.69	0.000	-0.461	-0.225
	ela53	0.076	0.032	2.36	0.018	0.013	0.139
	ela54	0.029	0.03	0.98	0.327	-0.029	0.088
	ela55	0.029	0.033	0.87	0.382	-0.036	0.095
	ela56	-0.515	0.021	-24.43	0.000	-0.556	-0.474
	ela61	0.286	0.127	2.26	0.024	0.037	0.534
	ela62	-0.634	0.137	-4.63	0.000	-0.902	-0.365
	ela63	-0.488	0.041	-11.97	0.000	-0.568	-0.408
	ela64	-0.026	0.068	-0.39	0.698	-0.16	0.107
	ela65	0.099	0.183	0.54	0.59	-0.26	0.457
income							
	ela1	0.723	0.012	58.26	0.000	0.699	0.747
	ela2	0.764	0.022	34.71	0.000	0.721	0.807
	ela3	1.14	0.017	67.71	0.000	1.107	1.173
	ela4	1.541	0.05	30.72	0.000	1.443	1.639
	ela5	1.157	0.007	156.16	0.000	1.142	1.171
	ela6	0.723	0.012	58.26	0.000	0.699	0.747

Appendix III

Table I – Absolute values of macro-regional annual CV and EV (Euro 1998)

Scenario B1

Equivalent variation

	2000	2001	2002	2003	2004	2005
North						
level1	4.3	7.0	3.4	5.6	4.7	4.4
level2	14.2	23.4	12.0	19.5	18.1	19.8
level3	25.8	42.4	22.2	34.7	34.9	37.4
level4	37.5	62.3	33.4	51.1	53.2	57.2
level5	63.7	106.8	59.0	86.2	93.0	99.8
Centre						
level1	4.0	6.7	2.6	5.5	4.1	3.5
level2	13.9	23.2	11.7	13.8	18.4	20.2
level3	24.8	41.1	21.7	22.9	34.4	37.0
level4	36.9	60.5	33.3	32.6	53.0	56.6
level5	59.0	98.2	54.6	51.7	89.4	97.4
South						
level1	4.6	7.0	3.1	5.9	4.1	3.7
level2	14.1	22.6	11.9	19.2	18.3	19.2
level3	24.8	40.4	21.6	34.0	34.0	35.7
level4	35.8	58.7	31.7	49.6	50.7	54.9
level5	56.0	97.8	51.5	81.0	82.1	89.8

Compensating variation

	2000	2001	2002	2003	2004	2005
North						
level1	5.1	8.5	4.4	7.3	6.9	7.2
level2	15.1	25.2	13.2	21.5	20.8	23.2
level3	26.8	44.1	23.3	36.4	37.6	40.7
level4	38.4	63.4	34.3	52.4	54.7	59.4
level5	63.2	105.4	58.4	83.9	90.7	96.7
Centre						
level1	4.6	8.0	3.5	6.3	6.3	6.2
level2	14.8	24.9	13.0	14.7	21.3	23.5
level3	25.9	42.8	22.7	23.7	37.2	39.8
level4	37.7	62.3	34.2	33.1	54.1	58.2
level5	58.3	97.2	53.7	50.1	87.4	94.7
South						
level1	5.2	8.3	4.0	7.6	6.3	6.4
level2	14.9	24.2	13.0	20.9	20.9	22.6
level3	25.7	42.0	22.6	35.4	36.2	38.4
level4	36.5	59.7	32.5	50.4	51.6	56.2
level5	55.7	96.6	50.8	78.9	79.6	86.2

Scenario B2

Equivalent variation						
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
North						
level1	0.2	1.1	0.5	0.4	1.4	0.5
level2	6.8	12.8	7.1	10.2	12.4	12.9
level3	15.0	26.9	15.1	21.1	26.5	27.5
level4	23.3	42.0	24.0	33.3	42.2	44.1
level5	42.9	77.1	45.5	60.5	77.1	80.7
Centre						
level1	0.3	1.0	0.1	0.5	1.1	0.1
level2	6.8	12.7	7.0	4.6	12.9	13.6
level3	14.4	26.1	14.8	9.7	26.4	27.4
level4	23.1	40.8	24.2	15.3	42.5	44.0
level5	39.9	70.2	41.5	27.4	74.4	79.2
South						
level1	0.6	1.2	0.5	0.8	1.0	0.0
level2	7.0	12.3	7.2	10.1	12.8	12.6
level3	14.4	25.5	14.7	20.9	25.9	26.1
level4	22.2	39.2	22.7	32.4	40.0	42.3
level5	36.8	69.7	39.0	57.1	67.3	71.9

Compensating variation						
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
North						
level1	0.8	2.3	1.4	1.9	3.5	3.1
level2	7.6	14.4	8.3	12.1	15.0	16.2
level3	15.9	28.5	16.2	22.9	29.2	30.7
level4	24.1	43.2	25.1	34.9	43.9	46.6
level5	42.8	76.6	45.4	59.5	75.8	78.7
Centre						
level1	0.7	2.2	1.0	1.3	3.2	2.6
level2	7.5	14.3	8.2	5.5	15.7	16.8
level3	15.3	27.7	15.9	10.6	29.2	30.3
level4	23.8	42.7	25.2	16.2	43.8	45.9
level5	39.6	70.0	41.2	27.0	73.3	77.8
South						
level1	1.0	2.3	1.2	2.3	3.0	2.6
level2	7.7	13.7	8.3	11.8	15.2	15.9
level3	15.2	27.0	15.8	22.4	28.2	28.9
level4	22.8	40.3	23.6	33.6	41.3	44.0
level5	36.9	69.3	38.7	56.2	65.7	69.5

