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ARTICLE INFO

Katrin Rehdanz and Carsten Schroder (2011). Residential energy expenditures in Germany: intertemporal evolution and determinants. *Environmental Economics*, 2(3)

RELEASED ON

Tuesday, 08 November 2011

JOURNAL

"Environmental Economics"

FOUNDER

LLC “Consulting Publishing Company “Business Perspectives”



NUMBER OF REFERENCES

0



NUMBER OF FIGURES

0



NUMBER OF TABLES

0

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Residential energy expenditures in Germany: intertemporal evolution and determinants

Abstract

For resource scarce countries improvements in energy efficiency is one way of reducing energy import dependency and mitigating climate change. Since the household sector is a major consumer of energy, understanding determinants of household energy expenditures is a prerequisite. Based on representative cross-sectional household income expenditure data, covering the period from 1978 to 2008, the paper examines determinants of energy expenditure patterns in Germany. The analysis covers information from about 50,000 households per cross section, and controls for a number of socio-economic, as well as regional characteristics, and endowment with inventories.

Keywords: residential heating, household expenditures, energy expenditures, fuels, electricity.

JEL Classification: D12, Q31, Q41.

Introduction

In the developed countries the household sector is a major consumer of energy. In Germany, for example, the residential energy demand amounts to about 30 percent of total final energy consumption. To reduce consumption and make energy use less inefficient a number of energy policy measures have been implemented over the last couple of years. However, like in other countries in temperate climatic zones electricity, gas, fossil and liquid fuels are used all day long 365 days per year, either directly for heating, hot water and lighting, or indirectly in combination with other goods and services for consumption (e.g., watching TV) and household production (e.g., cooking). Accordingly, energy like food and beverages belongs to the class of necessity goods. There is ample empirical evidence on an inverse relationship between the expenditure share for energy and household income, and on demand being price inelastic¹. For example, according to Grösche and Schröder (2011), German households in the lowest income quintile spend about 3.7 percent of their net income on electricity, as opposed to 1.3 percent in the highest income quintile, and Rehdanz (2007) finds fairly low income elasticities for Germany too ranging from 0.01 to 0.10 for different energy types. Other studies highlight that a certain minimum level of energy consumption is required to satisfy households' basic needs².

Understanding the determinants of residential energy consumption is interesting for a number of reasons. First, in order to design efficient and effective instruments for saving scarce resources, policy makers need to understand the interplay between households' characteristics, preferences, and activities on the one hand and energy consumption on the other (e.g., Druckman and Jackson, 2008). This is particularly important for resource scarce countries

as improvements in energy efficiency is one way of reducing energy import dependency and mitigating climate change. Second, assessing the distributive effects of changes in energy prices resulting from energy demand and supply shifts or from price-raising environmental policies requires information on the relationship between household income and energy expenditures. Third, for projections of future energy demands, today and historical patterns may serve as important ingredients.

Despite the broad range of potential applications, energy expenditure patterns of private households in Germany have attained surprisingly scant attention so far. Rare exceptions are Schuler et al. (2000), Rehdanz (2007), Rehdanz and Stöwhase (2008), Mills and Schleich (2009), Braun (2010), and Achtnicht (2010). Schuler et al. (2000) use data from Germany's 1988 Sample Survey of Income and Expenditure (IES) to econometrically explain the role of household characteristics (household size, social position, income, etc.) on space heating given technical building characteristics. Rehdanz (2007) explores the household-level determinants of household expenditures on space heating and hot water supply using two waves from Germany's Socio-Economic Panel collected in 1998 and 2003 covering about 12,000 households. Rehdanz and Stöwhase (2008) investigate cost liability and residential space heating expenditures of welfare recipients in Germany. The study by Braun (2010) uses the same data source as Rehdanz (2007) investigating the choice of space heating technology among home owners and tenants in 2003. Mills and Schleich (2009) analyze adoption of solar thermal technologies for space and water heating in the residential sector in Germany. Finally, based on choice experiments, Achtnicht (2010) investigates homeowners' willingness to pay for energy retrofits in Germany. Only one of these studies covers more than one survey year (Rehdanz, 2007).

The present work steps on aforementioned literatures, and expands it in two dimensions. First, our

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¹ According to Narayan et al. (2007), the short-run price elasticity for residential demand elasticities in G7 countries is -0.1068.

² See Spreng (2005) for details and a review of the early literature.

analysis, which relies on pooled IES data for Germany, covers an extensive time, namely the three decades from 1978 to 2008. The database enables us to investigate how expenditures related to the purchase of solid, liquid and gaseous fuels and electricity related to residential heating, lightning, and use of electric appliances have evolved over time. This is important as analyses based on a single year might ignore important changes and developments. Second, as the database is large (about 45,000 households per cross section) we can provide in-depth information on expenditure patterns and their micro-level determinants without running into the risk of having too few observations. So, the objective of the present study is (1) to present inter-temporal profiles of household energy expenditures over three decades, and (2) to investigate the main micro-level factors driving energy expenditures. Such results are most useful for designing and evaluating the effects of environmental policy measures. From a methodological perspective, we also discuss how a break in the IES survey design between 1993 and 1998 affects the inter-temporal comparability of household expenditure patterns.

The present article is organized as follows. Section 1 introduces the database, explains its preparation, and provides the central characteristics of our working sample. Section 2 provides the empirical results. Particularly, general information on changes in energy-consumption related expenditure patterns are provided in subsection 2.1, while trends in expenditures by type of resource follow in subsection 2.2. Other determinants including income and household composition but also endowment with energy-consuming items and housing size are analyzed in sections 2.3 and 2.4 respectively. The final section offers a discussion and some concluding remarks. The Appendix provides further details on the construction of the database.

1. Data preparation, sample selection and composition

1.1. Database. Our data are drawn from the IES provided by the German Federal Statistical Office. IES is a representative cross-sectional household quota sample, conveying information on about 0.2 percent of the population. Prior to German reunification, only West German households have been surveyed, while since unification East and West German households are entering the database (from 1993 onwards). The IES is collected in five-year intervals, and our dataset covers the period from 1978 to 2008. Altogether, these seven waves convey information for 311,522 households.

IES comprises micro-level information on various socio-demographic and economic characteristics of the households. Particularly, IES provides in-depth information on households' income, expenditures,

wealth, and inventories¹. Our empirical analysis focuses on households' "energy expenditures," interpreted in a broad sense as expenditures related to the purchase of electricity plus expenditures for solid, liquid and gaseous fuels for heating and warm water, plus apportionments for heating and warm water (mostly district heating). Accordingly, mobility-related expenditures for fuel or oil are not contained in the aggregate. See Table A1 in the Appendix for information on individual expenditure categories available from the IES.

As potential determinants of energy expenditure, we consider several socio-demographic variables such as family size and income; household endowments with energy-consuming durables such as TVs, freezers, refrigerators, dishwashers, washing machines and dryers; and also housing sizes in square meters. Further information on the aforementioned determinants of energy expenditures is assembled in Table A1 in the Appendix.

1.2. Inter-temporal comparability of expenditure variables. Between 1993 and 1998, the Federal Statistical Office changed the IES survey design: the surveying period was reduced from a full year to single quarters. While until 1993 households have been asked to report their expenditures during the whole year, since 1998 they are interviewed in a random quarter of the year, and are asked to report their expenditures during the same quarter.

The following example sheds light on how the reduction of the surveying-period impacts the distribution of reported expenditures. In the example, we consider four households, $h = 1, \dots, 4$, two commodities, v and w , and a time horizon of one year. We assume that the first commodity is purchased with high frequency, at least once per quarter. Electricity installments paid on a monthly basis are an example. The expenditures of household h in quarter p for the high-frequency good are denoted $v_{p,h}$. The second commodity is a low-frequency good, purchased only twice a year (not within any quarter) such as oil for heating. The expenditures of household h in quarter p for the low-frequency good are $w_{p,h}$. We assume that households' specific expenditures for the two commodities within the quarters of a year are as follows:

$$\text{High-frequency good: } \begin{pmatrix} v_{1,1} & v_{2,1} & v_{3,1} & v_{4,1} \\ v_{1,2} & v_{2,2} & v_{3,2} & v_{4,2} \\ v_{1,3} & v_{2,3} & v_{3,3} & v_{4,3} \\ v_{1,4} & v_{2,4} & v_{3,4} & v_{4,4} \end{pmatrix}.$$

¹ For a detailed description of the database see Bönke et al. (2010) and references cited therein.

$$\text{Low-frequency good: } \begin{pmatrix} 0 & w_{2,1} & 0 & w_{4,1} \\ 0 & w_{2,2} & 0 & w_{4,2} \\ w_{1,3} & 0 & w_{3,2} & 0 \\ 0 & w_{2,4} & w_{3,4} & 0 \end{pmatrix}.$$

When households are surveyed over a twelve months period, monthly expenditure is:

$$\begin{pmatrix} \sum_{q=1}^4 v_{q,1}/12 \\ \sum_{q=1}^4 v_{q,2}/12 \\ \sum_{q=1}^4 v_{q,3}/12 \\ \sum_{q=1}^4 v_{q,4}/12 \end{pmatrix}, \text{ and } \begin{pmatrix} (w_{2,1} + w_{4,1})/12 \\ (w_{2,2} + w_{4,2})/12 \\ (w_{1,3} + w_{3,3})/12 \\ (w_{2,4} + w_{3,4})/12 \end{pmatrix}.$$

Now consider that the surveying period is a quarter, and that household 1 is surveyed in quarter 4, household 2 in quarter 3, household 3 in quarter 1, and household 4 in quarter 2. Then the monthly expenditures derived from the expenditures in the surveyed quarter are:

$$\begin{pmatrix} v_{4,1}/3 \\ v_{3,2}/3 \\ v_{1,3}/3 \\ v_{2,4}/3 \end{pmatrix}, \text{ and } \begin{pmatrix} w_{4,1}/3 \\ 0 \\ w_{1,3}/3 \\ w_{2,4}/3 \end{pmatrix}.$$

Accordingly, purchases of the low-frequency good made by the first household taking place in the second quarter are not observed. Similarly, purchases in the second and fourth quarter are not observed for household 2. The same applies to purchases in the third quarter for households 3 and 4. This leads to a missing-information problem.

When seasonal effects are ruled out, the distributions of average monthly expenditures for the high-frequency good are not affected by the fact that only one out of four quarters per household is surveyed. For the low-frequency good, however, the reduction of the surveying period systematically affects the expenditure distribution. Ruling out seasonal effects, household monthly expenditures derived from quarterly-survey data are *higher* (compared with the same estimate from an annual survey period) *whenever a household's purchase actually falls within the surveyed quarter*. It is lower (namely zero), *when no purchase was made by the household within the surveyed quarter*¹.

We are confident that the change in the surveying period is innocuous for expenditures related to electricity and apportionments for heating and warm

water. However, due to low purchase frequencies it might matter for the categories solid, liquid, gaseous fuels. In case of the latter, inter-temporal comparability is guaranteed only during the period from 1978 to 1993 and again from 1998 and on.

1.3. Sample selection and composition. From the total number of 311,522 IES households several observations have been discarded. First, we restrict our attention to four household types. In the original IES database, single and two adult households with and without children as well as "other household types" are distinguished. The latter group is rather heterogeneous, and it thus has been excluded from the database (13,268 observations). We have also discarded four households with missing information on housing size. Moreover, some households reported unrealistically low incomes and energy expenditures. For this reason, in each period we have discarded all households falling in the lowest percentile of the respective distribution². This leaves us with a working sample of 291,853 household units. Table 1 contains details on the number of observations (not weighted) by year, region (Old and New states), and household type.

Table 1. Number of observations

Year	States	Childless single adult	Single parent	Childless couple	Couple with children
1978	Old	6,699	1,489	12,885	22,547
1983	Old	6,954	1,605	10,529	21,109
1988	Old	7,873	1,746	11,471	19,933
1993	Old	7,133	1,337	9,006	12,843
1998	Old	8,218	1,940	11,671	15,168
2003	Old	8,005	1,639	11,368	11,184
2008	Old	8,931	1,686	11,314	9,420
1993	New	1,273	552	2,650	3,609
1998	New	1,840	784	3,403	3,831
2003	New	1,632	570	3,163	2,785
2008	New	2,476	693	4,045	2,844

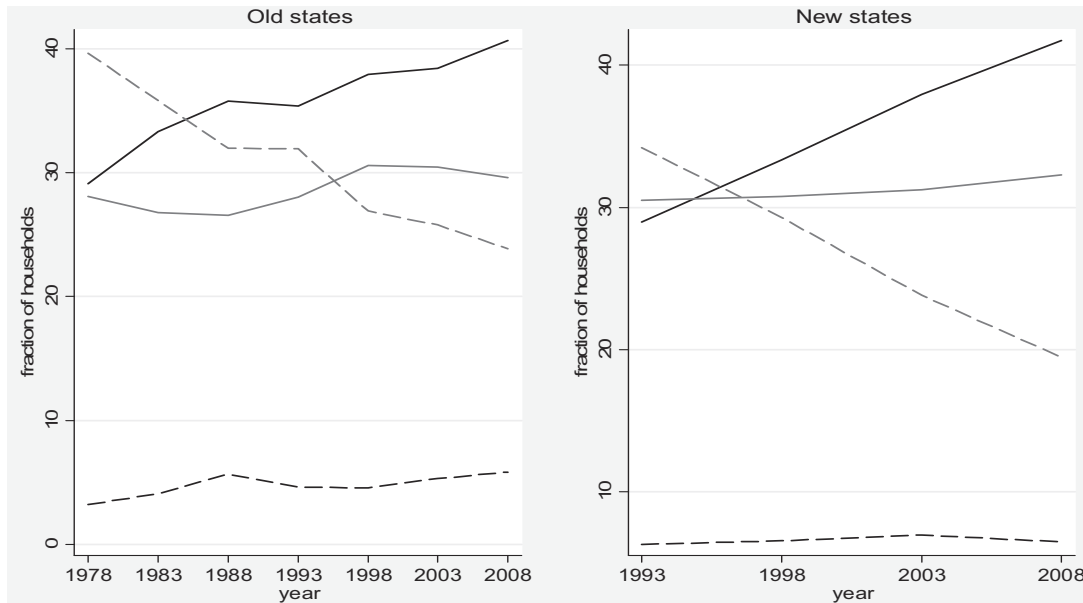
Figure 1 shows the relative frequency of the different household types in Germany. All results are derived using IES household frequency weights. The abscissa gives the survey period: 1978 to 2008 in the Old federal states; 1993 to 2008 in the New states. The ordinate depicts the fraction of households in the Old respectively New states belonging to a particular type. For the Old states (left graph), we observe a systematic inter-temporal rise of the share of childless households. The share of alone living females and males (black solid line) has risen sharply from 29.1 percent in year 1978 to 41.2 percent in year 2008, and also the share of childless couples (grey solid line) has increased moderately from 28.1 to 29.6 percent. In contrast, the share of couples with children (grey dashed line) has

¹ See Bönke et al. (2010) for details on such and other examples.

