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An Econometric Input-Output Model for EU Countries Based on Supply and use Tables: Private Consumption

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Archives: CGE models and econometrics

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Econometric Input-output model for EU countries based on Supply & Use tables: private consumption

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This paper presents the results of an econometric study on household private consumption in EU15 aiming at the estimation of a household demand system including price and income parameters as well as other socio demographic explanatory variables. The econometric model is estimated by consistently combining a time series cross section dataset of aggregated household expenditure data for EU15 countries, published by Eurostat as part of the national accounts, and a cross section dataset of household budget surveys for five European countries. The estimated household demand system of equations is integrated into an Econometric Input-Output (EIO) model based on Eurostat Supply and Use table, recently proposed by Kratena and Streicher (2009). That gives a sound representation of the European household budget allocation behaviour in response to change in commodity price, total available income and household characteristics and its impacts on output and employment in Europe. A set of policies and socio-demographic scenarios is analysed through the resulting EIO-modelling framework with a demonstrative purpose.

KEYWORDS: Household demand system, Micro and Macro data, Econometric Input-output model

1. Introduction

The Input-Output (IO) model has been the first modelling framework based on a general equilibrium concept and with a high industry detail to be implemented for economic analysis and forecast. In the last two decades, IO tools have been extensively used for environmental analysis as a main tool or as a complement of other bottom up modelling framework (LCA, partial equilibrium, etc.). Still in the era of fully-fledged Computable General Equilibrium (CGE) models, they are often preferred for the analysis of those scenarios (i.e. short term, etc.) where consumers' preferences, combination of factors of production or international trade patterns are not expected to play a relevant role and the stylized representation used for simple IO model is sufficient. However, whenever the level of complexity of the scenario becomes higher CGE models are used instead, which with few specific exceptions can anyway give only comparative static type of results neglecting the time dimension and with it the path through which an economic system adjusts and achieves new steady state equilibrium.

An alternative both to simple IO models and CGE ones is the Econometric IO model (EIO), constructed starting from simple IO model and integrating econometrically estimated blocks such as a households demand system for a more realistic consumers' preferences representation, a production block allowing for factors substitution and a module for trade representation. Interesting overviews and comparisons of the three different models briefly discussed so far IO, CGE and EIO are given already by West (1995) as well as Kratena and Streicher (2009) in their papers, hence the scope of this study is to present an econometric analysis of the household private consumption behaviour in EU15 and to illustrate its integration in EIO modelling framework.

A complete system of demand equation is estimated by consistently combining a time series and a cross section dataset derived by respectively the aggregated household expenditure data for EU15 countries, published as part of the National Accounts, and a cross section dataset based on the household budget surveys of five European countries. The estimated household demand system includes price and income elasticity as well as the influence on households' consumption of other socio demographic characteristics (household size, age of the reference person or number of owned cars). The emphasis of modelling is on consumption of energy (i.e. electricity, heating and private transportation) which is explained as a function of the 'service price', thereby measuring the households' response not only to price changes of the consumption item itself, say euro for kWh of electricity for instance, but also to the efficiency of the electric household appliances.

The household demand system is also complemented with an aggregate households' consumption function explaining the level of consumption in terms of disposable income. The demand system and the aggregate consumption function are then integrated in an Input-Output model based on Supply and Use tables, which constitutes a first step towards the setup of a complete EIO model.

The integration of household demand systems into EIO or CGE models, using both time series and cross section data is described in Jorgenson (1982), Bardazzi and Barnabini (2001), Kennes (1983) as well as Labandeira and Labeaga (1999). Similarly to the existing studies, our approach is based on established microeconomic theory of demand systems and application to time series and cross section data, and strives at overcome the often criticised aspect of the 'over-restrictive' structure of demand systems based on flexible functional forms (as in Almon (1996)) and on the assumption of the 'representative household' by combining economic variables (income, prices) with household characteristics.

The emphasis is on energy and on the environmental impact of households that constitutes a large part of the overall environmental impact of an economic system (Hertwich, 2008). Starting from these conclusions in the last years more and more policy initiatives for sustainability have improved their effectiveness by encompassing measures like incentives or ecolabel to steer households' final consumption towards a more environmental friendly choice. These measures have actually improved energy efficiency of household appliances, which implied a more productive use of energy for instance (i.e. less energy used per unit of final consumption). Nevertheless, the environmental loads associated to final consumption have increased as a consequence of higher living standard, growing population and might have increased also for a 'rebound effect' due to higher efficiency of the household devices. The rebound effect also known as '*Jevons paradox*', from the name of the first author that addressed this issue in 1865 (Jevons 1865), can undermine the efforts aiming at reducing resources consumption. Increased efficiency of appliances may indeed discourage 'cost-saving' behaviour due to a lower price of the resource input and can also produce an indirect scale effect on consumption as a lower expenditure on resource inputs makes available income for the purchase of additional electrical and electronic equipments (Khazzoom 1980, Green 1992, Kratena and Wuger 2005, Greening et al. 2000, Hertwich 2008).

In this paper the consumption block including the households' demand system plus the aggregate consumption function is coupled to an IO modelling framework based on the Supply-Use tables published for Denmark and the year 2000. The resulting EIO modelling framework is tested by analysing a scenario called including electric efficiency increase of both households' devices and increase of the share of households with a reference person unemployed.

The paper is structured as follows section two illustrate the theoretical derivation of the household demand system which is then econometrically estimated. Section three includes the econometric results of the time series and of the cross section households' demand models and illustrates the procedure adopted to consistently combine the results of the two econometric estimations. Section four sketches the aggregate consumption function. The fifth section is dedicated to the scenario analysis, while the sixth to the conclusions.

2. Household demand system derivation

The time series model will be set up for the sample of EU15 from 1995 on and a panel-estimation over countries will be carried out. The structure of our model distinguishes between aggregate household consumption, capital expenditure of households, and expenditure for heating and transport energy as well as for other goods and services. In principle the consumers' decisions can be described by utility maximization under constraints or by cost/expenditure minimization for a given level of utility (the dual model). In the following a dual model of private consumption is applied starting from the expenditure function of a demand system. The level of utility u and the vector of commodity prices p_i are the arguments of an expenditure function for non-durables $C(u, p_i)$ which together with expenditure for durables (investment I in appliances with price index p_I) gives total expenditure G:

$$G = C(u, p_i) + p_I I \qquad (1)$$

Total expenditure G could further be described as a function of disposable income. For a given savings rate and a given disposable income, an increase in expenditure for investment leads to lower expenditure for non-durables $C(u, p_i)$.

