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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 is expected to 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 consumer demand system with price heterogeneity between households. This novel method allows obtaining robust parameter estimates even when household expenditure surveys are limited, as is the case in many European countries. 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 of EUR 101 per household (in 2009 prices) in year 2020, or a nationwide welfare loss of more than EUR'2009 33 million. 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.

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 were expected to 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 have been analysed 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.

In this paper we consider distributional aspects of price increases induced by the EU's energy and climate package, by constructing a national household energy demand model for Cyprus, a small island

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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).

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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 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, while accounting for the Hicksian aggregation problem, our analysis focuses on a different aggregation problem arising from preference heterogeneity across households as described above, and proposes an analytical framework for exploiting this heterogeneity to increase price variation in the data. This allows obtaining robust price elasticities of demand for energy (and other commodities) in cases where the available data from consumer/household expenditure surveys are limited, as is the case with the 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 consumer demand analysis most often consist of individual goods grouped together because they satisfy broadly similar consumer needs, such as food, shelter, and transportation. 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 index 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).[2]

In the analysis below we allow the price of the composite commodity to be constructed as a true cost of living index, where the shares of items in composite commodity expenditure can vary with the relative prices of these items. The validity of this index does not depend on whether the Hicksian aggregation theorem is satisfied, i.e. it does not have to consist of items the prices of which move in proportion, because substitution between items within the composite commodity is accounted for.[3] In other words, the constructed index is not affected by households rearranging their consumption to avoid items that increase in relative price. Furthermore, allowing the true cost of living index (hereafter price, for short) of composite commodity to vary among households provides information to estimate the price elasticity of this commodity 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 cost function (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 $C(\cdot)$ is the cost function, p is the vector of G composite commodity prices, u_h is the utility level of household h, $a_h(p)$, $b_h(p)$ and $e_h(p)$ are homogeneous functions of prices of degree zero. Moreover, it is assumed that $a_h(p)$ has the translog functional form

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

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

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

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

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

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

where y_h is the budget of household. Share equations are obtained by differentiating Eq. (1) with respect to ln p_i, i.e. by application of the

[2] A procedure to obtain price variation across households and over time not based on the true cost of living approach is proposed by Jones and Labeaga (2003), whereby the price of tobacco is deflated by a weighted average of nine broad categories, where the weights are the household's budget share for each category. Closer to the spirit of our analysis, but addressing the problem as a household rather than a composite commodity unit cost, is the use of demographic information by Atella et al. (2004) to generate 'pseudo' unit values (Lewbel, 1989a) varying across regions, an approach based on Barten (1964) equivalence scale.

[3] This means that, from the theoretical point of view, one does not have to be concerned about which items should be included in the composite commodity. Nevertheless, the interpretation of empirical results may not be straightforward when primary goods that do not satisfy a common consumer need (e.g. food and clothing) are included in the composite commodity. We shall return to this point in the empirical analysis below.