² As we have no exceptionally high levels of income and expenditures we have abstained from symmetric trimming of the data.

fallen sharply from 39.6 percent in year 1978 to 23.9 percent in year 2008, while the share of single parents (black dashed line) in the same period has risen slightly from 3.2 to 5.8 percent. Results for the New

states are provided in the graph on the right. Again, a rising share of childless households is the most obvious pattern. The fraction of childless households is even higher compared with the Old states.



Note: Fractions in percent. Black solid line: alone living females and males; black dashed line: single parent; grey solid line: childless couples; grey dashed line: couple with children. All numbers derived using IES household frequency weights. Database is IES 1978-2008.

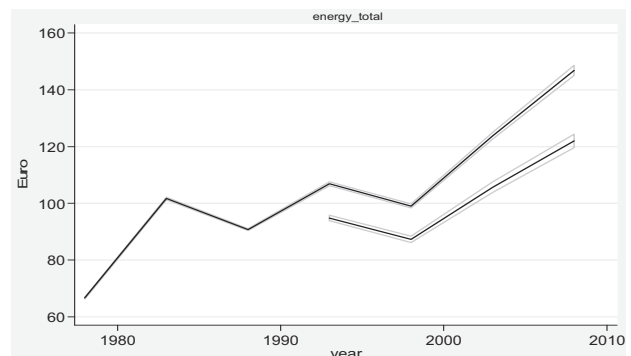
Source: Own calculations.

Fig. 1. Sample composition by household types

2. Empirical results

2.1 The general picture. Before analyzing the data in more detail, Figure 2 provides an overview over total household nominal energy expenditures in Germany (West) between 1978 and 2008. If not explicitly mentioned, throughout the paper expenditure (and also income) is provided on the household level, on a monthly basis expressed in euros. At this stage we would like to remind the reader that the break in the survey design limits the comparability of the data from the 1978 to 1993 period with those from the period 1998 and onwards. Moreover, our results are descriptive, and as such our findings should not be interpreted as causalities but as statistical associations.

Previous to 1993 information refers to Western Germany only, while results are distinguished by Old and New states from 1993 and on. The figure shows a sharp increase in expenditures between 1978 and 1983, a period of stagnation afterwards and another increase from 1998 onwards. In addition, the figure indicates that expenditures evolve similarly in both parts of Germany (after 1993). However, expenditures per household in the New are significantly lower compared to the Old states, by about 20 percent on average.

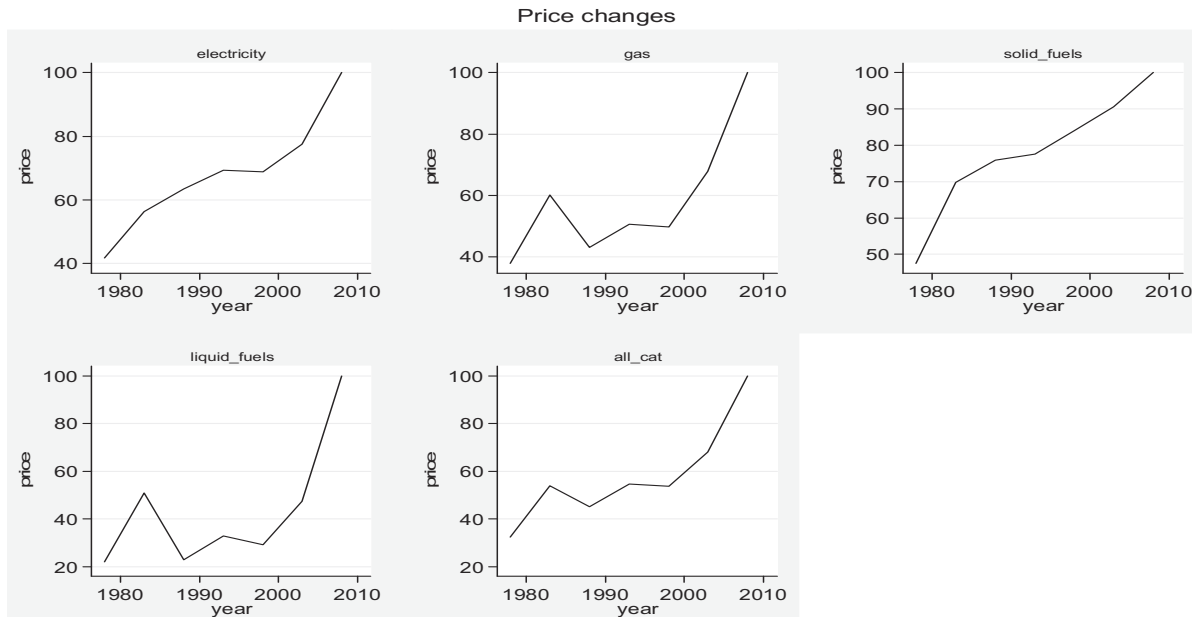


Note: Upper line relates to Old states; lower line to New states. All numbers derived using IES household frequency weights. Database is IES 1978-2008.

Source: Own calculations.

Fig. 2. Total energy-related expenditures in Old and New states

It seems that most of the trends in household energy expenditure can be explained by changes in prices over time (rather than changes in consumed quantities). As can be seen from Figure 3, consumer prices for energy (“all_cat”) in Germany have about tripled between 1978 and 2008 (Statistisches Bundesamt, 2011). Reasons are manifold including price increases on the commodity market, the trend of the exchange rate between euro and dollar but also the consequences of the German green tax on energy and other regulatory measures to increase energy efficiency and reduce energy consumption.

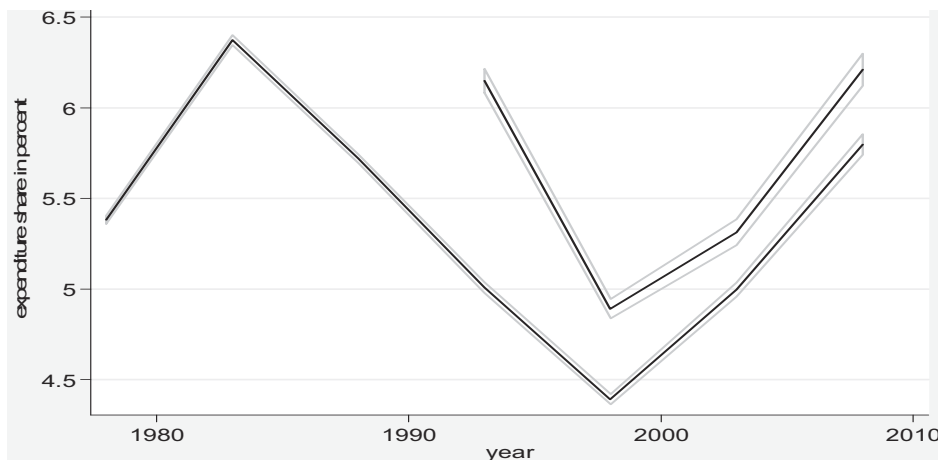


Note: Data provided by German Federal Statistical Office. “All cat” is the broad set of energy-related expenditures as defined in the text. Source: Own calculations.

Fig. 3. Intertemporal price trends

Figure 4 shows households’ energy-related expenditures relative to disposable income for the same period, thus indicating the relative energy related monetary burden for the average household¹. The expenditure share increases significantly between 1978 and 1983, followed by a period of stagnation and another increase after 1998. Overall the share is relatively stable, fluctuating between about 4.5 and 6.5 percent, and with a long-term average of around 5.5 percent. Accordingly, the rise of incomes about

compensated the increase in energy-related expenditures. However, most probably the trend of the last couple of survey years showing a steady increase the households’ monetary burden. Comparing households in New and Old states it is interesting to note that the former have lower total nominal expenditures (Figure 2) while exhibiting higher expenditure shares. In general this is because average income in the New states is lower compared to the Old states.



Note: Upper line relates to New states; lower line to Old states. All numbers derived using IES household frequency weights. Database is IES 1978-2008. Source: Own calculations.

Fig. 4. Expenditure share of energy in Old and New states

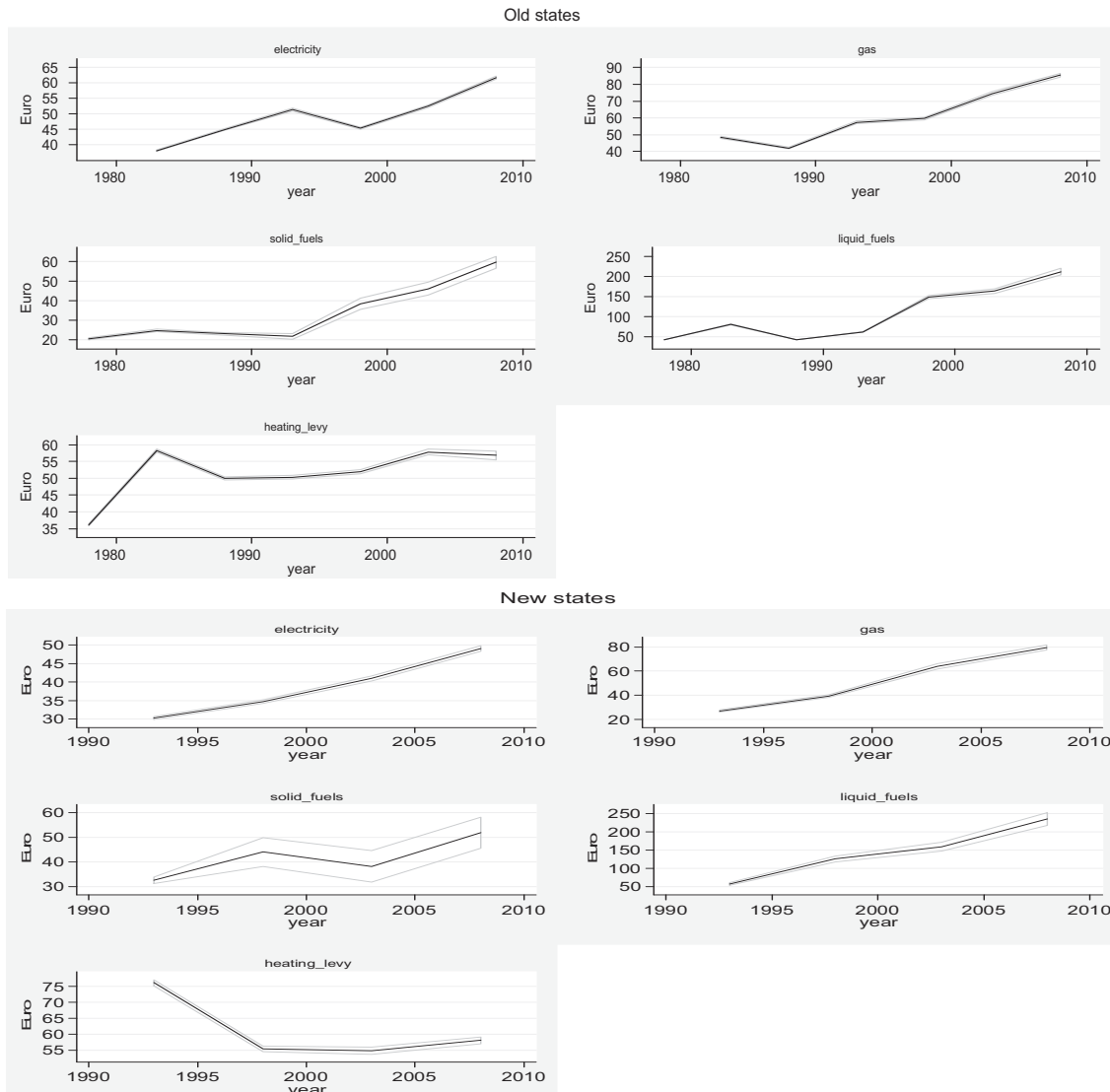
2.2. Trends in expenditures by type of resources. Refining our analysis, trends in monthly household energy expenditures by energy type are depicted in

Figure 5. For both regions (Old and New states), five graphs provide the inter-temporal trend of expenditures for each energy type. All numbers are conditional averages, derived from households’ reporting strictly positive expenditures. Since in year 1978 expenditures for gas and electricity are not contained in separate

¹ According to Narayan et al. (2007), the short-run price elasticity for residential demand elasticities in G7 countries is -0.1068.

variables, the respective trends are provided from 1983 on only. Yet, in the graph displaying total energy ex-

penditures (Figure 2), expenditures for gas and electricity are always considered.



Note: Household expenditures per month. Black line: conditional mean; grey lines: upper and lower bound of 95 percent confidence interval All numbers derived using IES household frequency weights. Database is IES 1993-2008. Source: Own calculations.

Fig. 5. Energy expenditures by types

In the Old states, two results stand out. First, total energy-related monthly expenditures per household more than doubled from slightly above 60 euro in year 1978 to more than 140 euro in year 2008, despite a long period of stability between 1983 and 1998. Second, expenditures evolved differently. Electricity-related expenditures have risen quite steadily over the entire observation period, whereas expenditures for gas, solid and liquid fuels remained relatively stable for the period 1978 to 1993, and increased since then. Since 1993, gas related expenditures have risen by about 50 percent, while solid- and liquid-fuel related expenditures more than doubled. Apportionments for heating and warm-water (“heating_levy”) exhibited a prominent rise between 1978 and 1993 and stagnate since then. In the New states, the trends are comparable. Only apportionments for heating and warm water, with

a prominent decrease from 1993 to 1998, exhibit a slightly different pattern.

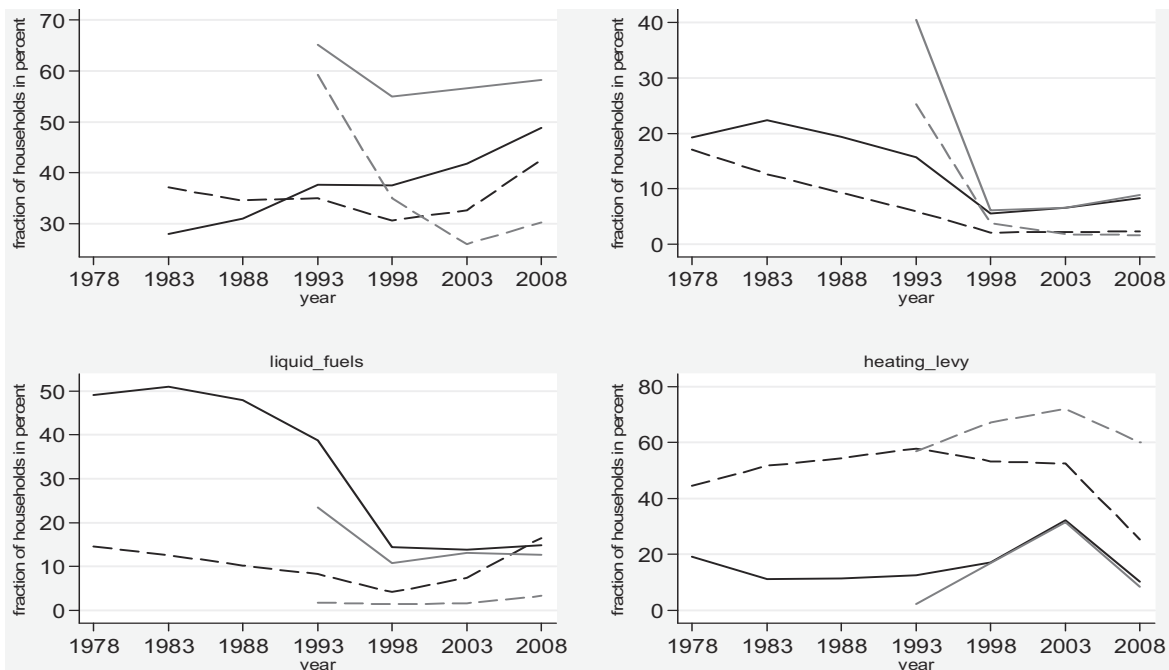
All the expenditure profiles closely track consumer price changes. This can be seen from Figure 3, where trends in energy prices are provided, except for heating and warm water apportionments where price information is unavailable. For all expenditure categories, prices have substantially risen over the observation period, particularly during the last decade. Between 1978 and 2008, electricity and gas prices have risen by about 150 percent, and by about 100 percent for solid fuels. Even stronger is the increase for liquid fuels, where 2008 prices are about five times higher than in 1978.

