DETERMINANTS OF RESIDENTIAL SPACE HEATING EXPENDITURES IN GERMANY

Katrin Rehdanz[a]

[a] *Research Unit Sustainability and Global Change, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany*

Working Paper FNU-66 (revised)

Abstract

We first examine the determinants of household expenditures on space heating and hot water supply in Germany. A number of socio-economic characteristics of households are included along with building characteristics. Our analysis covers information on more than 12,000 households in Germany for the years 1998 and 2003.

The analysis continues by investigating whether different kinds of households are affected differently by increases in energy prices. Households in owner occupied properties are less affected compared to those in rented accommodation, this could be because owners are more likely to have installed energy-efficient heating and hot water supply systems and landlords have less of an incentive to improve the conditions of their rented accommodations. An energy policy targeting especially the latter group might benefit not only households in rented accommodation, but might increase energy-efficiency and reduce greenhouse gas emissions as well.

Keywords: heating expenditures, Germany, space heating, energy-efficiency, price elasticity, income elasticity

JEL Codes: C2, Q2, Q4

1. