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ESTIMATING WELFARE ASPECTS OF CHANGES IN ENERGY PRICES FROM PREFERENCE HETEROGENEITY

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Abstract

The European Union's energy and climate policy package will cause an increase in end-user prices of electricity and fuels. This paper assesses the distributional effects of these price increases in Cyprus by specifying and estimating a household energy demand system with price heterogeneity between households. This novel method allows obtaining robust parameter estimates even when household expenditure surveys are limited. The empirical analysis is conducted both conditional on energy-related household characteristics and unconditionally. We then use the estimated demand system to conduct welfare analysis. We find that the rise in energy prices results in welfare losses (in 2009 prices) of EUR 31 and EUR 101 per household for 2013 and 2020 respectively, or a nationwide welfare loss of more than EUR'2009 33 million in 2020. Price increases will be regressive and will affect small and urban households more strongly than the rest of the population. Furthermore, we find that the largest proportion of welfare loss is due to loss of household's income purchasing power caused by higher energy prices, while the changes in relative prices induce deadweight loss which is a small part of welfare loss because of the limited substitutability of energy with other goods.

Keywords: deadweight loss; demand system; distributional effect

JEL Classification: D62, H23, Q58

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1. INTRODUCTION

In 2009 the European Union (EU) adopted a legislative package on energy and climate change, which involves several legally binding measures that aim at reducing greenhouse gas (GHG) emissions in the EU by the year 2020. This group of measures will substantially affect the economies of EU countries – households, firms and the public sector. Most importantly, they will lead to an increase in end-user prices of electricity and automotive fuels. Up to now, the overall economic impact has been studied in detail with the use of partial or general equilibrium models at international and national level – e.g. Capros et al. (2011) presented the economy-wide analysis carried out for the European Commission (the EU's executive body); and Böhringer et al. (2009) conducted an independent comparative analysis of these costs with three different computable general equilibrium models. However, since policy discussions were primarily focused on the cost-effectiveness of the policy targets, the distributional aspect of these measures has largely been overlooked. As Fullerton (2011) notes, although there is a rich public economics literature on the distributional effects of taxes, work on the distributional aspects of energy and environmental policies is limited.

Household demand for energy and the subsequent distributional effect of energy efficiency or carbon pricing schemes has been analyzed in several countries, with some examples being those of Brännlund and Nordström (2004) for Sweden, Ekins and Dresner (2006) for the United Kingdom, Kerkhof et al. (2008) for the Netherlands, Labandeira et al. (2006) for Spain, Rehdanz (2005) for Germany, and Wier et al. (2005) for Denmark.[1] These studies rely, inter alia, on data from household expenditure surveys conducted annually by national statistical agencies; this enables the empirical estimation of detailed income and substitution patterns. However, in several countries household expenditure surveys are conducted less frequently, e.g. according to the European Statistical Service, Cyprus, Greece, France, Ireland, Malta, Austria, Portugal, Finland and Sweden conduct household budget surveys with a frequency of about five years (Eurostat 2005). This poses serious problems to performing empirical demand analysis, as price variation over time is limited. To overcome this problem, some of the above-mentioned studies have used supplementary data from other sources such as aggregate national data, input-output data or other household related micro surveys.

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[1] See also the detailed review of Callan et al. (2009). For the United States, see the review of Fullerton (2009).

In this paper we consider distributional aspects of price increases induced by the EU's energy and climate package, constructing a national household energy demand model for Cyprus, a small island state in the Eastern Mediterranean with a population of about 800 thousand, which became an EU member in 2004. Faced with the same problem mentioned above, i.e. the limited availability of household micro data, we propose an approach that is based on the fact that price changes differ across goods, therefore their effect can vary between households due to preference heterogeneity. For example, vegetarians are not affected by changes in the price of meat; therefore, when the only item in the food basket that increases in price is meat, only meat eaters face an increase in the unit cost of food. Differences in unit cost changes due to preference heterogeneity are true for most (if not all) composite goods used in empirical demand analysis. In the case of energy, the unit cost is made from the prices of items such as electricity, petrol, gas, heating oil, solid fuels and renewable sources. To the extent that these items do not increase proportionately in price and their shares in consumption vary across households due to preference heterogeneity, then the unit cost of energy also varies across households.

We thus propose an approach to construct a consumer theory based measure of the unit cost of composite goods commonly used for empirical demand analysis, and use the variation in this cost across households to estimate a demand system from a limited (minimum two) household expenditure surveys. We apply the proposed method to estimate the price elasticity of household demand for energy in the context of an integrable complete demand system using data drawn from three household expenditure surveys conducted in Cyprus in 1996, 2003 and 2009. We then take advantage of the integrability of the estimated model (i.e. its property to compute indirect utility from the consumer demand parameters) to simulate the welfare effects of price increases anticipated from the adoption of EU's energy and climate policies on households grouped by income, location and demographic characteristics.

Our work adds to knowledge in several ways. On the theoretical side we propose a two-stage budgeting model that allows theoretically consistent aggregation of commodities over which consumer expenditure is allocated at each stage. The literature on devising aggregation procedures to cope with this problem dates back to Hicks (1946) and its main concern has been the presence of substitution effects making 'fixed' price indices of the Laspeyres and Paasche type inappropriate (Deaton and Muellbauer 1980, Diewert 1993). Here we focus on a different aggregation problem arising from preference heterogeneity across households – as described above – and propose an analytical framework for exploiting this heterogeneity. On the empirical front, the method we propose allows one to obtain robust energy demand estimates in cases where the available data from consumer/household expenditure surveys are limited, as is the case with the several European countries mentioned above which do not conduct surveys on an annual basis. These estimates enable simulations of the distributional effects from energy price changes and can be used for the formulation of energy and environmental policies that can properly account for trade-offs between efficiency and equity. Compared to earlier empirical work in the energy field, ours is probably the first one to address preference heterogeneity with the novel theoretical treatment mentioned above.

Section 2 outlines the theoretical model, while Section 3 describes the data, the empirical strategy and the estimation results. Welfare effects are reported in Section 4, and Section 5 concludes.

2. MODELLING CONSUMER DEMAND FOR COMPOSITE GOODS

The composite commodities used in empirical demand analysis most often consist of individual goods grouped together because they satisfy broadly similar consumer needs, such as food, shelter, transportation etc. Therefore, one needs to somehow aggregate the prices of the individual goods in each group to an index reflecting the cost of the composite commodity. The standard solution to this problem is to employ a statistical formula, typically the Laspeyers (or Divisia) form $p_{it} = \sum_{k=1}^{N} s_{ik0} \frac{r_{ikt}}{r_{ik0}}$, where s_{ik0} is the average - over households - share of good k in category i; and r_{ikt}, r_{ik0} the price of this good in the current and base periods, respectively. This formula, however, is an appropriate measure of the 'true' cost of living for the composite commodity only under restrictive assumptions about consumer preferences that are required for the shares of goods in the consumer budget to be constant over prices and income (Deaton and Muellbauer 1980).

In the analysis below we allow the unit cost of the composite commodity to be estimated as a true cost of living index, where the budget shares can vary with relative prices and the level of consumer's budget. In doing so the unit cost of the composite commodity not only is constructed in a way consistent with the fundamentals of consumer theory but, also, varies among households, thereby providing information to estimate the price elasticity of the composite good in situations where household expenditure surveys are not conducted frequently enough for this estimation to rely on time-series price variation alone.

Our modelling of consumer demand for composite goods is based on two-stage budgeting: first the total budget is optimally allocated among the G commodity groups; then, the amount corresponding to each commodity group i is optimally allocated among its N items in the group. Preferences over the G composite commodities are assumed to be implicitly separable and given by the Quadratic Logarithmic (Lewbel 1990) for household h,

$$\ln C(p, u_h) = a_h(p) + \frac{b_h(p) u_h}{1 - e_h(p) u_h}, \tag{1}$$

where $a_h(p)$, $b_h(p)$ and $e_h(p)$ are homogeneous of degree zero. Moreover, it is assumed that $a_h(p)$ has the translog functional form

$$a_h(p) = a_{0h} + \sum_{i=1}^{G} a_{ih} \ln p_i + 0.5 \sum_{i=1}^{G} \sum_{j=1}^{G} \gamma_{ij} \ln p_i \ln p_j, \tag{2}$$

and $b_h(p)$ and $e_h(p)$ are log linear:

$$b_h(p) = \beta_{0h} + \sum_{i=1}^{G} \beta_{ih} \ln p_i, \tag{3}$$

$$e_h(p) = \sum_{i=1}^{G} \varepsilon_{ih} \ln p_i \, . \tag{4}$$

The system of share equations for the G composite commodities is given by

$$w_{ih} = a_{ih} + \sum_{j=1}^{G} \gamma_{ij} \ln p_j + \frac{\beta_{ih}}{b_h(p)} [\ln y_h - a_h(p)] + \frac{\varepsilon_{ih}}{b_h(p)} [\ln y_h - a_h(p)]^2, \;\; i = 1,2, \dots, G \tag{5}$$

where y_h is the budget of household. The parameters of the share equations fulfil the adding-up ($\sum_{i=1}^{G} a_{ih} = 1$, $\sum_{i=1}^{G} \beta_{ih} = 0$, $\sum_{i=1}^{G} \varepsilon_{ih} = 0$, $\sum_{i=1}^{G} \gamma_{ij} = 0$), homogeneity ($\sum_{j=1}^{G} \gamma_{ij} = 0$) and symmetry ($\gamma_{ij} = \gamma_{ji}$) restrictions.

The demand system specified by equations (1)-(5) is the same as the Quadratic Almost Ideal Demand System (QUAIDS) of Banks et al. (1997), except for the $b_h(p)$ function which we specify as a log-linear (for analytical convenience) rather than as a Cobb-Douglas function. Nevertheless, as in the case of the QUAIDS model the demand system specified here belongs to the Rank-3 family, the most general specification of consumer preferences satisfying integrability, i.e. the ability to compute the cost function from the estimated parameters of the demand system.[2] This property of the demand system is particularly important in the context of our analysis, in the sense that the parameter estimates obtained from the empirical demand system in the next section are subsequently used for the analysis of the welfare effects of changes in energy prices.

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[2] See Lyssiotou et al. (2002) for a comparison of alternative empirical specifications of Rank-3 demand systems.

The price p_i for the composite commodity i is defined as a household-specific true cost of living index, $c_h(r_i, u_h)/c_h(\bar{r}_i, u_h)$, where $r_1, r_2, \dots, r_N$ and $\bar{r}_1, \bar{r}_2, \dots, \bar{r}_N$ are the prices of the N components in the composite commodity i in the current and base period respectively. The functional form of p_i depends on consumer preferences at the lower budgeting stage, which determine the allocation of expenditure among the components of composite commodity i.

In particular, preferences at the lower budgeting stage are assumed to be linear logarithmic:

$$\ln c_h(r_i, u_h) = \lambda_h(r_i) + \mu(r_i)u_h \tag{6}$$

where

$$\lambda_h(r_i) = \lambda_{i0h} + \sum_{k=1}^{N} \lambda_{ikh} \ln r_{ik} + 0.5 \sum_{k=1}^{N} \sum_{m=1}^{N} \xi_{ikm} \ln r_{ik} \ln r_{im} \tag{7}$$

and

$$\mu(r_i) = \mu_{i0} + \sum_{k=1}^{N} \mu_{ik} \ln r_{ik} \,. \tag{8}$$

The share (Hicksian) of component k in the composite commodity i is given by [3]

$$s_{ikh} = \lambda_{ikh} + \sum_{m=1}^{N} \xi_{ikm} \ln r_{im} + \mu_{ik} u_h \,. \tag{9}$$

Equation (6) can be expressed as a function of the share

$$\ln c_h(r_i, u_h) = \lambda_{i0h} + \mu_{i0} u_h + \sum_{k=1}^{N} s_{ikh} \ln r_{ik} - 0.5 \sum_{k=1}^{N} \sum_{m=1}^{N} \xi_{ikm} \ln r_{ik} \ln r_{im} \tag{10}$$

after multiplying equation (9) by $\ln r_{ik}$ and summing over the N components of the composite commodity. The true cost of living for the composite commodity i with the prices of its N components at the base period $\bar{r}_1, \bar{r}_2, \dots, \bar{r}_N$ set to one is given by

$$\begin{aligned} \ln p_{ih} &= \ln c_h(r_i, u_h)/c_h(\bar{r}_i, u_h) = \sum_{k=1}^{N} s_{ikh} \ln r_{ik} - 0.5 \sum_{k=1}^{N} (s_{ik} - s_{ik}^{*}) \ln r_{ik} \\ &= \sum_{k=1}^{N} (s_{ikh} - s_{ik}) \ln r_{ik} + 0.5 \sum_{k=1}^{N} (s_{ik} + s_{ik}^{*}) \ln r_{ik} \end{aligned} \tag{11}$$

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[3] The parameters of the share equations at the lower budgeting stage fulfil the adding-up ($\sum_{k=1}^{N} \lambda_{ikh} = 1$, $\sum_{k=1}^{N} \xi_{ikm} = 0, \sum_{k=1}^{N} \mu_{ik} = 0,$), homogeneity ($\sum_{m=1}^{N} \xi_{ikm} = 0$) and symmetry ($\xi_{imk} = \xi_{ikm}$) restrictions.

where s_{ik} and s_{ik}^* are the average (market) shares of component k in composite commodity i at the current and base period respectively.[4] The term $0.5\sum_{k=1}^{N}(s_{ik}+s_{ik}^*)\ln r_{ik}$ is a Tornqvist index (Caves et al. 1982) which takes into account the substitution effects within the composite commodity. The first term captures differences in preferences between households.

In the empirical analysis that follows we estimate the system of budget share equations for the composite commodities given in (5), where the prices of composite commodities are constructed as the true cost of living indices (11) and vary not only over time but also across consumers. Notably, the statistical sub-index often used as the unit cost of the composite commodity $p_i = \sum_{k=1}^{N} s_{ik}\, r_{ik}$ is a special case of the true cost of living index given in (11).

3. EMPIRICAL ANALYSIS AND RESULTS

3.1 Data

We use data drawn from the Cyprus Household Expenditure Survey (HES) for the years 1996, 2003 and 2009. The HES in Cyprus is carried out every 6-7 years, and surveys prior to 1996 are not comparable in terms of expenditure categories. The sample includes households with head younger than 60 years of age, consisting of two or more adults and at most four children. This sample selection helps towards reducing the number of parameters in the demand system (without introducing bias) and results in 4494 observations. Table 1 presents some descriptive statistics of the variables used in the analysis.

The price index for the two composite commodities is constructed according to equation (11) and the component prices are the price sub-indices of the published Consumer Price Index. The price indices for the components of energy (base year 1996) are constructed from individual price indices of electricity, heating fuels, automotive petrol and automotive diesel, all based on unpublished information kindly provided to us by the Cyprus Statistical Service.

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[4] By taking the average of equation (9) over the H households ($h = 1,2,\dots,H$) at current and base period prices, the average shares are given by $s_{ik} = \lambda_{ik} + \sum_{m=1}^{N}\xi_{ikm}\ln r_{im} + \mu_{ik}u$ and $s_{ik}^* = \lambda_{ik} + \mu_{ik}u$, where $\lambda_{ik} = (1/H)\sum_{h=1}^{H}\lambda_{ikh}$, $u = (1/H)\sum_{h=1}^{H}u_h$ and it follows that $s_{ik} - s_{ik}^* = \sum_{m=1}^{N}\xi_{ikm}\ln r_{im}$.