$$C(u, p_i) = \overline{G} - p_I I \qquad (2)$$

In order to take these links into account, a full model of private consumption must be set up as in Kratena and Wüger (2008). Such a model must also include investment functions for durables and requires a dynamic cost minimization or utility maximization model. Willett and Naghshpour (1987) set up a model of dynamic utility maximization with budget constraints from which the optimality conditions for investment are derived. In the present approach the consumer chooses a time path of capital expenditure, *K*, to minimize discounted costs for a given level of utility over a time horizon τ for which values for the exogenous variables are given. We can derive two main optimality conditions from such a cost minimization problem, namely Shephard's Lemma (3) and the envelope condition for the capital stock (4):

$$\frac{\partial C(u, p_i)}{\partial p_i} = x_i \tag{3}$$

$$-\frac{\partial C(u, p_i)}{\partial K} = (r + \delta) p_I \tag{4}$$

Shephard's Lemma determines the level of commodity demand x_i or in a logarithmic model the budget shares w_i according to:

$\frac{\partial \log C(u, p_i)}{\partial \log p_i} = \frac{\partial C(u, p_i)}{\partial p_i} \frac{p_i}{C(u, p_i)} = \frac{x_i p_i}{C(u, p_i)} = w_i$. The envelope condition states that the shadow price of fixed assets must equal the user costs of capital, i.e. the marginal benefit of a unit of capital must equal its marginal cost. The shadow price of capital is given by the negative of the term that measures the impact of capital inputs on expenditure.

Energy commodities are used by consumers for the 'production' of services (heating, lighting, communication, transport). These services are demanded by households and require inputs of energy flows, *E* and a certain capital stock, *K*. The main characteristic of this stock is the efficiency of converting an energy flow into a level of service:

$$E = \frac{S}{\eta_{ES}} \tag{5}$$

In (5) *E* is the energy demand for a certain fuel and *S* is the demand for a service inversely linked by the efficiency parameter (η_{ES}) of converting the corresponding fuel into a certain service. For a given conversion efficiency that allows to derive a service price p_S (marginal cost of service), which is influenced by the energy price and the conversion efficiency:

$$p_S = \frac{p_E}{\eta_{ES}} \tag{6}$$

This is similar to Khazzooms (1980, 1989) approach of dealing with services and shows the same property of a service price decrease with an increase in efficiency. These prices of services (p_S) become arguments of the vector of commodity prices in the overall consumption model (p_i). The budget shares of energy demand can be defined as the traditional energy cost share or as the 'service share': $\frac{p_E E}{C} \equiv \frac{p_S S}{C}$.

We proceed by applying the cost function of the AIDS model (Deaton, Muellbauer (1980)) $C(u, p_i)$:

$$\log C(u, p_i) = (1-u)\log(a(p_i)) + u\log(b(p_i)) \tag{7}$$

with the translog price index for $a(p_i)$:
$\log a(p_i) = \alpha_0 + \sum_k \alpha_k \log p_k + 0.5\sum_k\sum_j \gamma_{ij} \log p_k \log p_j$ approximated in our case by the Stone price index: $\log P^* = \sum_k w_k \log p_k$, the Cobb-Douglas price index for $b(p_i)$: $\log b(p_i) = \log a(p_i) + \beta_0 \prod_k p_k^{\beta_k}$ and the level of utility, u. As the level of utility u is an argument of the expenditure function, an indirect utility function can be derived:

$$U = \left[\frac{\log C(u,p) - \log a(p_i)}{\beta_0 \prod_k p_k^{\beta_k}}\right] \tag{8}$$

Applying Shephard's Lemma to the cost function (7), inserting the indirect utility function (8) and allowing for additional technological and socio-demographic factors captured in the vector of variables Z and D, gives the well known budget share equations for the i non-durable goods:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\left(\frac{C}{P}\right) + \beta_{iD} D \log\left(\frac{C}{P}\right) + \xi_i Z \tag{9}$$

Note that this formulation allows for the pure influence of socio-demographic variables (Z) as well as for interaction between socio-demographic factors and expenditure (D). If the model is set up without any socio-demographic variables it reduces to:

$$w_i^T = \alpha_i^T + \sum_j \gamma_{ij}^T \log p_j^T + \beta_i^T \log\left(\frac{C^T}{P^T}\right) \qquad (10)$$

The following expressions for income (ε_i) and uncompensated price elasticities (ε_{ij}^U) within AIDS can be derived (Green and Alston, 1992):

$$\varepsilon_i = \frac{\beta_i + \beta_{iD} D}{w_i} + 1 \qquad (11)$$

$$\varepsilon_{ij}^U = \frac{\gamma_{ij} - (\beta_i + \beta_{iD} D) w_j}{w_i} - \delta_{ij} \qquad (12)$$

Via the Slutsky equation the following general relationship holds between the compensated (ε_{ij}^K) and the uncompensated elasticity (ε_{ij}^U): $\varepsilon_{ij}^K = \varepsilon_{ij}^U + \varepsilon_i w_j$. The compensated elasticity measures the pure price effect and assumes that the household is compensated for the income effect of a price change. Applying the Slutsky equation in the case of AIDS yields for the compensated elasticity:

$$\varepsilon_{ij}^K = \frac{\gamma_{ij} - (\beta_i + \beta_{iD} D) w_j}{w_i} - \delta_{ij} + \varepsilon_i w_j \qquad (13)$$

In (12) and (13) δ_{ij} is the Kronecker delta with $\delta_{ij} = 0$ for i≠j and $\delta_{ij} = 1$ for i=j.
The demand for energy-commodity E_i is determined by the level of service demand S_i and energy efficiency for the appliance using this energy carrier (η_i) as well as energy efficiency for the other appliances (η_j). Energy efficiency for a different aaappliance (η_j) has an impact on energy demand for good i due to cross price effects, which is a special feature of our model of total household consumption. We analyse the cross price effects on a pairwise base between the energy goods in our model.

By totally differentiating the quantity demanded E_i (S_i , η_j) with respect to t gives:

$$\frac{dE_i}{dt} = \frac{\partial E_i}{\partial \eta_j}\frac{d\eta_j}{dt} + \frac{\partial E_i}{\partial S}\frac{dS}{dt} \qquad (14)$$

In (14) the total change in E_i is described as the sum of direct effects of efficiency changes and of indirect effects via service demand. The direct effects of an efficiency increase on energy demand (the first term in (14)) is equal to -1. But an increase in efficiency also leads to a decrease in the service price and thereby to an increase in service demand. Dividing both sides of (14) by E_i rearranging and taking into account the price elasticity of demand for energy services (ε_{ij}) gives:

$$\frac{d\log E_i}{d\log \eta_j} = -(1+\varepsilon_{ij}) \qquad (15)$$

This expression is identical with expressions of the total effect of efficiency on energy demand including the rebound effect derived by Berkhout, et.al. (2000) and Khazzoom (1980). The total impact is therefore also determined by the own price elasticity ε_{ii} of energy demand or, more precisely, the (service) price elasticity of service demand. Actually in our model energy commodities enter as service (with corresponding service prices) and therefore we can directly derive service price elasticities.