Scenario B3

Equivalent variation						
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
North						
level1	4.1	6.0	2.8	5.2	3.3	3.9
level2	7.3	10.6	4.8	9.3	5.7	6.8
level3	10.7	15.4	7.1	13.4	8.3	9.8
level4	14.1	20.1	9.3	17.6	10.9	13.0
level5	20.5	29.1	13.4	25.4	15.6	18.9
Centre						
level1	3.7	5.6	2.5	4.9	3.0	3.3
level2	7.1	10.3	4.7	9.1	5.5	6.6
level3	10.3	14.9	6.8	13.1	7.9	9.5
level4	13.7	19.4	9.0	17.1	10.4	12.4
level5	18.9	27.5	12.9	24.2	14.8	17.8
South						
level1	4.1	5.8	2.7	5.1	3.1	3.6
level2	7.1	10.2	4.7	9.0	5.6	6.5
level3	10.3	14.7	6.8	13.0	8.0	9.5
level4	13.5	19.2	8.9	17.0	10.5	12.5
level5	18.9	27.6	12.4	23.6	14.6	17.7

Compensating variation						
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
North						
level1	4.3	6.1	2.9	5.3	3.4	4.0
level2	7.5	10.7	4.9	9.3	5.7	6.9
level3	10.8	15.4	7.0	13.4	8.3	9.8
level4	14.1	19.9	9.2	17.3	10.6	12.7
level5	20.2	28.2	13.0	24.1	14.7	17.6
Centre						
level1	3.9	5.8	2.5	5.0	3.1	3.5
level2	7.2	10.5	4.8	9.1	5.5	6.6
level3	10.5	14.9	6.8	13.0	7.9	9.4
level4	13.7	19.3	8.9	16.8	10.1	12.1
level5	18.5	26.8	12.4	22.9	13.9	16.7
South						
level1	4.2	5.9	2.7	5.2	3.2	3.7
level2	7.2	10.3	4.7	9.1	5.6	6.6
level3	10.4	14.7	6.8	12.9	7.9	9.4
level4	13.6	19.1	8.8	16.6	10.2	12.1
level5	18.6	26.8	12.0	22.4	13.7	16.5

Table II – Aggregate compensating variations (welfare losses) for macro-region (million/Euro 1998)

		2000	2001	2002	2003	2004	2005	total	% on the total
NORTH	**level1**	0.167	0.308	0.145	0.288	0.238	0.233	1.380	0.9
	level2	1.374	2.248	1.340	2.262	2.088	2.454	11.765	7.7
	level3	3.942	6.889	3.713	5.575	5.818	6.712	32.648	21.4
	level4	4.145	6.737	3.600	5.450	6.159	7.120	33.211	21.7
	level5	9.441	15.795	7.875	11.999	13.992	14.730	73.766	48.3
	Total	**19.068**	**31.977**	**16.672**	**25.574**	**28.294**	**31.249**	**152.836**	**100**
CENTRE	**level1**	0.105	0.184	0.058	0.115	0.123	0.104	0.689	1.4
	level2	0.674	1.198	0.539	0.631	0.940	1.089	5.071	10.5
	level3	1.585	2.673	1.376	1.433	2.461	2.621	12.149	25.2
	level4	1.346	2.126	1.432	1.300	2.039	2.404	10.646	22.1
	level5	2.363	4.349	2.600	2.279	3.742	4.251	19.585	40.7
	Total	**6.073**	**10.530**	**6.004**	**5.759**	**9.304**	**10.470**	**48.140**	**100**
SOUTH	**level1**	0.225	0.362	0.170	0.325	0.330	0.306	1.718	2.7
	level2	1.250	2.159	1.079	1.680	1.794	1.981	9.943	15.4
	level3	2.428	3.712	2.097	3.125	3.087	3.532	17.981	27.9
	level4	1.767	2.720	1.531	2.414	2.245	2.404	13.080	20.3
	level5	2.940	4.916	2.379	3.762	3.695	3.963	21.643	33.6
	Total	**8.610**	**13.870**	**7.256**	**11.306**	**11.149**	**12.186**	**64.376**	**100**

		2000	2001	2002	2003	2004	2005	total	% on the total
NORTH	**famtipo1**	3.484	5.708	3.053	5.000	4.890	6.256	28.391	18.6
	famtipo2	4.076	6.755	3.307	5.125	5.093	6.288	30.644	20.1
	famtipo3	1.595	2.826	1.499	2.224	2.177	1.709	12.030	7.9
	famtipo4	3.752	6.126	3.149	4.575	4.793	5.244	27.639	18.1
	famtipo5	2.447	3.572	1.846	3.000	2.597	2.898	16.359	10.7
	famtipo6	3.715	6.990	3.818	5.650	8.745	8.854	37.773	24.7
	Total	19.068	31.977	16.672	25.574	28.294	31.249	152.836	100
CENTRE	**famtipo1**	0.959	1.756	1.135	1.110	1.612	1.892	8.464	17.6
	famtipo2	0.980	1.580	0.950	0.985	1.374	1.568	7.436	15.4
	famtipo3	0.582	0.950	0.576	0.581	0.818	0.860	4.368	9.1
	famtipo4	1.302	2.202	1.163	1.146	1.638	1.771	9.221	19.2
	famtipo5	0.885	1.399	0.730	0.741	0.922	1.139	5.816	12.1
	famtipo6	1.364	2.643	1.451	1.196	2.940	3.240	12.835	26.7
	Total	6.073	10.530	6.004	5.759	9.304	10.470	48.140	100
SOUTH	**famtipo1**	1.142	1.843	0.852	1.470	1.490	1.919	8.716	13.5
	famtipo2	1.240	1.788	0.964	1.383	1.421	1.625	8.421	13.1
	famtipo3	0.632	1.159	0.612	0.959	1.045	0.919	5.326	8.3
	famtipo4	2.528	3.736	2.032	3.125	2.665	3.086	17.172	26.7
	famtipo5	1.256	2.036	1.114	1.644	1.547	1.586	9.183	14.3
	famtipo6	1.813	3.308	1.681	2.725	2.981	3.051	15.559	24.2
	Total	8.610	13.870	7.256	11.306	11.149	12.186	64.376	100