Table 1: Descriptive statistics of the sample

Variable	Mean	Standard deviation	Minimum	Maximum
Shares in household budget				
Energy	0.1409	0.0630	0.0000	0.5851
Other commodities	0.8591	0.0630	0.4149	1.0000
Household-specific prices and budget (log)				
Energy	0.2967	0.2593	0.0000	1.0472
Other commodities	0.1666	0.1447	-0.0068	0.5584
Total household budget (log)	9.6721	0.5352	8.3105	10.884
Household characteristics				
Age of household head	43.578	9.0729	20.000	59.000
Number of children	1.3222	1.1404	0.0000	4.0000
Number of adults	2.5162	0.7358	2.0000	4.0000
Age of head squared	1981.3	782.61	400.00	3481.0
Number of children squared	3.0485	3.7872	0.0000	16.000
Number of adults squared	6.8727	4.2846	4.0000	16.000
Female household head	0.0478	0.2135	0.0000	1.0000
Located in urban areas	0.6778	0.4674	0.0000	1.0000
Number of cars	1.7695	0.7623	0.0000	6.0000
Number of cars squared	3.7121	3.0752	0.0000	36.000
House size in square metres	161.43	64.335	20.000	800.00
Heating or cooling system	0.6938	0.4610	0.0000	1.0000
Detached house	0.5532	0.4972	0.0000	1.0000
Duplex	0.2118	0.4087	0.0000	1.0000
Terraced house	0.0527	0.2235	0.0000	1.0000
Flat	0.1395	0.3465	0.0000	1.0000
Other house type	0.0427	0.2023	0.0000	1.0000
Survey year				
1996	0.3522	0.4777	0.0000	1.0000
2003	0.3689	0.4826	0.0000	1.0000
2009	0.2788	0.4485	0.0000	1.0000

Note: The descriptive statistics refer to the three Surveys 1996, 2003 and 2009 and the number of observations is 4494.

3.2 Empirical specification

The estimated demand system consists of two composite commodities: energy and other non-durable goods/services. Household expenditure on energy is comprised of expenditure on electricity, petrol and diesel, and other fuel; whereas, households expenditure on other goods/services is comprised of expenditure on food, beverage, clothing, footwear, water and sewage services, communications, transport, recreation goods and services, restaurants and hotels, and miscellaneous goods and services.[5]

The demand system is empirically specified as the budget share equations

$$w_{ih} = a_{ih} + \sum_{j=1}^{2} \gamma_{ij} \ln p_{jh} + \frac{\beta_i}{b_h(p)} [\ln y_h - a_h(p)] + \frac{\varepsilon_i}{b_h(p)} [\ln y_h - a_h(p)]^2, \ i = 1{,}2 \tag{12}$$

where

$$a_h(p) = a_{0h} + \sum_{i=1}^{2} a_{ih} \ln p_{ih} + 0.5 \sum_{i=1}^{2} \sum_{j=1}^{2} \gamma_{ij} \ln p_{ih} \ln p_{jh}, \tag{13}$$

$$b_h(p) = \beta_0 + \sum_{i=1}^{2} \beta_i \ln p_{ih}, \tag{14}$$

$$e_h(p) = \sum_{i=1}^{2} \varepsilon_{ih} \ln p_{ih}, \tag{15}$$

$$a_{ih} = a_i + \sum_{k=1}^{K} a_{ik} z_{kh}, \tag{16}$$

and $z_{1h}, z_{2h}, \dots, z_{Kh}$ are household characteristics or dummy variables relating to the survey year given in Table 1. The parameter a_{0h} is a fixed linear function of the number of children and adults in the household.[6] The price indices $\ln p_{ih}$ $(i = 1{,}2)$ are constructed according to equation (11); the components of the two composite commodities are as described above and their respective shares are computed from the data.

By differentiating (12) with respect to $\ln y_h$ and $\ln p_{jh}$, respectively, we obtain

$$d_{ih} = \frac{\partial w_{ih}}{\partial \ln y_h} = \frac{1}{b_h(p)} (\beta_i + 2\varepsilon_i Y_h) \tag{17}$$

$$d_{ijh} = \frac{\partial w_{ih}}{\partial \ln p_{jh}} = \gamma_{ij} - \frac{1}{b_h(p)} \left[\frac{\beta_j(\beta_i + \varepsilon_i Y_h) Y_h}{b_h(p)} + \kappa_j(\beta_i + 2\varepsilon_i Y_h)\right], \tag{18}$$

where $Y_h = \ln y_h - a_h(p)$ and $\kappa_j = a_{jh} + \sum_{i=1}^{2} \gamma_{ij} \ln p_{ih}$.

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[5] Transport expenditure does not include the cost of transportation fuels of the household. The cost of transportation fuels is classified under energy expenditure.

[6] In particular, we define $a_{0h} = a_0 + a_{01}(1 + 0.3z_{1h} + 0.7(z_{2h} - 1))$ where z_{1h} and z_{2h} is the number of children and the number of adults in the household respectively; a_0 is fixed to the level of the (log) total household budget that corresponds to the lowest 1% of households in the sample, a_{01} is set to one and this restriction is tested. Thus, fixed cost a_{0h} is allowed to vary with the demographic composition of the household; fixed cost increases by 70% for each adult in addition to the household head and by 30% for each child. The parameter a_0 can be viewed as the subsistence log cost at base prices for a household with two adults only.

The budget elasticity is defined as

$$e_{ih} = \frac{d_{ih}}{w_{ih}} + 1; \tag{19}$$

the own and cross price elasticities are given by(see e.g. Banks et al. 1997)

$$e_{iih} = \frac{d_{iih}}{w_{ih}} - 1 \text{ and } \quad e_{ijh} = \frac{d_{ijh}}{w_{ih}}. \tag{20}$$

The demand system given in (12) is estimated using a generalised method of moments (GMM) procedure which allows for the endogeneity of total expenditure and household-specific prices, heteroscedasticity and non-normality in the errors of the share equations, as well as for measurement errors (see e.g. Greene 2003, chapter 15). The estimation of the nonlinear system uses as initial values for the parameters the two-stage least squares estimates.[7] Possible effects of dynamics in the system are treated by conditioning on dummy variables relating to the survey year and the ownership of a number of durable goods such as the number of cars, house size and type (Blundell et al. 1993). Following the estimation of the parameters in (12), the budget and price elasticities for each household can be estimated using equations (19)-(20).