Not only expenditure levels but also item-specific market penetrations have changed over time, e.g.,

due to substitution effects as a response to changes in relative prices or technical innovations. As outlined above, the relative price for liquid fuels has increased relative to solid fuels or gas, providing an incentive to replace heating devices relying on liquid fuel. To allow a first assessment, Figure 6 gives the fraction of households in the sample actually reporting strictly positive expenditures for each energy category. All numbers are decomposed by Old and New states and by owners of housings (solid line) and tenants (dashed line). Concerning liquid and solid fuels, the share of household units actually reporting positive expenditures has decreased, at least over the period from 1978 to 1993. However, the further sharp decline between 1993 and 1998, most likely is a statistical artifact resulting from the break in the survey design. Pro-

bably many households purchase solid and liquid fuels once or twice per year, so that several purchases will remain unobserved after 1998. For the New states it could also be argued that in the years after reunification households' main heating type changed from solid fuels (mostly coal) to gas, oil or district heating also explaining a decline in the fraction of households with positive expenditures.

Comparing Old and New state estimates for the period from 1993 and on, differences are quantitatively small. More pronounced are the differences between tenants and home owners: the latter are more likely to report expenditures for gas, solid and liquid fuels, while the former pay apportionments for heating and warm-water more often.



Note: Solid line: owners; dashed line: tenants; Old states: black lines; New states: grey lines. All numbers derived using IES household frequency weights. Database is IES 1993-2008. Source: Own calculations.

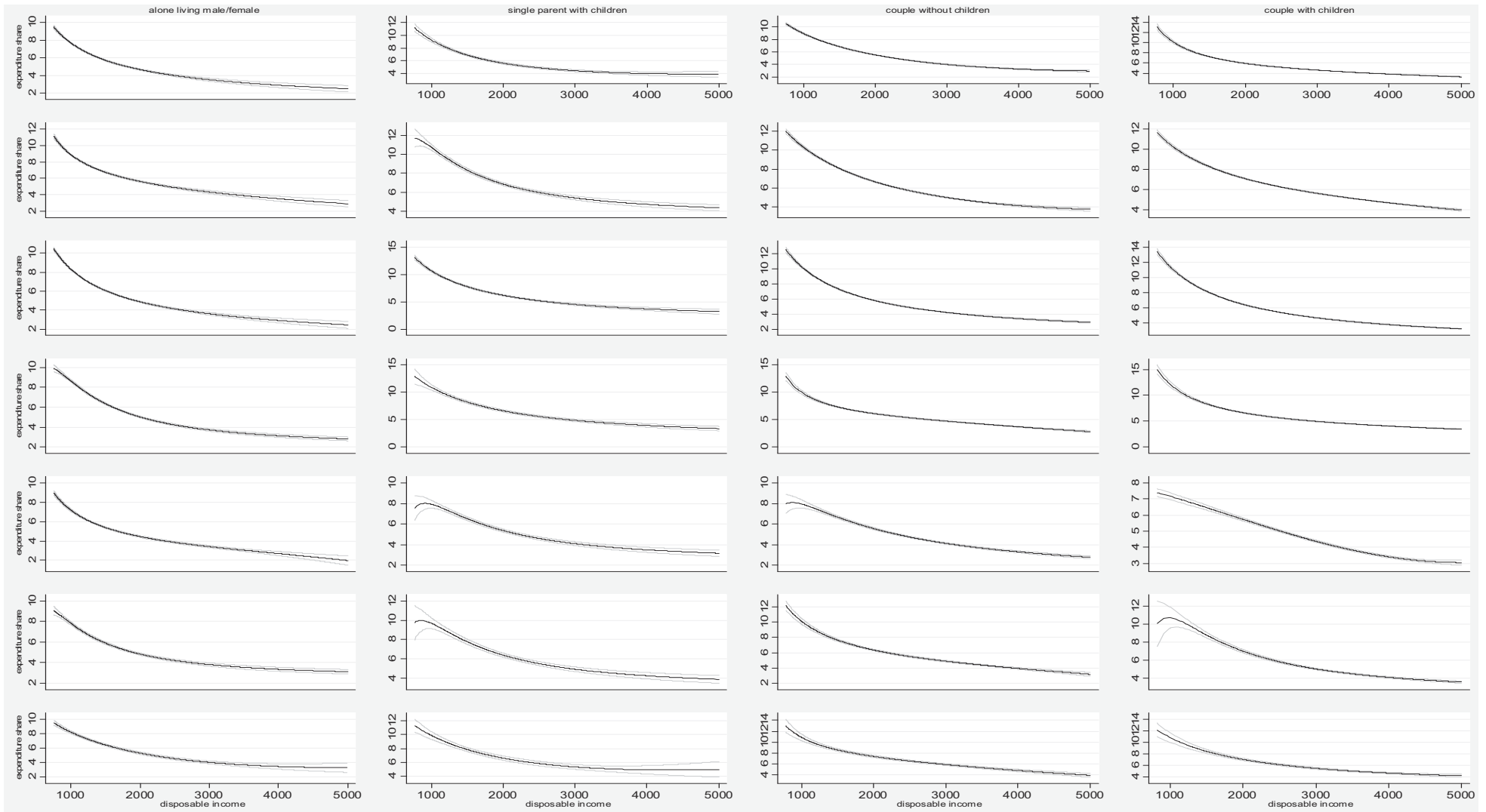
Fig. 6. Fraction of households with positive expenditures

3.3. Decomposition by socio-economic variables. In order to better understand the financial burden of energy-related expenditures incurred by the households, Figures 7a (Old states) and 7b (New states) depict total energy-related expenditures relative to household disposable income. These Engel curves are decomposed by year, and household type. In order to secure inter-temporal comparability of expenditure shares at a particular level of disposable income, the latter is expressed in year 2008 consumer prices¹.

Engel curves and associated confidence intervals

have been derived from estimates of fractional polynomials. Fractional polynomials fit non-linear functions, and are more flexible than standard (non-fractional) polynomials (e.g., Royston and Altman, 1994, or Sauerbrei and Royston, 1999). The linear predictor for a fractional polynomial of order M for covariate x is, $\beta_0 + \sum_{m=1}^M \beta_m x^{p_m}$, where p_m is usually taken from a restricted set of powers $\{-2, -1, -0.5, 0, 0.5, 1, 2, 3\}$ and x^0 is taken as $\ln(x)$. Models for all powers are fitted to the data and the model with the best fit is selected. Figures 7a and 7b have been obtained using the STATA tool “fpfitci” for the “twoway” graph option.