Table III –Excess burden for macro-region (Euro 1998)

North						
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
level1	2.5	4.9	2.0	4.1	3.3	3.1
level2	10.7	18.6	9.1	16.0	14.9	16.7
level3	20.4	34.6	17.6	28.6	29.4	31.8
level4	30.7	51.8	27.1	42.9	44.8	48.7
level5	53.5	91.0	49.8	72.0	78.8	83.5

Centre						
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
level1	2.1	4.9	1.2	3.5	3.0	2.6
level2	10.7	19.0	9.4	9.4	15.8	17.0
level3	20.3	34.9	17.4	16.3	29.7	31.2
level4	30.6	52.1	27.6	24.1	44.7	48.2
level5	49.0	84.0	45.7	39.0	76.3	81.5

South						
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
level1	3.2	5.6	2.2	5.0	3.7	3.9
level2	11.5	19.1	10.0	16.2	16.4	17.7
level3	20.9	35.0	18.2	29.2	30.1	31.7
level4	30.6	50.9	26.9	42.8	44.2	47.5
level5	48.5	85.8	44.3	69.1	70.3	75.9

References

Andersen, M. S., N. Dengsøe, A. B. Pedersen (2001), "An Evaluation of the Impact of Green Taxes in the Nordic Countries", TemaNord 2001:566, Nordic Council of Ministers, Copenhagen.

Anderson and Martin (2007), "Costs of Taxation and Benefits of Public Goods with Multiple Taxes and Goods", World Bank, Development Research Group.

Antonelli, G. B. (1886), Sulla teoria matematica della economia politica, Pisa: Tipografia del Folchetto.

Amemiya, T. (1974), "Multivariate regression and simultaneous equation models when the dependent variables are truncated normal", *Econometrica*, 42, 999-1012.

Atkinson, A. and N. Stern (1974), "Pigou, Taxation, and Public Goods", *Review of Economic Studies*, 4, 119-128.

Atkinson, A. B., and Stiglitz, J. E. (1980), Lectures on Public Economics, London: McGraw-Hill.

Auerbach, A. J. (1985), "The Theory of Excess Burden and Optimal Taxation", in Handbook of Public Economics, Vol. 1. A. J. Auerbach and M. Feldstein, eds. Amsterdam: North Holland, 61-127.

Autorità per l'Energia Elettrica e il Gas (2003), Relazione annuale sullo stato dei servizi e sull'attività svolta.

Autorità per l'Energia Elettrica e il Gas (2005), Relazione annuale sullo stato dei servizi e sull'attività svolta.

Autorità per l'Energia Elettrica e il Gas (2006), Relazione annuale sullo stato dei servizi e sull'attività svolta.

Babiker, M., Metcalf, G. and Reilly, J. (2003), "Tax distortions and global climate policy", *Journal of Environmental Economics and Management*, 46, 269–287.

Bach, S., M. Kohlhaas, B. Meyer, B. Praetorius, H. Welsch (2002), "The effects of environmental fiscal reform in Germany: a simulation study", *Energy Policy*, 30, 803-811.

Ballard, C. L. (1990), "Marginal Welfare Cost Calculations: Differential Analyisis vs. Balanced-Budget Analysis", *Journal of Public Economics*, 41, 263-276.

Ballard, C. L. and D. Fullerton (1992), "Distortionary Taxes and the Provision of Public Goods" *Journal of Economic Perspectives.* 6, 117-31.

Banks, J., R. Blundell and A. Lewbel (1997), "Quadratic Engle Curves and Consumer Demand", *Review of Economics and Statistics*, 79, 527-539.

Baranzini, A., J. Goldemberg and S. Speck (2000), "A Future for Carbon Taxes", *Ecological Economics,* 32, 395-412.

Barker, T. and J. Kohler (1998), "Equity and ecotax reform in the EU: achieving a 10 per cent reduction in CO2 emissions using excise duties", *Fiscal Studies*, 19, 375–402.

Barnett, W. A. (1979), "Theoretical Foundations for the Rotterdam Model", *The Review of Economic Studies*, 46, 109-130.

Basso, L. J. and T. H. Oum (2007), "Automobile Fuel Demand: A Critical Assessment of Empirical Methodologies", *Transport Reviews*, 27, 449 – 484.

Bento, A., L. Goulder, E. Henry, M. Jacobsen, and R. von Haefen (2005), "Distributional and Efficiency Impacts of Gasoline Taxes: An Econometrically-Based Multi-Market Study." *American Economic Review,* 95, 282-287.