The system of share equations is estimated under two alternative specifications regarding the household characteristics included in a_{ih} by conditioning on: (i) demographic characteristics, as well as on household characteristics and durables affecting the consumption of energy; and (ii) demographic characteristics only. The elasticities obtained from the first empirical specification can be thought to reflect short-run responses, in the sense that durable goods complementing or substituting energy consumption (heating system, number of cars, house type and size etc) do not change. The second specification of the estimated demand system can be thought to produce long-run elasticities, insofar as demand for energy is not constrained by the stock of household durables.[8]

3.3 Estimation results

Table 2 presents the parameter estimates and statistics of the demand system for the two alternative specifications, namely a model conditional on energy-related household characteristics

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[7] The following restrictions are imposed on the parameters during estimation: adding-up ($\sum_{i=1}^{2} a_i = 1, \sum_{i=1}^{2} a_{ik} = 0$, all k $\sum_{i=1}^{2} \beta_i = 0$, $\sum_{i=1}^{2} \varepsilon_i = 0$, $\sum_{i=1}^{2} \gamma_{ij} = 0$), homogeneity ($\sum_{j=1}^{2} \gamma_{ij} = 0$) and symmetry ($\gamma_{ij} = \gamma_{ji}$). Moreover, $\beta_0 = 1$.

[8] In the second specification (unconditional) only variables that relate to demographic and socio-economic characteristics of the households, which are not likely to change in the long run, are used as instruments in the GMM estimation.

and an unconditional model. As expected the price effects in absolute terms are larger in the conditional model, which relates to the short run, rather than in the unconditional empirical specification; the opposite is true for real expenditure (budget) effects.

Own prices of energy and of other goods/services influence positively the corresponding shares, and therefore (due to the parameter properties of the demand system) cross prices affect shares in the opposite direction. The parameters β_i and ε_i capture the effects of household budget net of any price changes, i.e. the effect of real household expenditure. The share of energy decreases as real household expenditure increases, with the negative impact being larger at higher real expenditure levels; the opposite holds for the share of other goods and services. In the conditional model, however, the significance of the higher order effects of real expenditure (quadratic log expenditure term) is rather weak. These estimates suggest that in the two-share demand system under consideration, energy is the necessity and other goods/services the luxury composite commodity.

The characteristics a_{ik} are interpreted as demographic substitution effects (Pashardes 1998), in the sense that they show the effect of the demographic composition of the household (number and age of family members) at a given level of utility. In our empirical results these parameters appear to be negative, indicating that at equivalent expenditure and by comparison with otherwise similar households, a household with fewer members favours energy at the expense of other goods/services. Notably, this effect weakens for both the conditional and unconditional demand for energy in the case of adults, and for the conditional demand in the case children; the children effect appears to be insignificant in the unconditional model.

The age of household head has a weak effect on conditional and almost no effect on unconditional energy demand; whereas his/her gender impacts more strongly on unconditional demand. As expected, the ownership of durables complementing the consumption of energy, such as the number of cars and the presence of heating or cooling systems, are associated with higher household demand for energy. In comparison with those in detached houses, residents of all other house types tend to prefer other goods/services over energy. Households in urban areas also spend a smaller share of their budget on energy than those in rural areas.

Table 2: Parameter estimates and statistics

	Conditional[1]				Unconditional[1]			
	Energy		Other		Energy		Other	
	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
Constant (a_i)	0.1604	6.01	0.8397	31.44	0.1693	5.95	0.8311	29.19
Log price energy (γ_{1j})	0.0869	3.03	-0.0870	-3.03	0.0526	0.85	-0.0547	-0.89
Log price other (γ_{2j})	-0.0870	-3.03	0.0869	3.03	-0.0547	-0.89	0.0526	0.85
Log expenditure (β_i)	-0.0942	-3.94	0.0943	3.94	-0.1085	-3.91	0.1093	3.93
Log expenditure squared (ε_i)	-0.0162	-1.76	0.0162	1.77	-0.0278	-2.69	0.0281	2.71
Household characteristics (a_{ik})								
Age of household head	-0.0018	-1.84	0.0018	1.84	-0.0010	-0.93	0.0010	0.92
Number of children	-0.0095	-3.21	0.0095	3.21	-0.0049	-1.52	0.0050	1.54
Number of adults	-0.0656	-4.32	0.0656	4.32	-0.0619	-3.78	0.0620	3.78
Age of head squared	0.0000	1.59	0.0000	-1.59	0.0000	0.71	0.0000	-0.69
Number of children squared	-0.0015	-1.95	0.0015	1.95	-0.0010	-1.17	0.0010	1.15
Number of adults squared	0.0060	2.14	-0.0060	-2.14	0.0080	2.70	-0.0080	-2.70
Female household head	-0.0075	-1.75	0.0075	1.75	-0.0127	-2.80	0.0127	2.78
Located in urban areas	-0.0058	-2.50	0.0058	2.50				
Number of cars	0.0380	7.97	-0.0381	-7.97				
Number of cars squared	-0.0060	-5.04	0.0060	5.04				
House size in square metres	0.0000	0.72	0.0000	-0.72				
Heating or cooling system	0.0141	5.30	-0.0141	-5.30				
Duplex[2]	-0.0030	-1.36	0.0030	1.36				
Terraced house	-0.0067	-1.73	0.0067	1.73				
Flat	-0.0072	-2.27	0.0072	2.27				
Other house type	-0.0096	-2.24	0.0095	2.24				
Survey year 2003[2]	0.0175	3.79	-0.0175	-3.79	0.0245	2.64	-0.0234	-2.51
Survey year 2009	-0.0032	-0.42	0.0032	0.41	0.0122	0.74	-0.0102	-0.62
Number of observations (H)	4492				4492			
Objective function * H	58.51				78.82			
Root mean squared error	Energy: 0.0592		Other: 0.0592		Energy: 0.0613		Other: 0.0613	
Symmetry test[3]	Wald statistic = 0.55, P-value=0.46				Wald statistic = 2.39, P-value=0.12			
Over-identifying restrictions test[4]	Chi-squared statistic = 58.51, P-value=0.95				Chi-squared statistic = 78.82 P-value=0.02			

Notes:

[1] The test for $a_{01} = 1$ (see footnote 8) results in P-value equal to 0.64 and 0.79 for the conditional and unconditional model respectively.