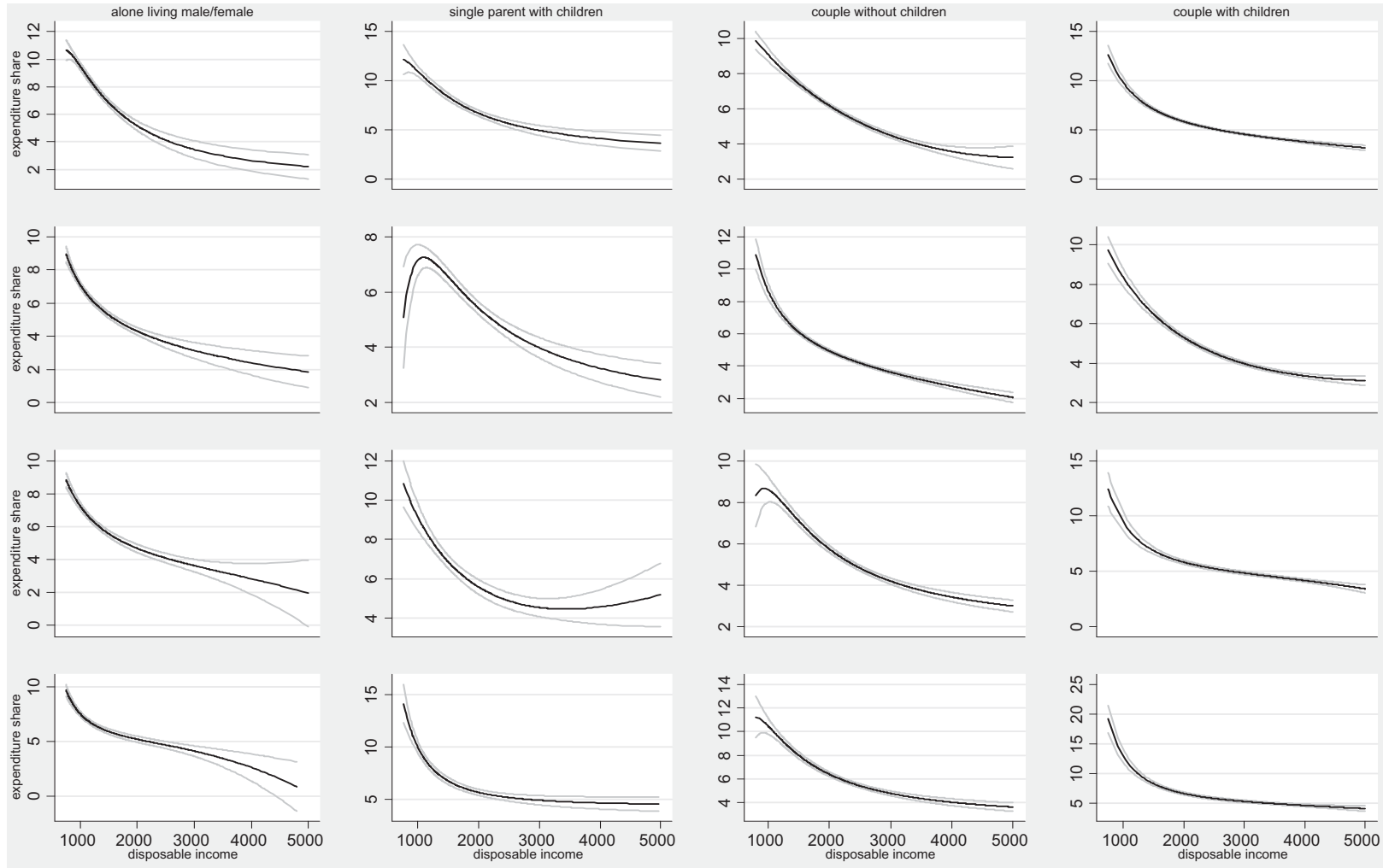
¹ See Table A2 in the Appendix for details.



Note: Household expenditure shares for energy. First (2nd, 3rd, 4th, 5th, 6th) row: 1978 (1983-2008). Black line: point estimate; grey lines: upper and lower bound of 95 percent confidence interval. All numbers derived using IES household frequency weights. Database is IES 1993-2003.

Source: Own calculations.

Fig. 7a. Engel curves for energy expenditures in the Old states



Note: Household expenditure shares for energy. First (2nd, 3rd, 4th) row: 1993 (1998-2008). Black line: point estimate; grey lines: upper and lower bound of 95 percent confidence interval All numbers derived using IES household frequency weights. Database is IES 1993-2003.

Source: Own calculations.

Fig. 7b. Engel curves for energy expenditures in the New states

For the Old states, the figure contains 28 separate graphs. All the graphs within a column relate to a particular household type, whereas household types appear in the sequence: alone living male/female; single parent with children; couple without children; couple with children. Each row refers to one survey period, starting with year 1978 in the first row, year 1983 in the second row, and so on. For the New states, the structure is the same as in Figure 7a, with the single exception that we have four observation periods only resulting in 16 separate graphs.

Negative slopes of Engel curves suggest that energy is a necessity good. As an example, for couples with children resident in the Old states in year 2008, the expenditure share for energy declines from about twelve percent to about four percent when disposable income rises from 1,000 euro to 5,000 euro. So, households belonging to the lower part of the disposable income distribution bear a higher energy-related monetary burden compared to households belonging to the upper part of the distribution.

Comparing Engel curves across household types, expenditure shares at a particular income level tend to be increasing in the number of family members. As an example, take an alone living male/female (couple without children) with a disposable income of 1,000 euro in the Old states in year 2008. At this income level, the expenditure share is about eight percent (ten percent). For a single parent with children (couple with children)

with the same disposable income, the expenditure share is about ten percent (twelve). So, larger households, *ceteris paribus*, bear a higher energy-related monetary burden compared to smaller households.

Comparing Engel curves over time, both the slopes and levels remain quite stable in the Old states. For example, take the case of a couple without children. Here we have an expenditure share of about ten percent at a disposable price-adjusted income of 1,000 euro both in 1978 and 2008. In general, the finding also holds for the New states except for single parents with children. Here the shape of the Engel curve exhibits substantial variation over time. The result, however, should be interpreted with care as the sample size for this particular household type is relatively small (see Table 1 for details).

2.4. Endowment with energy-consuming items and housing sizes. Households require energy for heating, cooking, lightning, entertainment, etc. The endowment of households with electric devices for such purposes has been subject to major inter-temporal changes. Today, e.g., PCs and notebooks are owned by the vast majority of households, while possession was a rare exception in the 1970th and 1980th. Also the endowment of households with TVs, washing machines and dryers changed over time. Therefore, changes in households' endowments with energy-consuming items provide interesting information to understand households' energy demand.

Table 2. Average endowments with energy-consuming devices and housing size

Year	States	TVs	PCs and notebooks	Refrigerators and freezers	Dishwashers	Washing machines and dryers	Housing size in square meters
1978	Old	1.167	n.a.	1.528	0.159	1.150	85.647
1983	Old	1.235	n.a.	1.623	0.244	1.210	87.915
1988	Old	1.249	n.a.	1.682	0.302	1.066	89.753
1993	Old	1.329	0.269	1.705	0.403	1.159	91.459
1998	Old	1.401	0.477	1.989	0.507	1.268	93.104
2003	Old	1.465	0.884	1.946	0.611	1.358	95.885
2008	Old	1.659	1.254	1.823	0.662	0.425	95.332
1993	New	1.269	0.181	1.754	0.030	0.979	67.670
1998	New	1.427	0.391	1.948	0.266	1.094	72.151
2003	New	1.448	0.757	1.723	0.472	1.163	76.423
2008	New	1.616	1.063	1.623	0.563	0.222	77.927

Note: Own computation using IES 1978-2008. All numbers weighted using IES frequency weights. In year 2008, information on the number of washing machines was not collected by the Federal Statistical Office.

