2009 International Energy Workshop
Venice, June 17th – 19th

The impact of technological and socio-demographic change on the energy demand of households

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Abstract:

This paper deals with integrating technology as well as lifestyles as driving forces of energy demand into a model of total private consumption. Private consumption is determined by economic variables like income and prices as well as these other factors. Technology is represented by variables measuring the efficiency of households' capital stocks and lifestyles by socio-demographic variables. Data for both types of variables are available in cross section consumer surveys and in time series data of aggregate consumption. The cross section surveys provide information on income and socio-demographic factors relevant for energy demand (characteristics of building and population density). The time series data contain information on prices and income as well as the energy efficiency embodied in household appliances. The final model of consumption consists of a consistent combination of both time series and cross section information into one comprehensive econometric model. This model describes demand for energy and non-energy commodities in an almost ideal demand system (AIDS) and is used in *ex post* simulation exercises to isolate the impact of technological and socio-demographic variables on the demand for gasoline/diesel, heating and electricity.

Key words: household energy demand, rebound effects, efficiency of appliances, lifestyles

JEL Code: D11, D13, Q53

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1. Introduction

Energy-consumption of households including fuel use for passenger transport, households' electricity and heat consumption are growing rapidly despite of technological progress. It is well known that households energy demand is determined by a complex interplay of economic (income, prices), technological (energy efficiency) and socio-demographic variables (households' lifestyles). As technological change leads to higher efficiency of energy using appliances and therefore has a *ceteris paribus* dampening effect on energy demand, other factors must have compensated this impact. One counterbalancing factor is the well known 'rebound effect' of efficiency improvements (Khazzoom, 1980 and 1989, Berkout, et.al., 2000) based on the mechanism that efficiency improvements lower the price of the 'service' of energy. High income growth and low or falling energy prices and their impact on demand can also compensate for efficiency improvements. A third factor is socio-demographic change that brings about changes in lifestyles that are relevant for households' energy demand.

A large body of literature on households energy demand exists (see: Madlener, 1996). Most of the literature is characterized by its partial analytical nature, the use of single equation estimation and the application of cross section or panel data sets. (e.g. Larsen and Nesbakken, 2004; Holtedahl and Joutz, 2004; Hondroyiannis, 2004). Some recent studies cover the whole residential energy demand (Labandeira et al., 2006) and only a few the whole energy relevant consumers' demand (e.g. Brännlund et al., 2007). Technological information is integrated into some studies within the concept of a synthesis between economic and engineering models (Larsen and Nesbakken, 2004) or as a combination of bottom-up and top-down modelling (Rivers and Jaccard, 2005). The importance of the stock of appliances is taken into account in some studies for single energy categories as heating (Nesbakken, 2001) and some studies also set up models of total consumption by applying system estimation techniques (e.g.: Baker, et.al., 1989), which allows capturing a large variety of cross price effects between different energy commodities as well as energy and non-energy commodities. Therefore a full account of technological progress and socio-demographic households' characteristics in a model covering different energy and non-energy commodities is – to our knowledge – still missing.

Another problem of studies using microeconomic data for estimation (mostly panel data sets) is that in most cases the variance in prices is very small compared to the variance in household income and household characteristics. This is due to the fact that the time series dimension is usually much smaller spanning only a few years than the households' dimension usually spanning thousands of households and can be overcome by interpolation techniques and the use of other information to enlarge the time series dimension of the data set, as is done in Labandeira, et.al., 2006.

We start from considering the time series information based on consumers' expenditure from National Accounts in Austria as an adequate source for price information. Being aware of conceptual problems of different Household Budget Surveys concerning the consistency with National Accounts we do not opt for the methodology of constructing a panel data set like Labandeira, et.al. (2006). Instead we use a different methodology of combining cross section and time series data sources, which should be equivalent to the construction of a panel data set by interpolation techniques or by a combination of data sources. In the literature we find only very few studies that combine cross section and time series models by an econometric methodology like Nichèle and Robin (199, and Bardazzi and Barnabani (2001). Both approaches use estimation results from either household survey data or time series data and insert them in the other model respectively. We follow this line of research and use as a criterion for inserting results from one model into the other the comparative advantage in information. For incorporating technological factors we use data on the efficiencies of the stock of appliances classified by types of energy-using appliances. The socio-demographic factors are taken into account from a rich dataset of a Household Budget Survey covering about 3,500 households. The influence of income and socio-demograhic variables on consumption is described well in the cross section data set, due to the large variance across types of households in different regions.

The paper is structured as follows: We present the methodological approach of modelling households' demand for energy and non-energy commodities in the cross section, the time series and the linked model in Section 2. The time series data and cross section data used to model energy demand patterns are laid down in Section 3. Section 4 summarises the model results in terms of elasticites and shows the results of two model simulations concerning the impact of technological and socio-demographic factors on households' energy demand. Conclusions will be presented in Section 6.

2. The model of consumers' demand

The structure of the model distinguishes between aggregate household consumption, expenditure of households for capital goods, and expenditure for heating/electrity and transport energy as well as for other goods and services. Energy commodities are used by consumers for the 'production' of services (heating, lighting, communication, transport etc.). 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 service level:

$$E = \frac{S}{\eta_{ES}} \tag{1}$$

In (1) 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, a service price p_S (marginal cost of service) can be derived, which is a function of the energy price and the efficiency parameter:

$$p_S = \frac{p_E}{\eta_{ES}} \tag{2}$$

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)) $C(u, p_i)$:

$$\log C(u, p_i) = (1-u)\log(a(p_i)) + u\log(b(p_i)) \tag{3}$$

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:

$$U = \left[\frac{\log C(u, p) - \log a(p_i)}{\beta_0 \prod_k p_k^{\beta_k}} \right] \tag{4}$$

Applying Shephard's Lemma to the cost function (3), inserting the indirect utility function (4) and allowing for additional technological and socio-demographic factors captured in the vector of variables *Z*, gives the well known budget share equations for the *i* non-durable goods:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\left(\frac{C}{P}\right) + \xi_i Z \qquad (5)$$

For the time series (T) version of (5) due to the low variance in factors captured in the vector of *Z* the parameter ξ_i cannot be identified and therefore the model reduces to:

$$w_i^T = \alpha_i^T + \sum_j \gamma_{ij}^T \log p_j^T + \beta_i^T \log\left(\frac{C^T}{P^T}\right) \qquad (6)$$

For the cross section version (C) the model in (5) can be written as:

$$w_i^C = \alpha_i^C + \beta_i^C \log\frac{C^C}{P^C} + \sum_{u=1}^{r} \xi_u dum_u + \sum_{s=1}^{l} \xi_s dum_s + \sum_{k=1}^{m} \xi_k dum_k \qquad (7)$$

In (7) the Stone price index P^C is equal to 1 and the dummy variables capture the socio-demographic variables *u* (construction year of building), *s* (area of dwelling) and *k* (population density).

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

$$\varepsilon_i = \frac{\beta_i}{w_i} + 1 \qquad (8)$$

$$\varepsilon_{ij}^U = \frac{\gamma_{ij} - \beta_i w_j}{w_i} - \delta_{ij} \qquad (9)$$

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:

$$\varepsilon_{ij}^{K} = \frac{\gamma_{ij} - \beta_{i} w_{j}}{w_{i}} - \delta_{ij} + \varepsilon_{i} w_{j} \qquad (10)$$

In (9) and (10) δ_{ij} is the Kronecker delta with $\delta_{ij} = 0$ for $i \neq j$ and $\delta_{ij} = 1$ for $i=j$.

Our methodolgy of linking the models in (6) and (7) consists of estimating both approaches and combining results of each model for the income term, which is a determining factor in both models. Income is the link variable of both models and we use the advantage of the cross section over the time series information concerning number of observations (3,500 households) 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 already mentioned quality of the cross section information concerning income leads us to take in a first step the income elasticity of the cross section model as given. We use this elasticity ε_{i}^{C} to derive income parameters β_{i}^{T*} of the linked model, which are consistent with the budget shares w_{i}^{T} of the time series model:

$$\beta_{i}^{T*} = \left(\varepsilon_{i}^{C} - 1\right) w_{i}^{T} \qquad (11)$$

Additionally we use this information to correct the income effect within the uncompensated own price elasticity. As stated above the uncompensated own price elasticity can be split up in a term measuring the substitution effect (= the compensated price elasticity) and a term measuring the income effect (= the income elasticity times the budget share). As price information is the comparative advantage of the time series model we take the substitution effect (= the compensated price elasticity) measuring the pure price induced effect on demand as given. This leads us to derive new values for the price parameter γ_{ii} using the value for β_i from equation (11):

$$\gamma_{ii}^{T*} = \left(\varepsilon_{ii}^{T} + 1 + \beta_{i}^{T*}\right) w_{i}^{T} \tag{12}$$

This procedure ensures that the original own price elasticity of the time series model ε_{ii}^{T} becomes consistent with the income information of the cross section level within the AIDS model approach. The new parameter γ_{ii}^{T*} following from this adjustment differs from the original γ_{ii} from the time series model by a budget share weighted difference in the income parameters of both models:

$$\gamma_{ii}^{T*} = \gamma_{ii}^{T} + \left(\beta_{i}^{T*} - \beta_{i}^{T}\right) w_{i}^{T} \tag{13}$$

The final step consists of setting up the linked model with the parameters derived in (11) and (12) and using estimation results of the cross section model for the socio-demographic variables. The estimation results for the parameters ξ_i (with $i = u, s, k$) measure the total impact of a certain household characteristic and therefore had to be transformed into a relative measure by taking the difference σ_i (with $i = u, s, k$) from the average impact $\bar{\xi}_i$. That allows using relative variables for the socio-demographic variables in terms of the shares of each household type wd_i (with $i = u, s, k$) concerning each socio-demographic variable:

$$w_i = \alpha_i + \sum_{i=1}^{n} \gamma_{ii}^{T*} \log p_i + \sum_{j \neq i} \gamma_{ij}^{T} \log p_j + \beta_i^{T*} \log \frac{C_h}{P} + \sum_{u=1}^{r} \sigma_u wd_u + \sum_{s=1}^{l} \sigma_s wd_s + \sum_{k=1}^{m} \sigma_k wd_k \quad (14)$$

The demand for energy-commodity E_i is determined by the level of service demand S_i and energy efficiency for the appliance using the relevant energy carrier (η_i) as well as energy efficiency for the other appliances (η_j). Additionally demand for energy-commodity E_i is determined by the distribution of households across the demographic variables: construction year of the building, useful area of dwelling, and population density. The first variable can also be seen as measuring efficiency of the entire heating system and the other variables as a measure for service demand.

3. Data sources

The commodity classification *i* in this model includes:

(i) services for private transport (via input of gasoline/diesel): *F*

(ii) services for heating (via input of solid fuels, oil, gas, district heating): *H*

(iii) services for electricity using appliances (via input of electricity): *H_E*

(iv)food and beverages, tobacco: *FO*

(v) clothing and footwear: *CL*

(vi) other (non-energy) commodities: *OTH*

The econometric model is applied to private consumption data of Austria (1990 – 2006) taking into account the estimation results of the cross section model. Time series data on private consumption in current prices and the corresponding price indices are directly taken from private household sector data in National Accounts of Austria (in COICOP classification).These data are then extended with information on conversion efficiency of household appliances comprising indices of efficiency of capital stocks for major energy-using appliances, in the sector of heating, electricity and passenger car transport. For electrical appliances and heating (including water heating) equipment the major data source was the ODYSSEE database (http://www.odyssee-indicators.org) for the historical sample from 1990 to 2006. The exact procedure of arriving at efficiency indicators by fuels is described in Kratena, Meyer and Wueger (2008). The data stock for the technological characteristics of the registered car fleet in Austria from 1990 to 2007 is based on the registered car fleet published by Statistics Austria (2007) and on energy relevant technological parameters for cars as described in Meyer and Wessely (2008). The relevant information for the model lined out in section 2 consists of the gap between the energy and the service price brought about by efficiency gains. Table 1 contains these results for the three energy using household consumption categories. It is obvious (as already lined out in Kratena, Meyer and Wueger, 2008) that considerable technological progress has been achieved concerning energy efficiency of households. Table 2 shows the descriptive statistics of the variables in the time series model.

>>>>>>*Table 1: Energy and service prices for gasoline, heating and electricity, 1990 – 2006*

>>>>>>*Table 2: Descriptive statistics of variables, 1990 - 2006*

In order to link the time series with the cross section dimension it was also necessary to collect data on those socio-demographic variables that constitute the relevant household characteristics in the cross section. For the variables *u* (year of construction of the building) and *s* (useful area of dwelling) the data could be directly taken from statistics of Austrian households (Mikrozensus).

Table 3 and 4 reveal that considerable shifts have occured in the household structure between 1990 and 2006 concerning the living conditions of households. In the case of the construction year of the building the sum of the shares of buildings before 1980 has decreased by almost 18 percentage points between 1990 and 2006. In the case of the useful area of dwellings the share of households with dwellings larger than 110 m2 has increased by 10 percentage points between 1990 and 2006.

>>>>>>>>> *Table 3: Shares of households (in %) by construction year of building*

>>>>>>>> *Table 4: Shares of households (in %) by useful area of dwelling*

For the variables *k* (population density) we had data in the population census 1991 and 2001 and a subsample of households from household statistics (Mikrozensus). Both sources have been used to interpolate the population census data between 1990 and 2006. The results in terms of shares of households are shown in table 5. High population density includes households living in areas of more than 50,000 inhabitants and with a density of more than 500 inhabitants per km^2, middle density is defined by the same characteristic of total inhabitants (50,000) plus more than 100 and less than 500 inhabitants per km^2 . All other household are grouped together in the third category. Table 5 reveals that the shifts between household groups were much smaller for this variable than for the other two.

>>>>>> *Table 5: Shares of households (in %) by population density of region*

Finally these data sets had to be complemented by the consumers' expenditure data of Household Budget Survey 2004/2005 from Statistics Austria covering information about expenditure and living standard of private households. The Household Budget Survey 2004/2005 was implemented as a random sample survey from 09/2004 to 09/2005 with a net sample-size of 8,400 households and a response rate of 42%. For the socio-demographic variables we were interested in we could finally use a sample of 3,500 households. The expenditure classification of the Household Budget Survey is a more disaggregated level of COICOP than for the data in National Accounts. Due to methodological and conceptual changes in Household Budget Surveys from 2004/2005 on we could not use information of former surveys in a consistent manner. This is the main reason why we were forced to combine the estimation of one cross-section model with the time series model.

4. Empirical results

In a first step we estimated the budget share equations (7) of the cross section model. Table 6 shows the corresponding parameter estimates. These results enable us to calculate in a first step the income elasticities described in Table 7. Using the mean value of the budget shares of the time series data (1990 to 2006) we derived the parameter β_i^{T*} using equation (11).

>>>>>>>>> Table 6: Parameter estimates from cross-section estimation

The uncompensated price elasticity of the time series model was derived by estimating the system of budget shares (6) , where according to the homogeneity restriction in AIDS one equation can be dropped and the estimation results are robust with respect to the choice of equation that is dropped (in our case it was the aggregate of other non-energy commodities). Estimating the time series model we applied the SUR (Seemingly Unrelated Regression) estimator and imposed the symmetry restrictions. Another general restriction in demand systems (concavity of cost function) and the introduction of linear time trends (describing preferences and tastes) has been treated as in Kratena, Meyer, Wueger (2008). The new parameter γ_{ii}^{T*} then directly follows from equation (13).