[2] Estimates for the parameters relating to house types are interpreted with reference to the detached house. Estimates for the parameters relating to survey years are interpreted with reference to 1996.

[3] In a two-share system non-rejection of the symmetry restriction implies non-rejection of the homogeneity restrictions and vice versa due to the adding up of the shares.

[4] The null hypothesis that the over-identifying restrictions of the models are valid is not rejected at 1% level of significance (see e.g. Hansen 1982). The test statistic is given by the value of the objective function times the number of observations. The degrees of freedom are given by the difference between the number of instruments times two (i.e. the number of equations) and the number of estimated parameters. The degrees of freedom for the conditional and unconditional model equal 78 and 56 respectively.

Using the parameter estimates reported in Table 2 in (19) - (20) we obtain budget and price elasticities for each household in the sample; we then construct average elasticities by weighting the individual household elasticities with the share of the household in total expenditure for the relevant commodity. Furthermore, using expression (11) for the household-specific price of the composite commodity we compute demand elasticities with respect to the price of each energy component; namely, electricity, petrol and diesel, and other fuel. Table 3 presents the budget and price elasticities obtained from the conditional and unconditional empirical specifications.

Table 3: Estimated budget and price elasticities[1]

	Conditional		Unconditional	
	Energy	Other	Energy	Other
Budget	0.595 (0.047)	1.063 (0.008)	0.720 (0.040)	1.045 (0.006)
Price[2]				
Energy[3]	-0.260 (0.025)	-0.114 (0.032)	-0.521 (0.032)	-0.077 (0.072)
Electricity	-0.071 (0.008)	-0.034 (0.011)	-0.140 (0.011)	-0.016 (0.010)
Petrol & diesel	-0.143 (0.012)	-0.059 (0.016)	-0.297 (0.016)	-0.028 (0.015)
Other fuel	-0.046 (0.004)	-0.020 (0.005)	-0.084 (0.005)	-0.009 (0.005)
Other	-0.335 (0.195)	-0.949 (0.032)	-0.241 (0.430)	-0.970 (0.070)

Notes:

[1] Approximate standard errors in parentheses.

[2] Uncompensated price elasticities (see e.g. Banks et al. 1997).

[3] By construction the price elasticities with respect to energy components add up to the demand elasticity (of energy or other) with respect to the energy price index and their relative magnitudes are determined by the component share in the energy composite commodity. The average share of electricity, petrol and diesel and other fuel in energy expenditure is 0.33, 0.50 and 0.17 respectively.

The estimated budget elasticity of demand for energy is less than unity, implying that, on average, households view energy as a necessity and other goods/services as luxury. When energy-related household characteristics are included in the model, demand for energy appears less sensitive to budget changes compared to energy demand from the unconditional model. The change in demand for other goods and services in response to income changes is about the same in the conditional and unconditional model.

As regards price elasticities our estimates suggest that demand for energy conditional on various characteristics relating to durables, is inelastic to changes in its own price. Although more elastic compared to the conditional model (due to the greater substitution possibilities), unconditional energy demand continues to be more inelastic than the demand for other goods/services. Cross price elasticities are negative indicating that energy and other goods/services are complements. In the unconditional model cross price elasticities in absolute terms are lower than their counterparts obtained from the conditional model, indicating that demand becomes more responsive to relative price changes.

Recall that the household-specific price for energy is constructed as linear function of the prices of electricity, petrol and diesel and other fuel - as depicted by equation (11). Using this feature of our model we can compute price elasticities of energy demand (and of the demand for other goods and services) with respect to prices of energy components. The resulting elasticities shown in Table 3 add up to the demand elasticity (of energy or other) with respect to the energy price index, and their relative magnitudes are determined by the component share in the energy composite commodity. Consequently, both demand for energy and demand for other goods/services is more responsive to changes in petrol and diesel prices than to price changes of either electricity or other fuels, since petrol and diesel expenditure forms the largest part of energy spending and changes in the price of the former affect more household-specific energy prices.

Overall, the empirical analysis shows that energy is a necessity, while the composite commodity consisting of other goods and services is a luxury, both conditional on energy-related household characteristics and unconditionally. The degree of responsiveness of energy demand to changes in energy prices is much smaller than that of the demand for other goods and services to own price changes. Conditioning on a number of household energy-related characteristics leads to more income and price inelastic energy demand than the demand estimated from a model that does not control for these characteristics.

Keeping in mind that our empirical specification includes only one non-energy good, our estimation results are comparable to those found by other empirical studies in European countries that have employed similar demand systems. Tiezzi (2005), using an Almost Ideal Demand System, estimated similar income elasticities but relatively higher own price and cross price elasticities for Italian households. Brännlund and Nordström (2004), using a QUAIDS model and a combination of household microdata and aggregate macrodata, found higher own price elasticities compared to our results but low cross price elasticities, similarly with our estimates. Labandeira et al. (2006) combined two surveys of micro level data for several years and used a QUAIDS to arrive at income elasticities for energy goods that are slightly higher than our results; their own price elasticities are similar to those of our study with the exception of a higher elasticity for electricity.