It might be seen as an important advantage of a model for total household consumption that different feedbacks between different energy commodities can be analyzed. That gives a number of different rebound effects, i.e. effects of changes in the efficiency of a certain appliances on the different energy demands. A change in the efficiency of an appliance implies an own price-rebound effect on *this* energy commodity, defined by the compensated own price elasticity ε_{ii}^{C}. Besides this pure price induced effect there exists also an income induced rebound effect, defined by the difference between the uncompensated and compensated price elasticity: $\varepsilon_{ii}^{U} - \varepsilon_{ii}^{C} = -w_i\varepsilon$.

The same holds true for the impact of the change in the efficiency of an appliance on the demand for *another* energy good. The pure price induced effect is again given by compensated cross price elasticity ε_{ij}^{C} and the income induced effect by the difference of the elasticities $\varepsilon_{ij}^{U} - \varepsilon_{ij}^{C} = -w_j\varepsilon_i$.

3. Econometric estimation: combining cross section with time series information

The demand system described in the previous section has been derived by consistently combining two different households' demand systems estimated with two different datasets: a cross section time series dataset for EU15 including income, price indexes and budget shares for some consumption categories, and a cross section dataset constructed by consistently merging the households survey of four European countries (Spain, Italy, France and Austria). The reason for combining such different datasets in an econometric study is that both contain useful and complementary information. Time series data provide with time series of price indexes by countries which permit the estimation and derivation of accurate price elasticities, but they are rather poor on socio-demographic variables as these variables are normally not available as a time series, hence a households' demand system including socio-demographic variables would be hardly possible to estimate just relying on aggregated data. On the other hand households' surveys are the richest source of data concerning final consumption by households, their living condition and socio-demographic status, but they do not include price data.

The combination of time series and cross section data to estimate a household demand system has been already proposed in few other studies (Bardazzi and Barnabini, 2001; Nichele aqnd Robin, 1995), which nevertheless used data for a single country. This study goes in the same direction and proposes a method that allows the combination of time series cross section econometric estimates to set up a household demand system for EU15 countries with all the desirable characteristics such as price and income elasticities as well as socio demographic influence. The following subsections 3.1, 3.2 illustrate the data and econometric methods used for the estimation of the two separate models. Section 3.3 explains the way the two models are combined.

3.1 Time series model and estimated coefficients

The econometric estimation of the time series model uses data on consumption expenditure from National Accounts for EU-15 and data on the efficiency of the stocks of energy consuming durables of households, including private cars, electricity using appliances and heating appliances. A special feature of this model is the derivation of a service price (marginal cost of service), which is defined by the relation of the energy price to conversion efficiency for a certain fuel. We treat this conversion efficiency as embodied in the stock of capital goods and appliances. This approach would, in a further step, allow us to directly link conversion efficiency to the path of capital accumulation resulting in a comprehensive description of embodied technological change.

The data on conversion efficiency comprise efficiency indices of capital stocks for major energy-using appliances, differentiated by heating and electricity. For electrical appliances, i.e. only electricity using appliances, we use data for refrigerators, freezers, washing machines, dish washers, TVs and dryers. For heating, water heating and cooking we directly use the aggregate efficiency indices for households. The main data source on specific energy consumption of these capital stocks is the ODYSSEE database (http://www.odyssee-indicators.org) for the historical sample from 1990 to 2006. The ODYSSEE database is the result of a project on "energy efficiency indicators in Europe" comprising in total the EU 27 members plus Norway and Croatia. We use the variable 'specific consumption' from the ODYSSEE database, which is defined as a hypothetical energy consumption given by the technological characteristics of the appliance and some base year unit consumption. In order to calculate an aggregate efficiency index for all electrical household appliances we derive a weighted average efficiency index according to the share of each appliance in total electricity consumption. This share was taken from the variable unit consumption of electricity by appliances, also contained in the ODYSSEE database. A major problem in the construction of our data set was filling the gaps for certain countries concerning specific appliances. Here we used a country grouping methodology, so that missing data were filled by taking over the data of a representative country in the same group (e.g.: data from UK for Ireland or data from Spain for Greece).

In the area of energy for heating several primary energy carriers are affected – next to electricity this is mainly gas, oil, coal and district heating. In total, the efficiency index for household heating (the technical ODEX index) comprises elements of efficiency in the heating equipment as well as in the outer shell of the building, including data on specific energy consumption from single family houses and multi family flats. Therefore we directly used this aggregate index as the variable for efficiency in heating.

For efficiency in private transport we calculated the average consumption per vehicle-km of the private car fleet in EU 15 countries, basing ourselves on the results of the TREMOVE-project (documented at: http://www.tremove.org/documentation/index.htm). We directly used the data on vehicle-km driven together with the energy consumption of private cars to calculate the average fleet consumption, the inverse of which is our measure for efficiency.

In the logics of our model the direct influence of efficiency improvements can be seen from the deviation of service prices from energy prices.

As will be explained below this dataset has been complemented by data sets on household characteristics that have also been used in the cross-section model. One data set of household characteristics introduced in the cross section model represents dummy variables at the level of individual households. In the time series model these characteristics have been transformed into aggregate variables of shares of households with certain characteristics within total households. This has been done for a common subset of household characteristics data that is available both in the cross-section dataset (consumer surveys) and in the time series data set (from EUROSTAT). Due to limitations in the latter dataset the cross-section estimation comprises more household characteristics than the time series model. The other data set of household characteristics consists of continuous variables (number of cars per household, persons per household) that are available at the individual household level (consumer surveys) as well as at the country level for the period 1995 – 2004.

The following tables display the results of our panel-regression of the time series model with data for EU15 from 1995 to 2004. We estimate the demand system derived from the AIDS model as a panel with fixed country-effects and applying the SUR estimator.

The continuous variables comprised in the vector *D,* that enter the interaction term between household characteristics and expenditure are: (i) the stock of cars per household, and (ii) the household size (persons per household). The socio-demographic variables captured in the vector *Z* comprise: (i) the population structure of professional activities (employed, unemployed, other, unknown), and (ii) the age structure of population. In section 3.2 we describe these variables as found in the cross-section dataset.

TABLE 1

As has been mentioned above the socio-demographic variables in the vector *Z* are defined as shares of households with the corresponding characteristic within the total of all households. A shift in the composition of the household structure compared to some base year therefore changes the expenditure pattern of households. This is equivalent to the treating of these variables as dummies in the cross-section analysis (see below), where the expenditure pattern of a household with a certain characteristic *ceteris paribus* (i.e. for same expenditure level) differs from another household with different characteristics. In the time series model the parameters linked to *Z* therefore measure the difference brought about by the difference in the household structure compared to some 'base case'.