Table 2 gives the average endowment of a household with some selected electric devices: number of TVs; number of PCs and notebooks; number of refrigerators and freezers; number of dishwashers; number of washing machines and dryers. Both in the Old and New states, households are equipped

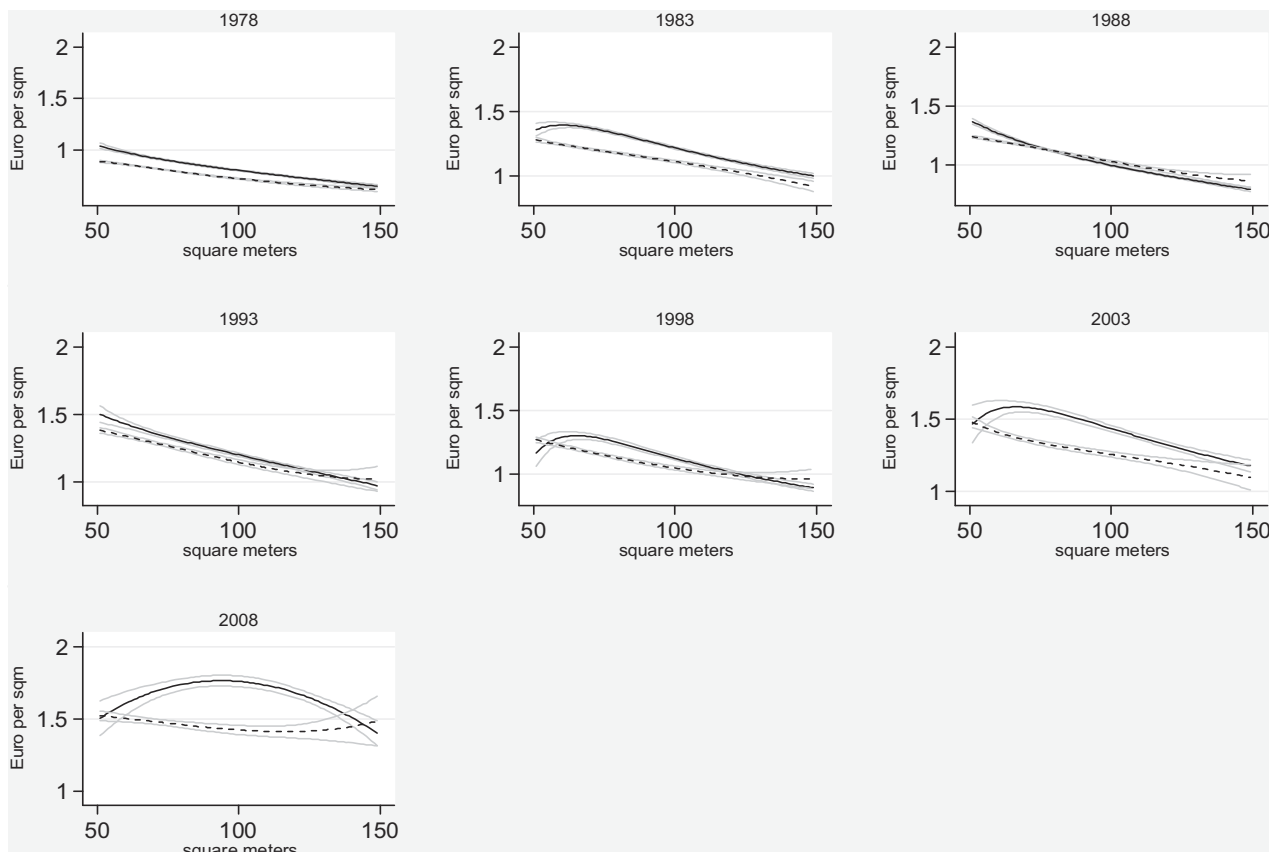
with more energy-consuming durables today than in previous years. For example, the average number of TVs in Old state households has risen from about 1.17 in year 1978 to 1.66 in year 2008, and the number of dishwashers from about 0.16 to 0.66. Most accentuated is the rise in the number

of PCs and notebooks. While the item had not even been surveyed in the 1970th and 1980th, the Old state households on average owned about 0.27 PCs and laptops in year 1993 compared with 1.25 in year 2008. Comparing the households' endowments in the Old and New states, the data document a rapid catch-up process. For example, in year 1993 the average Old state household owned about 0.40 dishwashers compared with only 0.03 in the New States. In year 2008, the divide has substantially narrowed (0.66 vs. 0.56).

Housing size in square meter is another central determinant of households' energy demand. Most plausible, larger housing sizes are associated with higher expenditures. However, in the presence of scale economies the increase is not necessarily linear. As can be seen from the last column of Table 2, average housing size has increased over the observation period, both in the Old and New states, and average housing size in the former is

higher. This is one plausible explanation why average energy expenditures are higher in the Old compared with the New states (see Figure 2 above)¹.

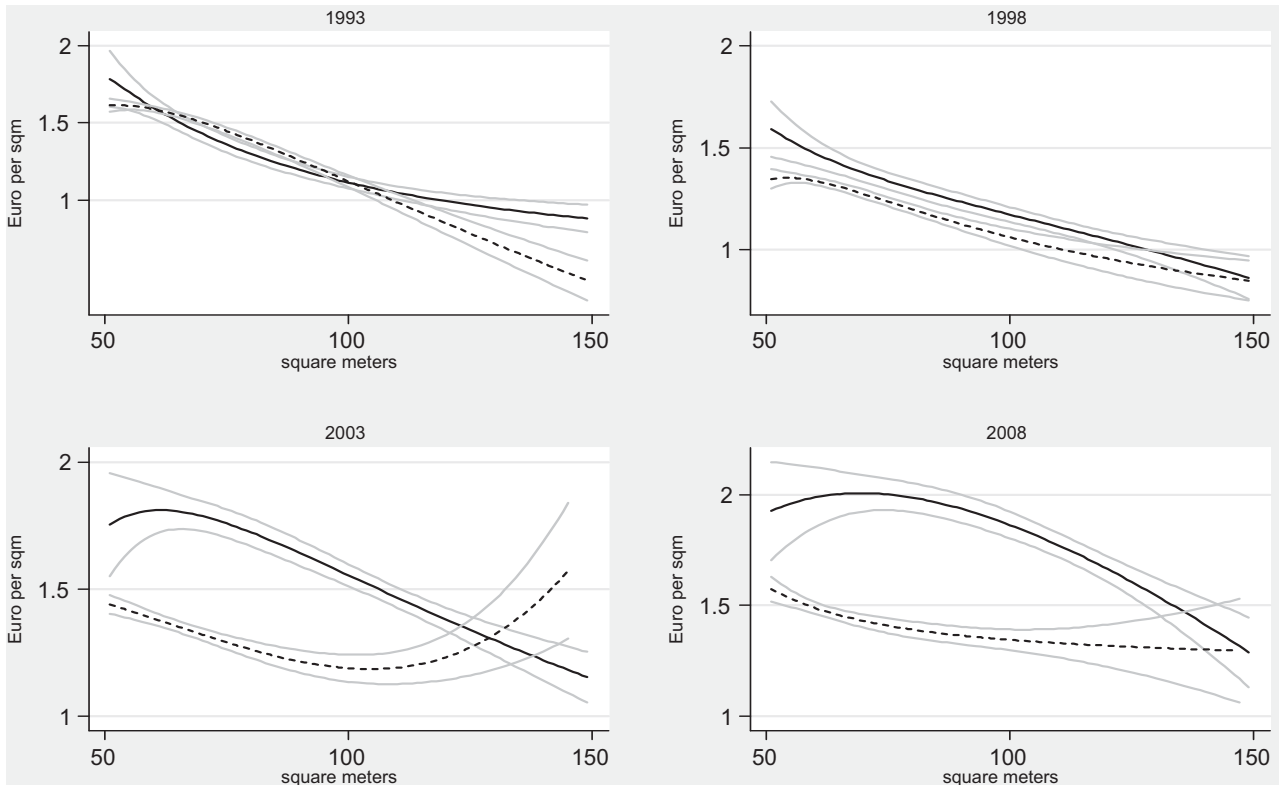
In Figures 8a (Old states) and 8b (New states) we have provided estimates on the relationship between housing size (in square meters) and energy expenditures per square meter. Results are decomposed by tenants (dashed line) and owners (solid line). Again, relationships are obtained from fitting fractional polynomials. In the Old states, energy-related expenditures per square meter are always falling in housing size, suggesting scale economies for energy consumption. Comparing expenditures of tenants and owners, expenditures per square meter – given a particular housing size in square meters – are slightly higher for the latter. In the New states, patterns are similar, but the smaller sample size makes the data noisy, as indicated by quite large confidence intervals.