Bernard, A., M. Vielle, L. Viguier (2003), "Carbon Tax and International Emissions Trading: A Swiss Perspective" Swiss National Centre of Competence (NCCR), Work Package 4: "Climate Risk Assessment" University of Geneva & Paul Scherrer Institute, NCCR-WP4 Working Paper 21.

Blackorby, C. and D. Donaldson (1988), "Money metric utility: A harmless normalization?", *Journal of Economic Theory*, 46, 120-129.

Blundell, R., P. Pashardes, G. Weber (1993), "What do we learn about consumer demand patterns from micro data?", *The American Economic Review*, 83, 570–597.

Blundell, R., J.M. Robin (1999), "Estimation in Large and Disaggregated Demand Systems: An Estimator for Conditionally Linear Systems", *Jornal of Applied Econometrics*, 14, 209-232.

Bovenberg, A.L,. and R.A. de Mooij (1994), "Environmental levies and distortionary taxation", *American Economic Review*, 84, 1085–1089.

Brännlund, R. and J. Nordström (2004), Carbon Tax Simulations Using a Household Demand Model. *European Economic Review*, 48**,** 211-233.

Browning, E. K. (1976), "The Marginal Cost of Public Funds", *Journal of Political Economy*, 84, 283-298.

Browning, E. K. (1987), "On the Marginal welfare cost of taxation", *American Economic Review*, 77, 11-23.

Buchner, B. K., and A. D. Ellerman (2006), "Over-Allocation or Abatement? A Preliminary Analysis of the EU ETS Based on the 2005 Emissions Data", FEEM Working Paper No. 139.06.

Bull, N., K. Hassett, and G. Metcalf (1994), "Who Pays Broad-Based Energy Taxes? Computing Lifetime and Regional Incidence", *Energy Journal*, 15, 145-164.

Callan, T., S. Lyons, S. Scott, R. S.J. Tol, S. Verde (2008), "The Distributional Implications of a Carbon Tax in Ireland", ESRI Working Paper No. 250.

Casler, S. D. and A. Rafiqui (1993), "Evaluating Fuel Tax Equity: Direct and Indirect Distributional Effects", *National Tax Journal*, 46, 197-205.

Chipman, J. S., and C. Moore (1971), "The Compensation Principle in Welfare Economics", in Papers in Quantitative Economics, Vol. II (edited by Arvid M. Zarley), 1-77, University Press of Kansas.

Christensen, L. R., D. W. Jorgenson, L. J. Lau (1975), "Transcendental Logarithmic Utility Functions**"**, *The American Economic Review*, 65, 367-383.

Comitato Interministeriale per la Programmazione Econominca (CIPE), Resolution 19.11.1998.

Comitato Interministeriale per la Programmazione Econominca (CIPE), Deliberation 137/98, "Linee guida per le politiche e misure nazionali di riduzione dei gas Serra".

Comitato Interministeriale per la Programmazione Econominca (CIPE), Deliberation 123/02, "Revisione delle linee guida per le politiche e misure nazionali delle emissioni di gas serra".

Corte dei Conti (2004), Delibera n. 3/2004/G, Relazione concernente la "Gestione delle misure per la riduzione delle emissioni inquinanti (Legge 448/1998)".

Coase, R. (1960), "The Problem of Social Cost", *Journal of Law and Economics*, 3, 1-44.

Corlett, W. J. and Hague, D. C. (1953), "Complementarity and the excess burden of taxation", *Review of Economic Studies*, 21, 21–30.

Cornwell, A. and J. Creedy (1997), "Measuring the Welfare Effects of Tax Changes Using the LES: An Application to a Carbon Tax", *Empirical Economics*, 22, 589-613.

Council Directive 2003/96/EC, "Restructuring the Community framework for the taxation of energy products and electricity", 27 October 2003.

CNEL-ENEA (2001), Incontrare Johannesburg 2002 - Rapporto Enea sullo Stato di Attuazione del Patto per l'Energia e Ambiente.

Creedy, J. (2000), "Measuring Welfare Changes and the Excess Burden of Taxation", *Bulletin of Economic Research*, 52, 1-47.

Cremer, H., P. De Donder and F. Gahvari (2004a), "Political sustainability and the design of environmental taxes", *International Tax Journal and Public Finance*, 11, 703-719.

Cremer, H., P. De Donder and F. Gahvari (2004b), "Taxes, Budgetary Rule and Majority Voting", *Public Choice*, 119, 335-358.

Deaton, A. and J. Muellbauer (1980a), *Economics and Consumer Behaviour*. Cambridge University Press, 1980.

Deaton, A. and J. Muellbauer (1980b), “An Almost Ideal Demand System”, *American Economic Review*, 70, 312-336.

Deaton, A. and Stern, N. (1986), “Optimally uniform commodity taxes, taste differences and lumpsum grants”, *Economics Letters*, 20, 263–266.

Decreto del Presidente Consiglio dei Ministri 15/1/1999, “"Modificazioni, per l'anno 1999, delle aliquote delle accise sugli oli minerali e delle aliquote dell'imposta sui consumi di carbone, coke di petrolio e orimulsion”.

Diamond, P. A. and Mirrlees, J. A. (1971), “Optimal taxation and public production: I and II”, *American Economic Review*, 61, 8–27 and 261–78.

Diewert, W. E. (1974), “A Note on Aggregation and Elasticities of Substitution”, Canadian Journal of Economics, 7, 12-20.