The results for these estimations are also shown in terms of own and cross price elasticities and income elasticities. We can use the uncompensated price elasticity as a direct measure of the rebound effect of energy efficiency improvements. According to our result this would give a rebound effect for gasoline/diesel (automotive fuels) between 56% and 71%, for heating fuels between 50% and 63% and for electricity between 24% and 47%. Comparing these results with other studies referred in the surveys of Greening, Greene (1997) and Greening, et.al. (2000) they can be characterized as lying at the upper bound of the range found in the literature. For heating (including water heating) rebound effects found in the literature are between 10% and 30% (Greening, et.al., 2000). They are slightly higher for cooling and lower for private car transport. Therefore, the rebound effect for private car transport identified here is significantly above the results found in the literature. The rebound effect of 24% for electricity reflects the average results in the literature. The compensated cross price elasticities between the energy commodities have a positive sign in all four models, indicating a substitutive relationship with the exception of the cross price elasticities between gasoline/diesel and electricity, which show a negative sign. Changes in efficiency lead to changes in the price system and therefore to demand reactions in all energy categories.

3.2 Cross section: model, data and estimated coefficients

For Engel curve is intended a function describing how a consumer allocates the overall available budget on some goods or services holding prices fixed. Engel curve can be also defined as Marshallian demand functions holding the prices of all goods fixed. A general form of an Engel curve is:

$$q_i = g_i(Y, z) \tag{16}$$

where q_i is the quantity consumed of good or service i, Y is total available wealth, usually proxied by total expenditures on goods and services, and z is a vector or matrix of other characteristics of the household, such as age and household size and composition. Engel curves are commonly expressed in the budget share form:

$$w_i = f_i(Y, z)$$

(17)

where w_i is the part of *Y* spent on good *i*. The goods are typically aggregate commodities such as total food, clothes, or transportation. In this study the analysed consumption categories of non durables are: food with alcohol and tobacco, clothes and footwear, operation of private transportation, fuels for heating, cooling and cooking, electricity and others.

As shown in (16) a comprehensive system of Engel curves expresses household's budget allocation for consumption purposes not only as a pure function of total available wealth but also as a function of other relevant household's characteristics influencing quantity and type of purchased goods and services. The additional variables cover a set of quantitative and qualitative socio-demographic characteristics introduced in the model respectively as dummy variables, so as an intercept shift, or as slope shift or interaction term with the income parameters. The functional form selected for this estimation is as shown in (18). Here we switched from the AIDS model used for the time series model to the specification of the quadratic AIDS model proposed by Banks, Blundell and Lewbel in 1996.

$$w_i = \alpha_i + \sum_k \delta_{ik} + (\beta_i + \beta^*_{ni} \varphi_{ni}) \log(Y) + (\lambda_i + \lambda^*_{ni} \varphi_{ni})[\log(C)]^2 + \varepsilon_i \qquad (18)$$

Where *w* stands for the consumption share of the *ith* consumption category, α is the constant for the *ith* consumption category, *δ* is a set of dummy variables that capture the effect of *k* specific demographic and social variables included in the analysis as intercept shift. The *β*'s are the coefficients for the linear term of the total expenditure *C* and the *λ*'s are the coefficients for the squared income term $log[C]^2$. *ε* is the error term. The terms $\beta^*\varphi$ and $\lambda^*\varphi$ capture the effects of a set of *n* household's characteristics introduced in this case as a slope shift for each of the analysed consumption categories. The household characteristics are introduced both in this study either as continuous or discrete variables. The qualitative are introduced as a set of *k* dummy variables, which are namely:

a) professional activity of the reference person' classified in three aggregated categories: 'employed' (d|_prof1), 'unemployed' (d_prof2), 'other' (d_prof3) and 'unknown' (d_prof4);

b) level of education of the reference person' classified in the following three categories: 'PhD or university degree' (d_edu1), 'secondary education' (d_edu2) and 'primary education or none' (d_edu3);

c) age of the reference person' classified in the following three groups: 'from 0 to 44 years old' (d_age1), 'from 45 to 59 years old' (d_age2) and 'over 60' (d_age3);

d) dummy variable for each of the country included in the database: Italy (d_it), Spain (d_es), Austria (d_at) and France (d_fr);

e) set of dummy variables for intervals of year of the construction of the building: older than 1946 (d_cons1), between 1947 and 1960 (d_cons2), between 1961 and 1980 (d_cons3), between 1981 and 1995 (d_cons4), beyond 1996 (d_cons5), non declared (d_cons6).

The other variables which are available in the continuous form are introduced in the model as a slope shift. These variables are 'household size' (l_hs and l_hs2) and 'number of owned cars' (l_car and l_car2) which is likely to influence the household's consumption of 'private transportation' and 'others' which includes the public transportation and the insurance services. As the model in (18) is for budget shares which sum up to one by construction, the additivity condition ensuring that the sum of the shares resulting from a change in one of the explanatory variable of the model is always one is automatically fulfilled without the need of additional regression constraints. The additivity conditions are as follows:

$$\begin{array}{ll} \sum_i \alpha_i = 1 & \sum_i \delta_{ik} = 0 \\ \sum_i \beta_i = 0 & \sum_i \beta^*_{ik} = 0 \\ \sum_i \lambda_i = 0 & \sum_i \lambda^*_{ik} = 0 \end{array} \qquad (19)$$

The dataset is constructed by using the household budget survey for the year 2004 of the following 3 countries: Spain (total number of observations 8881), Austria (total number of observations is 7349), Italy (total number of observations is 24853) and France (total number of observations is 10240).

The surveys required some adjustments to be used together consistently. For instance, the consumption expenditure are reported at a very detailed level of classification (COICOP for all the countries), which required a reclassification and grouping of the data to form the six consumption categories: 'Food, alcohol & tobacco', 'Clothes & footwear', 'Housing-solid & liquid fuels', 'Housing-electricity', 'Private transportation' and 'Others'. Some of the socio-demographic variables included in the estimation were not reported in the four surveys using the same classification. The variable "age of the reference person" for instance is reported in years in three of the four surveys therefore for consistency classes have been constructed and the variable is therefore used as a dummy. The same is true for the variables "level of education of the reference person" and "type of the professional activity of the reference person"; also in this case classes have been constructed consistently. To deal with the zero entries, some observations have been truncated on the basis of the following criteria:

1. if the consumption share for both 'Housing-electricity' and 'Housing-solid & liquid fuels' is zero. The observations truncated are 493;

2. if the consumption share for 'Others' is zero. The number of truncated observations is 874;

3. if both the consumption share of 'Private transportation' and 'Others' is zero. Number of dropped observations is 0;

4. if the consumption share of 'Private transportation' is zero and the number of cars owned by the household is larger than 1. Number of dropped observations is 1530;

5. if the consumption share for food is zero. Number of truncated observations is 83.