>>>>>>> *Table 7: Inputs from time series and cross section estimation for the linked model*

The relative measures σ_i for the impact of the socio-demographic variables described in section 2 can also be directly taken from the results of the cross section estimation and are listed in Table 8.

>>>>>> *Table 8: Relative impact of socio-demographic variables on budget shares*

The second step consisted in setting up the time series estimation of the linked model (equation (14)) using the inputs listed in Table 7 and 8. The estimated parameter values together with the data for the budget shares are, in a next step, used to calculate uncompensated as well as compensated price elasticities and income elasticities.Table 9 shows the values for the calculated elasticities with the sample mean of the budget shares. The estimation procedure of the linked model reproduces the income elasticity of the cross section and the own price elasticities of the time series model consistent with the income elasticity of the cross section model. We can use the uncompensated price elasticity as a direct measure of the (price-induced) rebound effect of energy efficiency improvements. According to our result this would give a rebound effect for gasoline (automotive fuels) of 48%, for heating fuels of 27% and for electricity of about 12%. 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 for Austria (48%) is significantly above the results found in the literature. As laid down in Kratena, Meyer, Wueger (2008), this can partly be explained with the increase of cross-border fuel shopping during the 1990es from consumers of the neighbouring countries. The cross price elasticities between the energy commodities have a positive sign indicating a substitutive relationship with the exception of the cross price elasticities between heating 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.

>>> Table 9: Uncompensated and compensated price elasticities

In section 3 we found that in the sample analysed here (1990 – 2006) considerable improvements in the efficiency of household's capital stock as well as important changes in the lifestyles of households – measured by the distribution of households across socio-demographic characteristics - have occured.

At the same time the energy demand of households has increased, so that the querstion arises how and in which order of magnitude the different factors have slowed down or accelerated this development. Our model can be used to trace back energy demand changes to changes in efficiency (technology) and these lifestyle changes. For this purpose we carried out two simulation exercises assuming that (i) the distribution of households across the socio-demographic variables would have remained constant at the level of the starting year (1990) over the observation period and (ii) the technolgy (efficiency) of households' capital stocks would have been constant at the level of the starting year (1990) over the observation period. The first simulation yields results about the impact of lifestyle changes on households' energy demand and the second simulation measures the impact of technological change on energy demand.

Table 10 shows that for socio-demographic variables the largest impact between 1990 and 2006 has been on electricity demand, which would have been by 11% lower than the actual level in 2006 without changes in the living conditions of households. For heating this impact still amounts to more than 7%, where for gasoline/diesel living conditions captured by our socio-demographic factors seem to have a negligible effect (only less than 1%). The single socio-demographic factors may have different directions of impact on energy demand as in the case of heating: the increase in the average area of dwelling between 1990 and 2006 increased energy demand by almost 11%, wheras the age structure of buildings decreased energy demand by 4%. As mentioned before the age structure of the buildings might also be interpreted as an indicator of technology. The single socio-demographic factors show the same direction of impact on electricity demand but with different intensities, where – as expected - the average area of dwelling shows by far the largest impact. In general the changes in socio-demographic factors between 1990 and 2006 have increased energy demand.

On the other hand the simulation results sow that technological changes have reduced energy demand considerably, especially for gasoline/diesel and heating. With constant technology of 1990 demand for gasoline/diesel would have been by 18% higher and for heating by about

16%. The impact is considerably smaller for electricity (8.6 %). Due to the former mentioned cross price and income effects changes in the efficiency of one category have an impact on all energy demands. This can be seen especially in the case of electricity and heating, which are complementary goods. Therefore the efficiency effect of heating on electricity is in opposite direction and vice versa.