Diewert, W. E. (1976), “Exact and Superlative Index Numbers”, *Journal of Econometrics*, 4, 115-145.

Diewert, W.E. (1981) “The economic theory of index numbers: A survey”, in *Essays In the theory and measurement of consumer behaviour in honour of Sir Richard Stone*, ed. A. Deaton, 163-208, Cambridge University Press.

Diewert, W.E. and Wales, T.J. (1987), “Flexible Functional Forms and Global Curvature Conditions”, *Econometrica*, 55, 43-68.

ENDS (2000), *ENDS-Environment Daily*, Issue 739, 7 April 2000.

ENDS (2001), *ENDS-Environment Daily*, Issue 1012, 19 June 2001

ENDS (2002), *ENDS-Environment Daily*, Issue 1204, 25 April 2002.

ENDS (2003a), *ENDS-Environment Daily*, Issue 1437, 6 May 2003.

ENDS (2003b), *ENDS-Environment Daily*, Issue 1559, 24 November 2003.

ENDS (2005), *ENDS-Environment Daily*, Issue 1848, 30 March 2005.

ENDS (2006), *ENDS-Environment Daily*, Issue 2220, 6 December 2006.

ENDS (2007), *ENDS-Environment Daily*, Issue 2305, 20 April 2007

ENEA (2000), Rapporto Energia Ambiente.

ENEA (2005), Rapporto Energia Ambiente.

Enerdata (2006), Yearbook 2006 Edition.

Engel, E. (1895), "Die Lebenskosten Belgischer Arbeiter-Familien Fruher and jetzt", *International Statistical Institute Bulletin,* 9, 1-74.

Espey, M. (1998), "Gasoline demand revisited: an international meta-analysis of elasticities", *Energy Economics*, 20, 273-295.

European Commission, "Proposal for a Council Directive restructuring the Community framework for the taxation of energy products. Presented by the Commission", COM/97/30, final, 12.03.1997.

European Commission, "Proposal for a Council Directive Introducing a Tax on Carbon Dioxide Emissions and Energy", COM/92/226, final, 30.06.1992.

European Communication "An Energy Policy for Europe", COM(2007)1.

European Communication "Limiting global climate change to 2 degrees Celsius", COM(2007)2.

European Communication "Towards a European Strategic Energy Technology Plan" COM(2006)847.

European Council Decision 2002/358/EC.

European Commission Press Release (23/05/2008), "Emissions trading: 2007 verified emissions from EU ETS businesses", IP/08/787.

European Environment Agency (2008), "Annual European Community greenhouse gas inventory 1990 - 2006 and inventory report 2008", Technical Report No 6/2008, European Environment Agency, Copenhagen.

Finnish Economic Council (2000), "Environmental and Energy Taxation in Finland– Preparing for the Kyoto Challenge", Prime Minister's Office Publication Series 2000/4.

Fischer, C. (2004), "Who pays for energy efficiency standards?", Resources for the Future, Discussion Paper 04-11.

Freeman III, A. M. (1979), "Approaches to measuring public goods demands", *American Journal of Agricultural Economics,* 61, 915-20.

Frisch, R. (1965), Theory of Production, Rand McNally, Chicago.

Fullerton, D. and G. E. Metcalf (2001), "Environmental Controls, Scarcity Rents, And Pre-Existing Distortions", *Journal of Public Economics*, 80, 249-267.

Georgescu-Roegen, N. (1936), "The Pure Theory of Consumer Behaviour", *Quarterly Journal of Economics*, 50, 133-170.

Giraudet, L. and P. Quirion (2008), “Efficiency and Distributional Impacts of Tradable White Certificates Compared to Taxes, Subsidies and Regulations”, FEEM Working Paper No. 88.08.

Golan, A., J.M. Perlo and E.Z. Shen (2001), “Estimating a Demand System with Non negativity Constraints: Mexican Meat Demand”, *The Review of Economics and Statistics*, 83, 541-550.

Goodwin, P., J. Dargay and M. Hanly (2004), “Elasticities of road traffic and fuel consumption with respect to price and income: a review”, *Transport Reviews*, 24, 275–292.

Gorman, W. M. (1959), “Separable utility and aggregation”, *Econometrica*, 27, 469-481.

Gorman, W. M. (1981), “Some Engel Curves”, in Essays in the Theory and Measurement of Consumer Behaviour in Honor of Sir Richard Stone, ed. by Angus Deaton, Cambridge: Cambridge University Press.

Goulder, L. H., I.W. H. Parry, R.C. Williams and D. Burtraw (1999), “The Cost-effectiveness of Alternative Instruments for Environmental Protection in a Second-best Setting”, *Journal of Public Economics*, 72, 329-60.

Graham, D. and G. Glaister (2002), “The demand for automobile fuel: a survey of elasticities”, *Journal of Transport Economics and Policy*, 36, 1–26.

Greene, W. H. (2000), Econometric Analysis, Fourth edition, Prentice-Hall International.

Grusky, D. B., S. M. R. Kanbur and A. K. Sen (2006) Poverty and Inequality: The conceptual foundations of poverty and inequality measurement, Stanford University Press.

Harberger, A. C. (1971), “Three Basic Postulated for Applied Welfare Economics”, *Journal of Economic Literature*, 9, 785-797.

Hausman, J. (1981), “Exact Consumer’s Surplus and Deadweight Loss”, *American Economic Review*, 71, 662-676.