TABLE 2

As shown in Table 2, the total number of observations is 48467 and the dataset offers large variance of the main variables of the analysis as shown by the standard deviation. The negative figure in Table 2 for the minimum value of the categories private transportation and fuels is so because few families receive subsidies for these two categories. The surveys' data on goods and services household expenditures have been aggregated to the five categories, subject of the study, from the very detailed level usually COICOP with five digits. The aggregation has been straightforward for all the categories as based on a common classification code. From the consumption categories construction the energy expenditure for the second dwelling has been excluded to avoid distortions. The model has been estimated using the SUR estimator (Zellner 1962).

TABLE 3

By looking at the previous results what we can quickly observe is that only 13 parameters out of 110 have a statistical significance below 10%. As the estimated system Engel curves includes the squared income term, it can classify the commodity groups as necessities (i.e. negative slope, so a smaller consumption share with an increasing income) or luxuries (i.e. positive slope, so a larger consumption share with an increasing total expenditure) at different levels of total expenditures. All the total expenditures parameters are statistically significant. The categories 'Food, alcohol and tobacco', 'Private transportation' and 'Fuels for housing' are luxuries at low level of total expenditures and become necessities at higher levels of total expenditures (i.e. inverted U-shape). While the remaining categories 'Others' and 'Electricity' are necessities at low level of total expenditures and become luxuries at higher levels of expenditures (i.e. U shape). The household size variable, which has been introduced in the model as interaction term with the natural logarithm of total expenditure, has a different influence over the consumption categories. Household size 'slopes up' the consumption of 'Food, alcohol and tobacco', the consumption of 'Private transportation' and of 'Electricity', while it 'slopes down' the consumption of 'Fuels for housing' and of 'Others'. The next independent variable in the list is the number of cars owned. This variable is expected to explain a substantial part of the variation of the consumption share for 'Private transportation', with a positive influence on the slope of this curve. The estimated parameters not surprisingly confirm this expectation, indeed an increasing number of cars owned positively influence the slope of this curve. The variable number of cars owned also should have an influence on the slope of the curve for 'Others' that includes both the consumption of public transportation and of insurance services related to the ownership of a car. The estimated results for this variable indicate a negative influence on the slope of this curve and implicitly a substitution between public and private transportation. The effect of this variable on all the remaining categories despite statistically relevant, can not be explained clearly. All the remaining explanatory variables are introduced in the model as intercept shift (i.e. dummy variables).

3.3 Combining cross section and time series estimation via calibration

In principle the link between the time series model described in section 3.1 and the cross section model presented in section 3.2 could be done by combining both model approaches in one comprehensive estimation procedure or by simply calibrating an unique model using the estimation results of both models. Recently Kratena, Meyer and Wueger (2009) have proposed a methodology of combining estimation results for calibrating some parameters that are then a priori fixed in a final estimation process. This methodology has been applied for Austria, where one aggregate time series has been combined with one cross section-consumer survey. This methodology also heavily relies on calibration, but determines the cross price parameters still by econometric estimation.

In our case the data bases used for the EU model are not a one-to-one correspondence of pure time series and cross section data for a certain sample of countries. Instead we have produced pooled time series regression results for the EU 15 and cross section results for 4 countries. As a final step of our research we want to derive a model of private consumption for the EU 15 that can be linked to input-output models. One option therefore is to link the time series and the cross section model by choosing best fitting elasticity values and parameters for socio-demographic variables from both approaches and calibrating a full consumption model for a new data set (a single country or the EU 15, etc.). Income is the main link variable of both models and we can use the advantage of the cross section over the time series information concerning number of observations and higher variance across different household types.

As results from the estimations we use the elasticities representing a relative measure of the properties of each demand system (cross section and time series). The elasticities of both models are used together with the budget shares to derive parameter restrictions. The full model set up in terms of budget share equations can be written as:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_{ij} + \beta_i \log\left(\frac{C}{P}\right) + \beta_i^{hs} \log\left(\frac{C}{P}\right)\log(hs) + \beta_i^{car} \log\left(\frac{C}{P}\right)\log(car) + \sum_k \zeta_{ik}^{prof} D_k^{prof} + \sum_k \zeta_{ik}^{age} D_k^{age} + \sum_k \zeta_{ik}^{edu} D_k^{edu} \quad (20)$$

The variables D_k^{prof} , D_k^{age} D_k^{edu} and represent the shares of the household groups with the corresponding characteristics (professional activity, age and educational level of the reference person) within the total of households. The household characteristic 'construction of the dwelling' has been excluded, as aggregate data at the country level usually are not available for this variable.

In general the calibration procedure uses the elasticity formulas and combines them with the data set of the country in the base year chosen for the calibration in order to derive the parameter values. For the price parameters (γ_{ij}) we directly apply the own and cross price elasticities of the time series model and combine them with the budget share data. That yields the following expressions for the γ_{ii} and the γ_{ij}::

$$\gamma_{ij} = \varepsilon_{ij} w_i - w_i w_j + \delta_{ij} w_i \quad (21)$$

$$\gamma_{ii} = \varepsilon_{ii} w_i - w_i^2 + \delta_{ij} w_i \quad (22)$$

Again δ_{ij} is the Kronecker delta with $\delta_{ij} = 0$ for $i \neq j$ and $\delta_{ij} = 1$ for $i=j$.

For the expenditure parameters the procedure becomes more complicated, as the interaction terms also influence the expenditure elasticities. Starting point of deriving all the β_i parameters is the calculation of elasticities in the cross section model, consisting of the three different terms that can be rearranged to yield:

$$(\varepsilon_i - 1)w_i = \beta_i + 2\lambda_i \log C + \beta_i^{hs} \log(hs) + 2\lambda_i^{hs} \log(hs)\log C + \beta_i^{car} \log(car) + 2\lambda_i^{car} \log(car)\log C \quad (23)$$

Note that this representation contains the explicit representation of all quadratic expenditure terms from the cross section estimation results, which are added to the linear part captured in β_i. We concentrate the six terms on the right hand side of (23) to three terms, each one for the impact of C, *hs* and *car* and assume that the weights of these three terms in determining the expression on the left hand side are also given from the cross section estimation. That allows us calculating the single β_i parameters for a given income elasticity (from the cross section estimation) and the data for budget shares as well as *log(hs)* and *log(car)* of the country in the base year chosen for the calibration.

Finally the parameters ζ_{ik} for the socio-demographic variables are calculated taking as a starting point also the cross section estimation results. The parameter values from these results are taken together with the constant term to arrive at the total impact of the dummy variables. The specific parameters for the influence of each household group can then be calculated as the difference between the mean of this total impact and each single total impact value. This methodology guarantees that the sum of the so calculated impact parameters is zero and is multiplied with a variable D that expresses shares of households in the population. Therefore these terms always have a zero total impact on consumption, but change the consumption patterns, when the household structure changes.