Table 10 also allows interpreting the relative impact of technological and socio-demographic factors on energy demand. For gasoline/diesel the technological change is much more important than the socio-demographic change. For heating the socio-demographic factors have about half of the impact of technological change and – as mentioned above – the socio-demographic variable 'construction year' also contains technological effects. Therefore the total impact of the efficiency of the heating system could be approximated by the technology effect of household equipment (17.6%) plus the construction year-effect (4%). For electricity we find a more balanced relationship between the efficiency-effect and the effect of socio-demography.

>>>>>> *Table 10: Change in energy demand 2006 with constant socio-demography and constant technology of 1990*

5. Conclusions

In this paper a consistent link between time series and cross section estimation in one comprehensive econometric model for households' energy demand has been presented. The methodological innovation of our approach consists of using the comparative advantage of both data sets in terms of variance in prices and income from estimation results. This is done by estimating both types of models (time series and cross section) and deriving useful parameter restrictions for the linked model. Therefore we use the information of both data sets in a similar way as in the construction of a panel data set.

This approach enables us to include not only income and prices as variables of household demand, but also technological and socio-demographic factors. Therefore we can calculate the impact of a large variety of factors of influence on energy demand of households with special emphasis on technological change and lifestyles. An additional important feature of our model is the description of total private consumption via a demand system, so that important repercussions and feedbacks between different energy and non-energy commodities can be taken into account.

An *ex post* simulation exercise for Austria (1990 – 2006) shows that technological and lifestyle change has a significant influence on energy demand of household. In general socio-demographic (lifestyle) change has increased energy demand in the past, especially for electricity, whereas technological change has dampened energy demand growth, especially for gasoline/diesel. In the case of gasoline/diesel and heating the impact of technological change on energy demand was large enough to compensate for the demand drivers within the lifestyles of households. As energy demand in these two categories (gasoline/diesel, heating) has also increased between 1990 and 2006, this must be assigned to the development of income and prices or other socio-demographic variables not captured in our analysis. In the case of electricity the socio-demographic variables taken into account here to measure lifestyles had a larger energy increasing impact on demand that could not be compensated for by the increase in efficiency of appliances.

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Table 1: Energy and service prices for gasoline, heating and electricity, 1990 – 2006

	Gasoline energy price	Gasoline service price	Heating energy price	Heating service price	Electricity energy price	Electricity service price
1990	70.84	85.93	82.51	101.17	84.58	94.49
1991	69.40	82.10	84.96	103.37	85.49	93.87
1992	73.96	85.64	84.59	100.67	87.04	93.70
1993	72.52	81.90	84.22	99.17	88.58	94.36
1994	74.84	82.92	84.23	97.08	89.58	94.45
1995	80.04	86.98	83.77	93.46	90.95	94.91
1996	86.29	92.03	88.22	94.62	95.95	99.27
1997	88.53	92.91	91.96	95.49	98.54	101.07
1998	83.84	86.65	88.43	90.27	98.54	100.20
1999	85.18	86.74	89.32	90.19	97.75	98.56
2000	100.00	100.00	100.00	100.00	100.00	100.00
2001	96.20	94.51	104.70	103.66	102.10	101.28
2002	93.60	89.82	103.15	101.35	99.04	97.40
2003	93.88	88.05	104.55	101.94	100.03	97.61
2004	101.96	94.78	111.66	108.63	102.73	99.52
2005	113.99	105.03	123.48	118.04	105.81	101.77
2006	122.36	111.92	132.03	123.34	109.46	104.60

Table 2: Descriptive statistics of variables, 1990 – 2006

	Mean	Maximum	Minimum	Std. Dev.
Budget shares				
Food	0.122	0.136	0.110	0.008
Clothing	0.062	0.077	0.051	0.008
Gasoline/Diesel	0.024	0.027	0.021	0.002
Heating	0.018	0.021	0.016	0.001
Electricity	0.014	0.015	0.014	0.001
Other	0.760	0.777	0.728	0.016
Price indices				
Food	100.41	112.43	88.10	6.85
Clothing	96.87	101.32	84.50	4.97
Gasoline/Diesel	91.06	111.92	81.90	8.26
Heating	101.32	123.34	90.19	8.80
Electricity	98.06	104.60	93.70	3.30
Other	96.33	112.13	78.39	9.93
Total expenditure	128796	166004	93294	21189
Stone Price index	96.81	111.84	80.48	9.08