Hausman, J.; W. Newey and J. Powell (1995), “Nonlinear errors in variables estimation of some Engel curves”, *Journal of Econometrics*, 65, 205-233.

Heady, C. (1993), “Optimal Taxation as a Guide to Tax Policy: A Survey”, *Fiscal Studies*, 14, 15-41.

Heckman, J. (1978), “Dummy endogenous variables in a simultaneous equation system”, *Econometrica*, 46, 931-959.

Heien, D. and C. R. Wessels (1990), “Demand Sytems Estimation with Microdata: a Censored regressions Approach”, *Journal of Business and Economic Statistics*, 8, 365-371.

Hicks, J. R., e R. G. D. Allen (1934), “A Reconsideration of the Theory of Value”, *Economica*, 1, 52-75 and 196-219.

Hicks, J. R. (1942), “Consumer’s Surplus and Index Numbers”, *Review Economics Studies*, 9, 126-137.

Hoerner, J. A., and B. Bosquet (2001), “Environmental Tax Reform: The European Experience”, Washington, DC: Center for a Sustainable Economy.

Hourcade, J.-C. (2001), “Articulating National, Regional and International Policy: Simple Signals in an Heterogeneous World”, IPIECA Symposium, 15–16 October 2001, Cambridge, Boston, USA.

Hurwicz, L., and H. Uzawa, H. (1971), “On the Integrability of Demand Functions”, in Chipman, J. S., *et al.*, *Preference, Utility, and Demand*, New York: Harcourt Brace Jovanovich, pp. 114-148.

International Energy Agency (1999), Italy 1999 Review, Energy policies of IEA countries.

International Energy Agency (2004), World Energy Outlook 2004.

International Energy Agency (2006), Key World Energy Statistics.

International Energy Agency (2007), Energy Prices and Taxes, Quartely Statistics.

International Emission Trading Association (2007), Greenhouse gas market sentiment survey.

International Institute for Sustainable Development (2007), *Earth Negotiation Bullettin*, 12, 354.

Istituto Sviluppo Sostenibile Italia (2004), Il Protocollo di Kyoto in Italia.

ISTAT, I consumi delle famiglie, Standard Files, 1997-2005.

Johansson, O. and L. Shipper (1997), “Measuring the long-run fuel demand of cars: separate estimations of vehicle stock, mean fuel intensity and mean annual driving distance”, *Journal of Transport Economics and Policy*, 31, 277-292.

Jorgenson, D.W., L. J. Lau and T.M. Stoker (1982), “The Transcendental Logarithmic Model of Aggregate Consumer Behavior”, in: Advances in Econometrics, R. Basman and G. Rhodes, Eds., Greenwich: JAI Press.

Johnstone, J. and J. Alavalapali (1998), “The Distributional Effect of Environmental Tax Reform”, Environmental Economics Program, IIED, London, DP 98-01.

Johansson, B. (2000) “Economic Instruments in Practice 1: Carbon Taxes in Sweden”, Swedish Environmental Protection Agency, 8.

Kaplow, L. (2006), “Public goods and the distribution of income”, *European Economic Review*, 50, 1627-1660.

Keen, M. (1986) “Zero expenditures and the estimation of Engel curves”, *Journal of Applied Econometrics*, 1, 277-286.

Klein L. R. and H. Rubin, (1947), “A Constant Utility Index of the Cost of Living”, *Review of Economic Studies,* 15, 84–87.

Kleven, H. J. (2004), “Optimum taxation and the allocation of time”, *Journal of Public Economics*, 88, 545-557.

Kohlhaas, M. (2000), “Ecological tax reform in Germany: from theory to policy”, *Economic Studies Program Series*, Volume 6, American Institute for Contemporary German Studies, The Johns Hopkins University.

Konus, A. A. (1939), “The Problem of the True Index of Cost-of-Living”, *Econometrica*, 7, 10-29.

Kriström, B. (2003), Framework for Assessing the Distribution of Financial Effects of Environmental Policies, Department of Forest Economics, SLU-Umeå, Sweden.

Labandeira, X. and J. M. Labeaga (1999), “Combining Input–Output Analysis and Micro-Simulation to Assess the Effects of Carbon Taxation on Spanish Households”, *Fiscal Studies*, 20, 305–320.

Labandeira, X., J.M. Labeaga and M. Rodríguez (2006), “A residential energy demand system for Spain”, *Energy Journal*, 27, 87-111.

Lau, L. J. (1978), “Testing and imposing monotonicity, convexity, and quasi convexity constraints” in Fuss, M., McFadden, D. (Eds.), Production Economics: A Dual Approach to Theory and Applications, Vol. 1, North Holland, Amsterdam.

Legge 23.12.1998 n. 448, “Misure di finanza pubblica per la stabilizzazione e lo sviluppo”.

Lewbel, A. (1985), “A Unified Approach to Incorporating Demographic or Other Effects into Demand Systems”, *Review of Economic Studies* 52, 1–18.

Lewbel, A. (1989), “Household Equivalence Scales and Welfare Comparisons”, *Journal of Public Economics*, 39, 377-91.

Lewbel, A. (1990), “Full Rank Demand Systems”, *International Economic Review,* 31, 289-300.

Lewbel, A. (1996), “Aggregation without Separability: a Generalized Composite Commodity Theorem”, *American Economic Review*, 86, 927-945.

Lewbel, A. (2003) “A Rational Rank Four Demand System”, *Journal of Applied Econometrics,* 18, 127-135.