In a first exercise we have designed calibration files for 4 countries (Belgium, Denmark, Finland and Germany) for the benchmark year 2000 that can be immediately adjusted for other countries and years. Comparing the results for the parameters in these countries following from this calibration exercise we find small differences in γ_{ij} as well as in β_i, which are due to different budget shares in the benchmark year (2000). On the other hand all parameters linked to the socio-demographic variables ζ_{ik} are identical, as these are directly derived from the cross section estimation results and budget shares play no role. For the parameters β_i^{hs} and β_i^{car} of the interaction terms of *hs* and *car* with total expenditure the results are mixed. One important and striking result is that the impact of cars per household has positive as well as negative impacts on gasoline/diesel demand, although the budget shares closely spread around the value of 6%. Small changes in the budget share obviously can lead to a change in the sign of this impact parameter (β_i^{car}). This result of the calibration procedure must be seen critical and might call for a final adjustment procedure in the calibration methodology in order to correctly represent the time series and cross section-model estimation results.

4. Aggregate consumption function

The households' demand system described in sections 2 and 3 represents the households' behaviour decision on the allocation among certain goods and services of a given overall expenditure. However, the integration in the modelling framework of an aggregate consumption function permits the aggregated level of expenditure to be determined as an endogenous variable. An aggregate consumption function explains the level of households' consumption in terms of disposable income and for the modelling framework presented in this paper it has been estimated in the form of an Error Correction Model (ECM). The ECM is an econometric procedure applied to explain the relationship between two cointegrated time series variables, such as disposable income and consumption in this particular case, which converge to equilibrium in the long run but exhibit an independent random walk in the short term. In these cases the ECM explains both the short term reaction and the long term path toward equilibrium. Equation (24) shows the specification for the ECM model, where $\Delta log(c_t)$ is the difference between logarithm of total expenditure at time *t* and *t-1*, α_0 a constant, β the parameter for the short term reaction of overall consumption as a function of disposable income, γ is the correction parameter and measures the speed at which prior deviations from equilibrium are corrected, υ the error term.

$$\Delta \log(c_t) = \alpha_0 + \sum_{i=0}^{n} \beta(i) \Delta \log(x_{t-i}) + \gamma(\log(c_{t-1}) - \beta_0 - \beta_1 \log(x_{t-1})) + \upsilon_t \qquad (24)$$

The ECM consumption model specification is a convenient form of representing aggregate consumption in terms of disposable income as it includes both short term reactions and long term adjustments of consumption as a function of disposable income. The ECM has been estimated using time series from 1990 to 2008 for Gross disposable income and Households' consumption obtained from Danish sectoral national accounts as this paper implements the Econometric IO modelling framework with the Danish Supply and Use tables and Household demand system.

Prior to the estimation of an ECM is the estimation of a pure Keynesian long-term consumption function of the form of:

$$\log(c_t) = \alpha_0 + \beta \log(x_t) + \varepsilon_t \qquad (25)$$

to test for the existence of a cointegrated relationship between the two variables disposable income and consumption. In general, a high R^2 value and a low Durbin-Watson statistic (DW statistic) indicate the presence of a cointegrated relationship as the high R^2 reflects the presence of a common long term trend in the data while the low DW statistic indicates non stationary residuals. In the present case R^2 and DW for the model in (25) is respectively 0.99314 and 0.87907. An Augmented Dickey-Fuller test on the residuals ε confirms the presence of a cointegrated relationship though in a weak form, which might depend on the relatively short time series available for these variables.

TABLE 4

The estimated parameters exhibit a good overall significance except for the intercept. The ECM is in the form of log-log therefore the estimated parameters can have a quick interpretation as elasticities. The β is larger than 1 which means that in the short term consumption reacts more than proportionally to an increase of disposable income. The γ

has the expected negative sign and indicate the yearly rate at which a deviation of consumption from disposable income approaches the long term equilibrium. In particular its value of -0.48148 means that an initial deviation is almost halved in one year and in total it takes a bit more than two years to return to equilibrium. The *t* test of significance for the γ parameter is a further test confirming the presence of a cointegrated relationship between disposable income and consumption.

5. Scenario analysis

The model presented in this paper is applied for the analysis of a set of two scenarios concerning some of the variables of the household demand system, namely:

- Efficiency rate of utilization of electricity for housing purposes;
- Share of households with non employed person of reference;

The increase of efficiency use of electricity for housing purposes is analysed to look and quantify the 'rebound effect' associated to an increase of the efficiency rate and a consequent decrease of the service price. All the simulations have a pure demonstrative scope, as the socio-demographic variables and of the efficiency rate are assumed to follow an arbitrary path of development.

Table 5 shows the assumed path of development underlying the scenarios.

TABLE 5

The scenarios are analysed individually using as indicator the electricity consumption. The scenarios are analysed from 2000, the base year, until 2015.

FIGURE 1

In both Figure 1 and 2, the plotted lines exhibit a growing trend depending on the aggregate consumption function, which has a long term equilibrium equal to 0.95, the β_1 coefficient shown in Table 4; the long term equilibrium between overall consumption and income means that consumption grows until achieving a level equal to 95% of available income. For this reason also at the baseline, final consumption of Electricity in this particular case exhibits a growing trend.

Figure 1 shows the results for the first of the analysed scenarios, called 'Efficiency'. The scenario 'Efficiency' is analysed by looking at the consumption of the category 'Electricity'. The graph shows three lines one for the consumption of electricity for the baseline, one considering only the increase of the efficiency rate and a last line corresponding to electricity consumption taking into account the rebound effect. The rebound effect is an increase of the demand for electricity as a consequence of a decrease of the service price (section 2 for details). An increase of the efficiency rate of utilization of electricity in household devices, indeed, has a positive effect as it implies a decrease of the consumption of electricity, however the decrease of the price of the service, calculated as the ratio between the price and the efficiency rate (section 2 for details), undermines this positive effect as a lower price for electricity induces a higher consumption. The distance between the two lines represents the calculated rebound effect.

FIGURE 2

The second scenario assumes an increase of 1% per year of the share of the households with a non employed reference person, and of course a decrease of the share of the households in the population with an employed reference person. This scenario is modelled by exogenously assuming a change of the structure of the households influencing the consumption patterns through the intercept shift coefficients estimated in section 3.2 and calibrated for Denmark. The results plotted in Figure 2 show lower electricity consumption as a consequence of an increase of the non employed reference person in the Danish households.