Table 3: Shares of households (in %) by construction year of building

	before 1945	1945 to 1980	after 1980
1990	34.6	52.4	12.9
1991	33.9	51.9	14.2
1992	33.5	51.2	15.3
1993	33.2	50.6	16.2
1994	32.0	49.5	18.5
1995	31.3	48.7	20.0
1996	30.5	48.0	21.5
1997	29.6	47.7	22.7
1998	29.1	46.8	24.1
1999	28.3	46.0	25.7
2000	27.7	45.4	26.8
2001	27.3	44.6	28.2
2002	26.8	44.3	28.9
2003	26.9	44.0	29.1
2004	25.7	44.3	29.9
2005	25.0	43.6	31.4
2006	25.9	43.5	30.6

Table 4: Shares of households (in %) by useful area of dwelling

	up to 60 m2	60 to 110 m2	more than 110 m2
1990	27.8	48.0	24.2
1991	27.8	47.5	24.8
1992	27.4	47.5	25.1
1993	26.7	47.6	25.6
1994	26.8	47.4	25.8
1995	25.9	47.3	26.8
1996	25.0	47.8	27.2
1997	24.3	47.9	27.8
1998	24.1	47.9	28.0
1999	23.4	47.9	28.7
2000	22.8	48.0	29.1
2001	22.4	47.9	29.7
2002	22.0	47.8	30.2
2003	21.5	46.9	31.6
2004	21.0	46.1	32.9
2005	20.6	45.7	33.6
2006	20.5	45.3	34.2

Table 5: Shares of households (in %) by population density of region

	high	middle	other
1990	25.0	28.4	46.6
1991	24.8	28.6	46.6
1992	24.6	28.9	46.5
1993	24.4	29.1	46.5
1994	24.3	29.3	46.4
1995	24.1	29.5	46.4
1996	23.9	29.7	46.3
1997	23.8	30.0	46.3
1998	23.6	30.2	46.2
1999	23.4	30.4	46.2
2000	23.3	30.6	46.1
2001	23.1	30.9	46.1
2002	22.8	30.7	46.5
2003	22.6	30.5	47.0
2004	22.3	30.3	47.4
2005	22.0	30.1	47.9
2006	21.8	29.9	48.4

Table 6: Parameter estimates from cross-section estimation

	Food	Clothing	Gasoline/Diesel	Heating	Electricity
log (C/P)	-0,068	0,005	-0,025	-0,024	-0,015
standard error	0,003	0,002	0,001	0,001	0,000
t-value	-24,660	2,090	-22,190	-25,070	-35,240
Construction before 1945	0,000	0,000	0,000	0,000	0,000
standard error	0,000	0,000	0,000	0,000	0,000
t-value	.	.	.	.	.
Construction 1945-1980	-0,014	0,006	0,001	-0,002	0,000
standard error	0,004	0,003	0,002	0,001	0,001
t-value	-3,580	1,810	0,610	-1,550	0,420
Construction after 1980	-0,022	0,009	0,001	-0,007	0,000
standard error	0,004	0,003	0,002	0,001	0,001
t-value	-5,760	2,790	0,370	-5,100	-0,690
Space to 59 m2	-0,021	0,016	0,004	-0,021	-0,010
standard error	0,005	0,004	0,002	0,002	0,001
t-value	-4,660	3,780	2,120	-13,330	-14,210
Space 60 m² - 109 m²	-0,008	0,007	-0,001	-0,009	-0,005
standard error	0,003	0,003	0,001	0,001	0,000
t-value	-2,750	2,930	-0,460	-8,950	-9,960
Space > 110 m²	0,000	0,000	0,000	0,000	0,000
standard error	0,000	0,000	0,000	0,000	0,000
t-value	.	.	.	.	.
high pop. Density	0,717	0,019	0,249	0,228	0,145
standard error	0,023	0,021	0,010	0,008	0,004
t-value	31,140	0,910	26,080	28,660	39,500
middle pop. Density	0,727	0,015	0,251	0,232	0,149
standard error	0,023	0,020	0,009	0,008	0,004
t-value	31,930	0,740	26,580	29,540	41,070
low pop. Density	0,739	0,009	0,256	0,236	0,151
standard error	0,023	0,020	0,009	0,008	0,004
t-value	32,810	0,470	27,400	30,390	42,090
R^2, adjusted	0,843	0,520	0,751	0,654	0,799