Lewbel A. and K. Pendakur, (2008), “Tricks With Hicks: The EASI Demand System”, *American Economic Review,* forthcoming.

Markandya, A. (2004), “Economic Principles nd Overview of Valuation Methods for Environmental Impacts” In, Ščasný, M., Melichar., J., ed. (2004), Development of the Czech Society in the European Union.

Mayshar, J. (1990), “On Measures of Excess Burden and their Applications” *Journal of Public Economics*, 43, 263-289.

Metcalf, G. E. (1994), “The Lifetime Incidence of State and Local Taxes: Measuring Changes During the 1980s” in J. Slemrod (Eds.), Tax Progressivity and Income Inequality. Cambridge University Press, Cambridge, MA.

Metcalf, G.E. (1999), “A Distributional Analysis of Green Tax Reforms”, *National Tax Journal*, 52, 665-681.

Ministero dell’Ambiente e della Tutela del Territorio e del Mare (2002), Third National Communication under the Framework Convention on Climate Change.

Ministry of Sustainable Development Sweden (2005a) “The Swedish Report on Demonstrable Progress – Under the Kyoto Protocol”.

Ministry of Sustainable Development Sweden (2005b) “Sweden’s fourth national communication on climate change - Under the United Nations Framework Convention on Climate Change”.

Moro, D. (2004), Analisi della domanda. Teoria e metodi, Studi di economia agroalimentare, Smea, FrancoAngeli.

Moschini, G. (1998), “The Semiflexible Almost Ideal Demand System”, *European Economic Review*, 42, 349-364.

Mountain, D. C. (1988), “The Rotterdam model: an approximation in variable space”, *Econometrica*, 56, 477-484.

Musgrave, R. A. and P. B. Musgrave (1989), Public finance in theory and practice, Mc Graw-Hill.

Myles, J. and G. Picot (2000) “Poverty indices and policy analysis”, *Review of Income and Wealth*, 46, 161-179

Nichele, V. and J. Robin (1995), “Simulation of indirect tax reforms using pooled micro and macro French data”, *Journal of Public Economics*, 56, 225-244.

Nilsson, C. (1999), “A Unilateral Versus a Multilateral Carbon Dioxide Tax - A Numerical Analysis with the European Model GEM-E3”, Working Paper 66, National Institute of Economic Research.

Nordhaus, W. D. (2007), “To tax or not to tax: Alternative approaches to slowing global warming”, *Review of Environmental Economics and Policy*, 1, 26–44.

Nordic Council (2006), “The Use of Economic Instruments in Nordic and Baltic Environmental Policy 2001-2005”.

OECD (2004), Environment And Distributional Issues: Analysis, Evidence And Policy Implications, OECD, Paris.

OECD (2005), “The United Kingdom Climate Change Levy: a study in political economy”, National Policies Division, Environment Directorate, OECD, Paris.

OECD (2006), The Political Economy of Environmentally Related Taxes, OECD, Paris.

Pareto, V. (1906), Manuale di economia politica, Milano: Società Editrice Libraria.

Park A. and J. C.V. Pezzey (1998), “Reflections on the double dividend debate”, *Environmental and resource economics*, 62, 539-555.

Parry, I. W. H., H. Sigman, M. Walls and R. C. Williams III (2005), “The incidence of pollution control policies”, Resources for the Future, Dicussion Paper 05-24

Patrizii, V. and N. Rossi (1991), Preferenze, prezzi relativi e redistribuzione. Il Mulino-Ricerca,
1991.

Pazienza, M. G., R. Bardazzi and F. Oropallo (2004), “Accise energetiche e competitività delle imprese: un’applicazione sull’esperimento della Carbon Tax”, *Economia delle Fonti di Energia e dell’Ambiente*, 47, 121-164.

Pearce, D. (1991), “The role of carbon taxes in adjusting to global warming”, *Economic Journal*, 101, 938-48.

Pendakur, K., (1999), “Semiparametric estimates and tests of base-independent equivalence scales”, *Journal of Econometrics*, 88, 1-40.

Perali, F. (1999), “Stima delle Scale di Equivalenza Utilizzando i Bilanci Familiari Istat 1985-1994”, *Rivista Internazionale di Scienze Sociali*, 4, 481-541.

Perali, F. and J. Chavas (2000), “Estimation of Censored Demand Equations from Large Cross-Section Data”, *American Journal of Agricultural Economics*, 82, 1022-1037.

Pollak, R. A., and T. J. Wales (1969), “Estimation of the Linear Expenditure System”, *Econometrica*, 37, 611-628.

Pollak, R. A., and T. J. Wales (1992), Demand System Specification and Estimation, New-York, Oxford University Press.

Poterba, J. M. (1989), “Lifetime Incidence and the Distributional Burden of Excise Taxes”, *American Economic Review*, 79, 325-330.

Poterba, J. (1991), “Is the Gasoline Tax Regressive?”, in *Tax Policy and the Economy*, D. Bradford, ed. Vol. 5, Camdridge: MIT Press.

PricewaterhouseCoopers (2007), “Saving the planet - can tax and regulation help?”, PricewaterhouseCoopers, United Kingdom.

Ramsey, F. P. (1927), “A contribution to the theory of taxation”, *Economic Journal*, 37, 47–61.

Richter, W. F. and K. Schneider (2003), “Energy taxation: reasons for discriminating in favour of the production sector”, *European Economic Review*, 47, 461-476.