6. Conclusions

This paper has presented the results of an econometric study aiming at the estimation of a household demand system suitable to be integrated in an Econometric IO model. The household demand system includes price and income parameters as well as other socio demographic explanatory variables and is estimated by consistently combining aggregated time series data from National Account, with household survey cross section dataset. The combination of these two different types of data permits the estimation of a household demand system with price elasticities, as the aggregated time series data offer enough variety for price indexes, as well as with a rich set of socio-demographic explanatory variables derived from the household surveys. The paper also presents the results of the estimation of an aggregated consumption function as an error correction model relating overall available household income to total expenditure.

The estimated household demand system, along with an aggregated consumption function, are then integrated into an Econometric Input-Output (EIO) model based on

Eurostat Supply and Use table of Denmark, as recently proposed by Kratena and Streicher (2009).

The modelling framework integrating econometric models for consumption and supply-use table is used for the analysis of two scenarios. The first scenario analysis calculates the rebound effect associated to a decrease of the service price for electricity induced by an increase of the efficiency rate of electricity utilization for housing purposes. The results show that a lower service price for electricity induces a higher demand for this good, which undermine the positive effects of higher efficiency.

The second scenario is about the influence of a higher share of the household with an unemployed reference person and shows this induces a lower electricity consumption.

The Econometric IO model is proposed as an alternative both to simple IO models and CGE; it is constructed starting from a supply and use model and integrating econometrically estimated blocks such as a households demand system for a more realistic consumers' preferences representation and an aggregate consumption function for the relationship between income and total expenditure.

TABLES AND FIGURES

	Parameters	standard errors	
γ_{FOFO}	0.101	0.016	***
γ_{FOCL}	0.026	0.006	***
γ_{FOF}	0.008	0.004	**
γ_{FOH}	-0.004	0.003	
γ_{FOH_E}	-0.004	0.003	
γ_{CLCL}	0.009	0.004	**
γ_{CLF}	-0.005	0.002	**
γ_{CLH}	-0.001	0.002	
γ_{CLH_E}	-0.003	0.002	**
γ_{FF}	0.026	0.002	***
γ_{FH}	0.002	0.001	*
γ_{FH_E}	-0.002	0.001	*
γ_{HH}	0.006	0.002	***
γ_{HH_E}	0.002	0.001	***
$\gamma_{H\_EH\_E}$	0.010	0.001	***
	0.000	0.000	
β_{FO}	-0.017	0.005	***
β_{CL}	-0.013	0.007	**
β_{F}	-0.024	0.005	***
β_{H}	-0.006	0.005	
β_{H_E}	-0.005	0.003	*

TABLE1

Variable	n	Mean	S.D.	Min	.25	Mdn	.75	Max
				-------------- Quantiles	--------------------			
w_food	48467	0.35	0.18	0.00	0.21	0.32	0.46	0.97
w_others	48467	0.36	0.21	0.00	0.17	0.37	0.53	0.98
w_transp_priv	48467	0.11	0.11	-0.00	0.02	0.09	0.16	0.92
w_electricity	48467	0.03	0.03	0.00	0.02	0.03	0.04	0.54
w_hous_en	48467	0.06	0.07	-0.00	0.01	0.03	0.07	0.75
w_clot_ftw	48467	0.09	0.10	0.00	0.01	0.07	0.14	0.83
l_exp	48467	9.60	0.68	6.24	9.17	9.65	10.07	12.67
exp	48467	18383	12910	512	9574	15457	23578	3.2e+05
food_al_tob	48467	5353	3345	15	3003	4704	6944	45402
others	48467	7690	8893	28	1740	5124	10597	3.0e+05
clot_ftw	48467	1908	2889	0.00	90	999	2520	79557
transp_priv	48467	2095	2950	-1.20	307	1400	2760	96806
electricity	48467	482	417	0.00	228	378	606	5760
hous_en	48467	856	1107	-42.15	180	516	1172	37363
household size	48467	2.65	1.32	1.00	2.00	2.00	4.00	19.00
n. cars	48467	1.39	0.86	0.00	1.00	1.00	2.00	18.00

TABLE 2

	Food	Electricity	Heating	Private transportation	Others
β	-0.1243***	-0.1612***	0.0485***	0.0822***	0.1365***
	(0.0013)	(0.0047)	(0.0104)	(0.0134)	(0.0016)
λ	--	0.0072***	-0.0043***	-0.0032***	--
		(0.0003)	(0.0006)	(0.0007)	--
β^*_{size}	0.0060***	0.0018***	-0.0181***	0.0180***	-0.0060***
	(0.0002)	(0.0004)	(0.0009)	(0.0012)	(0.0002)
λ^*_{size}	--	-0.0001***	0.0018***	-0.0019***	--
	--	(0.0000)	(0.0001)	(0.0001)	--
β^*_{car}	-0.0034***	0.0036***	-0.0012	0.0195***	-0.0018***
	(0.0002)	(0.0006)	(0.0014)	(0.0018)	(0.0002)
λ^*_{car}	--	-0.0003***	0.0002	-0.0014***	--
	--	(0.0001)	(0.0001)	(0.0002)	--
$\delta\ prof_1$	0.0961***	-0.0007*	-0.0070***	0.0433***	-0.1479***
	(0.0024)	(0.0005)	(0.0011)	(0.0016)	(0.0030)
$\delta\ prof_2$	0.0932***	0.0034***	-0.0107***	0.0295***	-0.1134***
	(0.0046)	(0.0009)	(0.0021)	(0.0031)	(0.0058)
$\delta\ prof_3$	0.1107***	-0.0021***	-0.0081***	0.0289***	-0.1401***
	(0.0026)	(0.0005)	(0.0012)	(0.0018)	(0.0032)
$\delta\ age_1$	-0.0375***	-0.0036***	-0.0175***	0.0163***	0.0169***
	(0.0022)	(0.0004)	(0.0010)	(0.0015)	(0.0028)
$\delta\ age_2$	-0.0068***	-0.0008***	-0.0127***	0.0143***	-0.0071***
	(0.0021)	(0.0004)	(0.0009)	(0.0014)	(0.0026)
$\delta\ cons_1$	0.0581***	0.0027***	0.0274***	0.0257***	-0.1108***
	(0.0037)	(0.0007)	(0.0017)	(0.0025)	(0.0047)
$\delta\ cons_2$	0.0679***	-0.0008	0.0208***	0.0269***	-0.1202***
	(0.0038)	(0.0007)	(0.0017)	(0.0026)	(0.0047)