Table 7: Inputs from time series and cross section estimation for the linked model

	Income elasticity cross section	w_i time series	Parameter β_i* linked model	Uncompensated price elasticity time series	Parameter γ_{ii}* linked model
Food	0.5919	0.1220	-0.0498	-0.1152	0.1019
Clothing	1.0549	0.0619	0.0034	-1.5864	-0.0361
Gasoline /Diesel	0.4836	0.0237	-0.0123	-0.4789	0.0121
Heating	0.3159	0.0181	-0.0124	-0.2742	0.0129
Electricity	0.3338	0.0145	-0.0096	-0.1278	0.0125

Table 8: Relative impact of socio-demographic variables on budget shares

	Food	Clothing	Gasoline /Diesel	Heating	Electricity
construction year building					
σ_{11}	0,0097	-0,0043	-0,0007	0,0018	-0,0007
σ_{12}	-0,0013	0,0008	0,0005	0,0010	0,0005
σ_{13}	-0,0084	0,0035	0,0002	-0,0028	0,0002
area of dwelling					
σ_{21}	-0,0159	0,0097	0,0012	-0,0129	-0,0069
σ_{22}	0,0010	0,0002	-0,0018	0,0009	0,0003
σ_{23}	0,0150	-0,0098	0,0006	0,0120	0,0066
population density					
σ_{31}	-0,0128	0,0064	-0,0027	-0,0074	-0,0051
σ_{32}	-0,0006	0,0004	-0,0010	0,0007	0,0012
σ_{33}	0,0134	-0,0068	0,0037	0,0067	0,0040

Table 9: Uncompensated and compensated price elasticities

Uncompensated price elasticities					
	Food	Clothing	Gasoline /Diesel	Heating	Electricity
Food	**-0,1111**	0,2601	0,1510	-0,0568	-0,1037
Clothing	0,4606	**-1,5953**	-0,0473	0,0294	0,0363
Gasoline	0,7906	-0,0866	**-0,4750**	0,1238	0,1844
Heating	-0,3496	0,1460	0,1666	**-0,2699**	-0,3819
Electricity	-0,4591	0,1979	0,3050	-0,4760	**-0,1241**
Compensated price elasticities					
	Food	Clothing	Gasoline /Diesel	Heating	Electricity
Food	**-0,0389**	0,2966	0,1650	-0,0461	-0,0952
Clothing	0,5893	**-1,5301**	-0,0223	0,0485	0,0515
Gasoline	0,8490	-0,0570	**-0,4635**	0,1325	0,1913
Heating	-0,3117	0,1651	0,1740	**-0,2642**	-0,3774
Electricity	-0,4183	0,2186	0,3129	-0,4700	**-0,1193**

Table 10: Change in energy demand 2006 with constant socio-demography and constant technology of 1990

Socio-demographic variables	Gasoline/Diesel	Heating	Electricity
Total impact	-0.86	-7.33	-10.82
of which			
construction year effect	0.01	3.98	-0.61
area of dwelling effect	-0.30	-10.63	-8.50
population density effect	-0.56	-0.68	-1.70
Technological variables			
Total impact	18.03	15.90	8.55
of which			
efficiency, transport	12.83	3.82	8.28
efficiency, heating	2.76	17.59	-13.46
efficiency, electricity	2.45	-5.52	13.73