4. WELFARE ANALYSIS

As explained earlier, the demand system estimated in this paper belongs to the Rank-3 family and satisfies integrability, thereby enabling us to use the results of the empirical analysis in the previous section to compute the welfare effects of changes in energy prices. More specifically, the parameter estimates of the demand system are used here to quantify, in money terms, the loss in welfare that households might undergo under alternative scenarios about the future evolution of energy prices induced by various policies.

The money metric of welfare loss evaluated at minimum expenditure (i.e. $u_0 = 0$) is defined as the cost required by households to maintain a given utility level under alternative price regimes,

$$\ln \frac{C(p_t,u_0)}{C(p_0,u_0)} = \sum_{i=1}^{2} a_{ih} \ln p_{iht} + 0.5 \sum_{i=1}^{2} \sum_{j=1}^{2} \gamma_{ij} \ln p_{iht} \ln p_{jht} \qquad (22)$$

where p_0 are the reference prices and p_t the alternative prices regimes under consideration. Thus, it is interpreted as the compensation required by household h to remain at the initial utility level when prices change from p_0 to p_t. The difference in the cost functions in (22) is known as compensating variation and measures the total cost or benefit of a policy to the consumer. The total cost of a policy is comprised of the change in household's income purchasing power (first term) and the deadweight loss induced by substitution effect (second term) as a result of the change in relative prices due to the policy intervention.

Zachariadis and Shoukri (2011) have conducted a preliminary review of the direct effects of the EU energy and climate package on energy prices in Cyprus, which was based on consultation with public authorities and local experts. According to their analysis, there will be an increase in prices of

(i) electricity by 4.7% and 12.6% in 2013 and 2020 respectively; and

(ii) petrol and diesel by 1.5% and 7.0% % in 2013 and 2020, respectively.

These price increases induce an increase in the household specific price index for the energy composite commodity of 2.4% and 7.6%, on average, for 2013 and 2020 respectively.

Using the prices in 1996 as reference (unity) we compute (22) sequentially by replacing p_t with the prices in the last year in the dataset (i.e. 2009) prices in 2013 and in 2020 under the scenarios (i) and (ii) above.[9] This gives the percentage change in the household true cost of living due to the change in energy prices in 2013 and 2020 compared to 2009. For instance, when this change is positive, the corresponding amount is a money metric of the welfare loss incurred by households. The welfare loss from the future changes in energy prices is computed for different household characteristics such as total expenditure group, area of residence and household composition. The results are shown in Table 4 to 6 below.[10] Moreover, the cost from energy price changes considered is decomposed into the loss of household's income purchasing power and deadweight loss.

Table 4 shows that the assumed changes in energy prices in 2013 and 2020 lead to an increase in total household cost of 0.14% and 0.44% respectively. The welfare loss, in 2009 prices, from the rise in prices amounts to EUR 31 and EUR 101 for 2013 and 2020 respectively. The largest part of welfare loss is associated with the loss of income's purchasing power, while deadweight loss accounts for about a quarter of cost increase. Deadweight loss appears to be a small proportion of welfare loss because of the limited substitution possibilities of energy with other goods as estimated by the second order price effects shown in Table 2; in fact, the estimated cross price elasticities in Table 3 indicate that energy and other goods/services are complements.

Table 4: Welfare loss from increase in energy prices, by total expenditure group

Deciles of total expenditure	2009	2013				2020			
	Cost EUR (2009)	Change in cost (%)	Loss EUR (2009)			Change in cost (%)	Loss EUR (2009)		
			Welfare (total)	Purchasing power	Dead-weight		Welfare (total)	Purchasing power	Dead-weight
1st	9441	0.18	17	14	3	0.56	53	42	11
2nd	14499	0.15	22	17	5	0.48	69	52	17
3rd	17337	0.14	24	18	6	0.44	77	57	20
4th	19882	0.13	27	20	7	0.43	86	64	23
5th	22477	0.13	30	23	7	0.43	97	73	24
6th	25430	0.12	32	24	7	0.42	106	79	26
7th	28589	0.12	36	26	9	0.41	117	86	31
8th	32195	0.13	41	31	10	0.42	134	100	34
9th	37001	0.12	44	33	11	0.39	145	105	39
10th	45390	0.12	54	39	14	0.39	176	127	49
All households	23016	0.14	31	24	7	0.44	101	75	25

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[9] Here we use the parameter estimates of the unconditional model to conduct welfare analysis, as the price changes which are considered correspond to long run-demand for energy. Also, it should be noted that the money metric may not be 'base independent' (IB), obscuring the interpretation of the results (Lewbel 1989). For base independence the restrictions $\sum_{i=1}^{2} \beta_i \, ln \, p_{iht} = 0$ and $\sum_{i=1}^{2} \varepsilon_i \, ln \, p_{iht} = 0$, are necessary (but not sufficient).

[10] The percentage change in cost is rounded to two decimals and monetary values are shown to the nearest euro thus differences are due to rounding.

According to the results of Table 4, the energy and climate policy measures are projected to be regressive: the percentage change in cost experienced by low expenditure (i.e. low income) households is larger, although the welfare loss, and consequently income's purchasing power and deadweight loss, induced by higher energy prices increases with total expenditure. The rise in electricity prices will be mainly responsible for this result because electricity expenditures are particularly regressive in Cypriot households. These results are in line with most findings from the international literature, which also find energy and carbon taxes to be regressive (Speck 1999; Callan et al. 2009).