$\delta\ cons_3$	0.0533***	0.0010	0.0163***	0.0340***	-0.1113***
	(0.0036)	(0.0007)	(0.0016)	(0.0024)	(0.0044)
$\delta\ cons_4$	0.0510***	0.0034***	0.0135***	0.0366***	-0.1123***
	(0.0037)	(0.0007)	(0.0017)	(0.0025)	(0.0047)
$\delta\ cons_5$	0.0287***	0.0028***	0.0144***	0.0200***	-0.0645***
	(0.0040)	(0.0008)	(0.0018)	(0.0027)	(0.0050)
$\delta\ edu_1$	0.0463***	-0.0003	0.0036***	0.0101***	-0.0577***
	(0.0024)	(0.0005)	(0.0011)	(0.0016)	(0.0030)
$\delta\ edu_2$	0.0147***	-0.0003	-0.0016	0.0030**	-0.0187***
	(0.0024)	(0.0005)	(0.0011)	(0.0017)	(0.0031)
α	1.3424***	0.9071***	-0.0093	-0.4784***	-0.6257***
	(0.0129)	(0.0214)	(0.0475)	(0.0614)	(0.0161)
R^2	0.3379	0.2402	0.0999	0.1088	0.2615

TABLE 3

	Estimated ECM parameters
α	0.157817
	(0.261246)
β	1.012341^{***}
	(0.326077)
γ	-0.48148^{**}
	(0.230782)
β_1	0.955278^{***}
	(0.040251)

TABLE 4

Scenarios	Assumed path development	Analysed variable
'Efficiency'	1% of yearly increase of the efficiency rate	Electricity consumption
'Non-employed'	1% yearly increase of the share of households with the reference person non employed	

TABLE 5

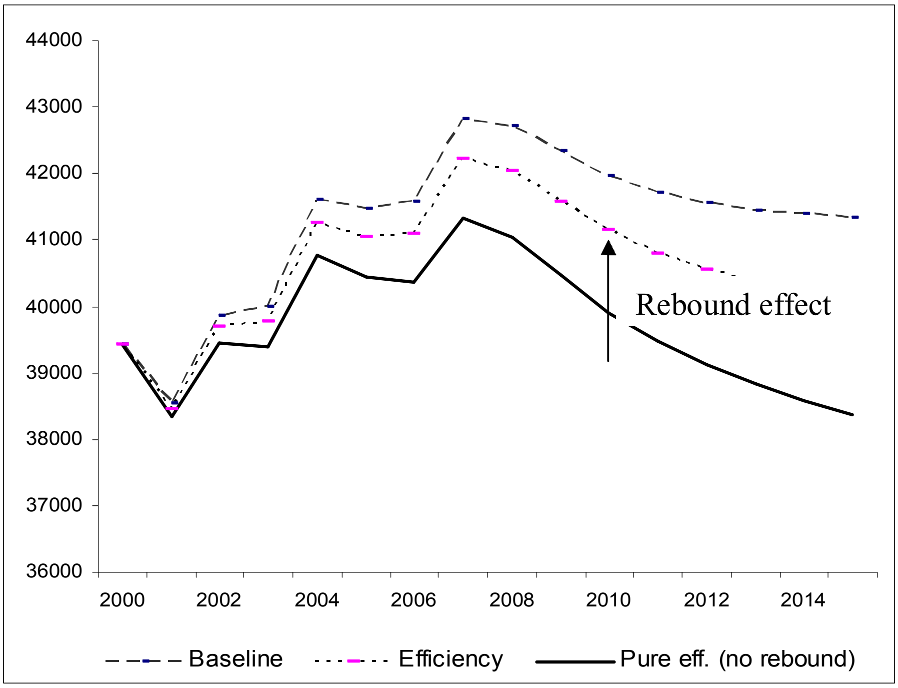

FIGURE 1

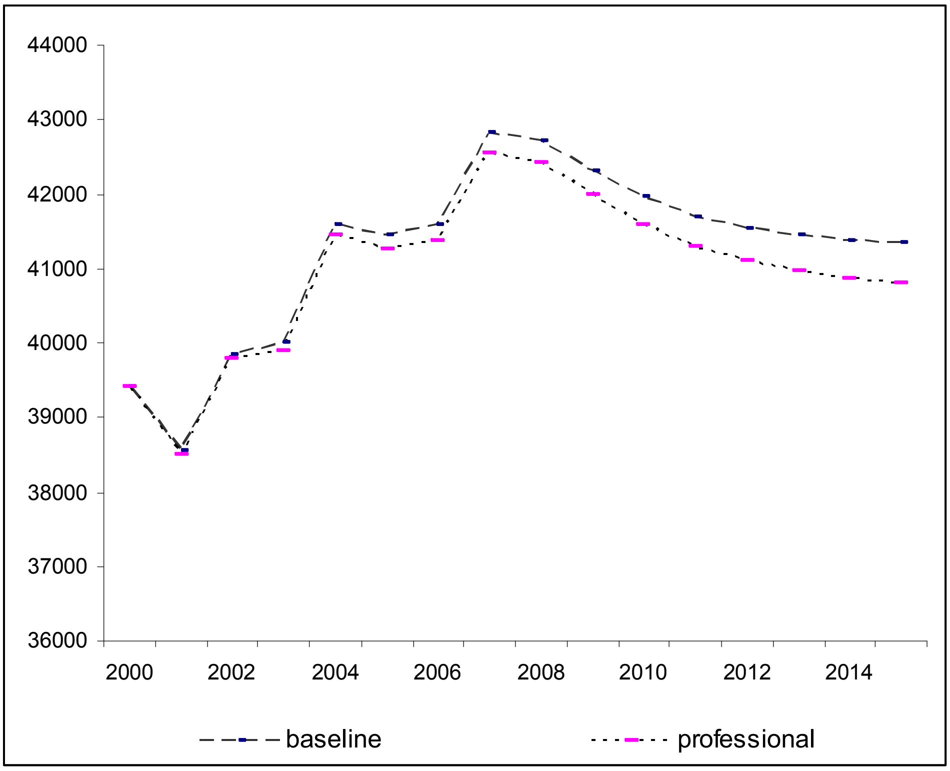

FIGURE 2

CAPTIONS

Table 1: Parameter estimates for EU 15 (price and income): AIDS model with interaction variables (car stock, household size) and household characteristics (age structure and professional activity).

*, ** and *** indicate a significance level of 10%, 5% and 1% respectively. FO=food, CL= clothing, F=gasoline/diesel, H=heating (solid fuels, oil, gas, district heating), H_E=electricity.

Table 2: Descriptive statistics for the cross section dataset;

Table 3: cross section results. *** Significance with p-value<0.01, ** Significance with p-value<0.05, *Significance with p-value<0.1, Standard error in parentheses.

Table 4. Coefficients estimated for the Error Correction model of aggregated consumption. *** Significance with p-value<0.01, ** Significance with p-value<0.05, *Significance with p-value<0.1, Standard error in parentheses.

Table 5: analysed scenarios.

Figure 1: electricity consumption resulting from the scenario 'Efficiency'.

Figure 2: electricity consumption resulting from the scenario 'Unemployment'.

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