Note: Upper line relates to Old states; lower line to New states. Dashed line relates to tenants; solid line – to owners. All numbers derived using IES household frequency weights. Database is IES 1978-2008. Source: Own calculations.

Fig. 8a. Total energy-related expenditures per square meter in the Old states

¹ Of course, housing size is correlated with other determinants of energy consumption, e.g., number of household members or income.



Note: Upper line relates to Old states; lower line to New states. Dashed line relates to tenants; solid line to – owners. All numbers derived using IES household frequency weights. Database is IES 1993-2008. Source: Own calculations.

Fig. 8b. Total energy-related expenditures per square meter in the New states

Discussion and concluding remarks

We use a unique cross-sectional dataset for Germany containing information for about 45,000 households per cross-section covering the period from 1978 to 2008. To demonstrate potential applications of this new dataset the present study describes energy expenditures patterns and its determinants across household-type, income levels and over time.

The analysis presented in this paper has revealed several insights, some of which are exclusive to the use of our unique dataset. As expected, households' total nominal energy expenditures show a pronounced increase over the last decades. Since 1998, also the expenditure share has been rising by more than one percentage point equivalent to a 20 percent increase. Further, estimates of Engel curves suggest a negative relationship between expenditure shares and households' disposable income. For this reason the average household in the New states bears a higher monetary burden compared to the average household in the Old states. The fact that low-income households face a higher monetary burden has immediate implications for the distributional effects of Germany feed-in tariffs and other price increasing regulatory measures: as such levies and taxes are usually proportion to consumption, they have a regressive effect on the income distribution (for feed-in tariffs see also Grösche und Schröder, 2011).

With its commitment to further increase the share of renewable energy by 2020 Germany's government pursues a potentially costly policy cause. As a consequence, the regressive effect is likely to strengthen, potentially undermining the social acceptability of these kinds of environmental policy measures. This requires policy makers to think about a more balanced design of instruments. Policy measures have been implemented to make the use of energy consumed in homes more efficient. This includes subsidies or affordable credits for households who are willing to invest in energy efficient homes (including, e.g., new heating technology) but also means of transportation to reduce energy related costs of households in general. Information campaigns and energy labeling of energy-consuming appliances have been used to influence peoples' behavior regarding energy consumption. However, the success of these measures is limited. One reason is that measures like subsidies and credits are more often requested by households with higher levels of income. These are also more often households with own property. Households with lower levels of income are more likely to live in rented accommodation but landlords in Germany have fewer incentives to invest in energy saving technology (Rehdanz, 2007). New policy measures need to take this more explicitly into account. In addition, non-uniform energy

prices or energy-tax exemptions, for example, should also be considered to reduce the energy-related expenditure burden of low income households. So far, our analysis has been purely descriptive. In the future, we plan a more detailed analysis of the determinants of energy expenditures by means of regression analysis. This includes the estimation of household and income dependent price elasticities of energy demand.

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Appendix. Residential energy expenditures in Germany: inter-temporal evolution and determinants

1. Variables. In IES, variables are identified by so-called field identification numbers, consisting of the acronym "EF" plus a serial number. For example, in the IES 1978, "EF2" gives the region of residence, while EF498 reports expenditures for gas and electricity. Frequently, field identification numbers and variable have changed over time. Table AX defines all IES variables considered in the present study.

Table A1. Definition of variables

Variable	Description	1978	1983	1988	1993	1998	2003	2008
Socio demographics								
Region	New/Old German states	2	2	2	2u1	3u1	2u1	2u1
Household type	Different household types	22	20	56	87	184	89	35
Disposable income	Euro per month	29	29	20	99	117	42	59
Energy-related expenditures								
Gas	Euro per month, price adjusted	498	588	589-590	707,719	773, 774	259	252
Electricity	Euro per month, price adjusted		587	588	705	770, 771	258	251
Solid fuels for heating	Euro per month, price adjusted	499-502	590-593	592-595	711, 713, 715, 717	779, 780	261	254
Liquid fuels for heating	Euro per month, price adjusted	503	589	591	709	776, 777	260	253
Apportionments for heating and warm water	Euro per month, price adjusted	504	594	596	718	782, 783	262	255
Inventories and housing								

Acknowledgments

The database underlying the present work has been assembled in a joint research project together with Timm Bönke and Clive Werdt whose input is greatly acknowledged. Further, we wish to thank employees of the IES division of the German Federal Statistical Office for most valuable technical support.

Table A1 (cont.). Definition of variables

Variable	Description	1978	1983	1988	1993	1998	2003	2008
Socio demographics								
Number of TVs	Number of items owned	59, 60	70u1, 71u1	71u1, 72u1	192u1, 193u1	223	413	430, 431
Number of PCs & notebooks	Number of items owned	n.a.	n.a.	n.a.	202u1	229, 230	427, 428	444, 445
Refrigerators and freezers	Number of items owned	79-81	89u1, 90u1, 91u1	91u1, 92u1, 93u1	209u1, 210u1, 211u1	240, 241	436, 437	454, 455
Dishwashers	Number of items owned	82	92u1	94u1	212u1	242	438	456
Washing machines and dryers	Number of items owned	87-89	97u1, 98u1, 99u1	99u1, 100u1	217u1, 218u1	245, 246	441, 442	458 ^a
Living in own home	0 = no, 1 = yes	92	104	104	178	205	19	19
Living space	Square meters	95	105	105	152	206	20	20

Note: Numbers indicate EVS field identifiers. a – Washing machines are not reported in year 2008; n.a. – not available.

2. Time dimension and adjustment for inflation. All income and expenditure variables are provided on a monthly basis, and are expressed in euro. When explicitly stated in the text, reported numbers have been adjusted for changes in consumer prices to secure intertemporal comparability of income and expenditure. Then we have used the conversion factors summarized in Table A1. Accordingly, the year 2008 serves as the reference.

Table A2. Consumer prices

Year	Consumer price index over all expenditure categories	Price index for electricity, gas and other fuels	Price index for electricity	Price index for gas	Price index for liquid fuels	Price index for fossil fuels
1978	0.568	0.323	0.418	0.379	0.219	0.474
1983	0.720	0.538	0.564	0.602	0.510	0.699
1988	0.763	0.451	0.635	0.431	0.228	0.759
1993	0.781	0.547	0.694	0.506	0.329	0.775
1998	0.853	0.536	0.689	0.497	0.292	0.842
2003	0.909	0.679	0.776	0.680	0.475	0.906
2008	1.0	1.000	1.000	1.000	1.000	1.000

Source: Data from German Federal Statistical Office (2011).