Table 5: Welfare loss from increase in energy prices, by area of residence

Area of residence	2009	2013				2020			
	Cost EUR (2009)	Change in cost (%)	Loss EUR (2009)			Change in cost (%)	Loss EUR (2009)		
			Welfare (total)	Purchasing power	Dead-weight		Welfare (total)	Purchasing power	Dead-weight
Urban	23304	0.14	33	25	8	0.45	104	78	26
Rural	22422	0.13	29	22	7	0.42	94	70	24

Moreover, as shown in Table 5, households in urban areas are expected to face a higher percentage change in their total cost and to incur greater loss in welfare from the assumed increases in energy prices than those in rural areas. For both urban and rural households the cost increase is mainly due to the income effect, namely the decrease in real household income arising from the higher energy prices, and to a smaller degree to the substitution effect induced by the change in relative prices.

Table 6: Welfare loss from increase in energy prices, by household composition type

		2009	2013				2020			
Adults	Children	Cost EUR (2009)	Change in cost (%)	Loss EUR (2009)			Change in cost (%)	Loss EUR (2009)		
				Welfare (total)	Purchasing power	Dead-weight		Welfare (total)	Purchasing power	Dead-weight
2	0	16792	0.18	30	25	5	0.57	96	79	17
2	1	21309	0.17	36	28	7	0.54	116	90	25
2	2-4	24468	0.14	34	25	8	0.44	108	80	28
3-4	0	24731	0.11	28	21	8	0.37	92	66	26
3-4	1	26901	0.11	29	21	9	0.35	94	64	30
3-4	2-4	26523	0.09	24	14	10	0.29	76	44	32

As regards household size, Table 6 illustrates that two-adult households, with or without children, experience larger percentage change in their total cost and greater welfare loss compared to similar households in terms of child composition but with more adults. Given the number of adults in the household, the welfare loss in money terms peaks when there is only one child in the household, while it takes its smallest value in the case of households with the largest size. As the number of household members increases the proportion of welfare loss attributed to deadweight loss rises, reaching as high as 40%.

In aggregate terms, the welfare loss from the energy price increases resulting from the implementation of the EU energy and climate package is estimated to approach 10 million Euros (at 2009 prices) in year 2013 and rise gradually up to more than 33 million Euros'2009 in 2020.[11]

5. CONCLUSION

The European Union's energy and climate policy package will cause an increase in end-user prices of electricity and automotive fuels, and possibly of other energy products as well. In this paper we tried to assess the distributional effects of these price increases on the population of Cyprus. We specified and estimated econometrically a household energy demand system with price heterogeneity between households. This method allows one to obtain robust parameter estimates in cases where the available data from consumer/household expenditure surveys are limited, as is the case with Cyprus and many other European countries that do not conduct expenditure surveys on an annual basis.

The empirical analysis was conducted both conditional on energy-related household characteristics and unconditionally thus providing parameter estimates and elasticities that reflect short-run and long-run effects respectively. Both budget and own price elasticities of energy demand turned out to be more inelastic when we control for characteristics associated with energy consumption. This finding can be interpreted demand for energy is more inelastic to changes in household income and energy prices in the short run. The estimated cross price elasticities indicate that energy and other goods and services are complements. We then used the estimated demand system to conduct welfare analysis assuming that, as a result of energy and climate legislation, energy prices will gradually rise in the period 2013-2020 in line with predictions provided by national energy

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[11] We assumed that the number of households will rise to 320 000 in year 2013 (compared to about 300 000 in 2010) and will rise slightly to 330 000 in 2020.

authorities. We found that the assumed rise in energy prices results in higher total household cost of 0.14% in 2013 and of 0.44% in 2020. These percentages correspond to a welfare loss (in 2009 prices) of EUR 31 and EUR 101 for 2013 and 2020 respectively, or a nationwide welfare loss of more than EUR'2009 33 million in 2020. In line with evidence from other countries, our results show that the welfare loss can vary with the household total expenditure, composition and area of residence: the price increases will be regressive and will affect small and urban households more strongly than the rest of the population. Furthermore, we found that the largest proportion of welfare loss is due to loss of household's income purchasing power caused by higher energy prices, while the changes in relative prices induce deadweight loss which is a small part of welfare loss because of the limited substitutability of energy with other goods.

Reflecting on these calculations, it is important to keep in mind that the economic environment in Europe has changed substantially since the announcement of the energy and climate package. As a result of weak economic growth in the EU in recent years, the growth in GHG emissions has been considerably slower than foreseen a few years before, which in turn has led to a decline in the price of GHG emission allowances. Therefore, the increase in energy prices that was projected in 2008/09 and was used in the calculations presented here can be considered as a high-end estimate under economic conditions prevailing in early 2013.

Obviously, energy price increases induced by environmental policies will affect the prices of all goods and services, which in turn will influence household demand for other goods as well. In the absence of appropriate data, it is not possible to construct a computable general equilibrium model for Cyprus which would be able to capture the interaction between the production and consumption side. Preliminary results from parallel work conducted for the production sectors of the Cypriot economy (Ketteni et al. 2013) indicates that the effect of the EU policy package on unit production costs will be rather small, so that end-user prices of other goods and services are expected to change only marginally. Therefore, the welfare impact simulated in this paper seems to be a reasonable approximation of real-world effects. Linking a detailed production model with the household demand model presented in this paper is a subject of future research.

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