Rizzi, P.L., F. Balli (2002), “La domanda al consumo di beni non durevoli e servizi in Italia negli anni ’90: analisi di breve periodo con un sistema Almost Ideal a due stadi”, Quaderni, n. 352, Dipartimento di Economia Politica, Università degli Studi di Siena.

Ruiz-Castillo, J. (1987), “Potential Welfare and the Sum of the Individual Compensating or Equivalent Variations”, *Journal of Economic Theory*, 41, 34-53.

Ryan, D.L. and T. Wales (1998), “A Simple Method for Imposing Local Curvature in Some Flexible Consumer-Demand Systems”, *Journal of Business and Economic Statistics*, 16, 331-38.

Samuelson, P. A. (1938), “A Note on the Pure Theory of Consumer’s Behaviour”, *Economica*, 5, 61-71.

Samuelson, P. A. (1947), “Some Implications of ’Linearity’”, *Review of Economics*, 15, 80–90.

Samuelson, P. A. (1950), “The Problem of Integrability in Utility Theory”, *Economica*, 17, 355-385.

Samuelson P.A., Swamy S., (1974), “Invariant economic index numbers and canonical duality: survey and synthesis”, *The American Economic Review*, 64, 566-593.

Sandmo, A. (1995), “Public Finance and the Environment”, in Bovenberg and Cnossen (eds.) Public Economics and the Environment in an Imperfect World, Kluwer academic Publishers.

Sen, A. K. (1979), “Utilitarianism and welfarism”, *The Journal of Philosophy*, 76, 463 489.

Sen, A. K. (1995), “Rationality and social choice”, *American economic review*, 85, 1-24.

Sen, A. K. (1999), “The possibility of social choice”, *American economic review*, 89, 1-24.

Sen, A. K. (1985), Commodities and capabilities, Amsterdam: North-Holland.

Shonkwiler, J.S. and S. Yen (1999) “Two-Step Estimation of a Censored System of Equations”, *American Journal of Agricultural Economics*, 81, 972-982.

Sipes, K. and R. Mendelsohn (2001), “The Effectiveness of Gasoline Taxation to Manage Air Pollution", *Ecological Economics*, 36, 299 – 309.

Slesnick, D. T. (1994), “Consumption, Needs and Inequality”, *International Economic Review*, 35, 677-703.

Slesnick, D. T. (1998) “Empirical Approaches to the Measurement of Welfare”, *Journal of Economic Literature*, 36, 2108-2165.

Smith, A. (1776), An Enquiry into the Nature and Causes of the Wealth of Nations.

Smith, Z. (2000), “The Petrol Tax Debate”, Briefing Note n. 10/2000, The Institute for Fiscal Studies, London.

Sorensen, P. B. (2007), “The Theory of Optimal Taxation: What is the Policy Relevance?”, EPRU Working Paper Series.

Stiglitz, J. E. and P. S. Dasgupta (1971), “Differential Taxation, Public Goods, and Economic Efficiency”, *Review of Economic Studies*, 38, 151-174.

Stone, J. R.N (1954a) “Linear Expenditure Systems and Demand Analysis: an Application to the Pattern of British Demand”, *Economic Journal*, 64, 511-527.

Stone, J. R. N. (1954b), The Measurement of Consumers’ Expenditure and Behaviour in the United Kingdom, 1920-1938. Cambridge: Cambridge University Press.

Symons, E. and J. Proops (1998) “The Distributional Implications of Pollution Taxes on European Families” Keele University, Keele, UK.

Symons, E., S. Speck and J. Proops (1998), “The Effects of Pollution and Energy Taxes across the
European Income Distribution”, Keele University, Working Paper 5/2000.

Tiezzi, S. (2005), “The Welfare and Distributive Effects of Carbon Taxation on Italian Households”, *Energy Policy*, 33, 1597-1612.

Unione Petrolifera (2004), Relazione annuale 2004.

Unione Petrolifera (2005), Relazione annuale 2005.

Unione Petrolifera (2006), Relazione annuale 2006.

West, S E. and R. C. Williams III (2004), “Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes”, *Journal of Environmental Economics and Management*, 47, 535-558.

West, S. E., (2004), “Distributional Effects of Alternative Vehicle Pollution Control Policies” *Journal of Public Economics*, 88, 735-757.

Wier, M., K. Birr-Pedersen, H. K. Jacobsen, and J. Klok (2005), "Are CO_2 Taxes Regressive? Evidence from the Danish experience" *Ecological Economics,* 52, 239-251.

Willig, R. E. (1976), "Consumer's Surplus without Apology", American Economic Review, 66, 4, 589-597.

Working, H. (1943), "Statistical Laws of Family Expenditure", *Journal of the American Statistical Association*, 38, 43-56.

World Bank (2007), State and trend of carbon market 2007, World Bank, Washington D.C.

World Bank (2008), State and trend of carbon market 2008, World Bank, Washington D.C.

Yen, S.T. and B. Lin (2006), "A Sample Selection Approach to Censored Demand Systems", *American Journal of Agricultural Economics*, 88, 742-749.

Yen, S.T., B. Lin and D. Smallwood (2003), "Quasi- And Simulated-Likelihood Approaches to Censored Demand Systems: Food Consumption by Food Stamp Recipients in the United States", *American Journal of Agricultural Economics*, 85, 458-478.

Zhang, Z., A. Baranzini (2004), "What do we know about carbon taxes? An inquiry into their impacts on competitiveness and distribution of income", *Energy Policy*, 32, 507-518.

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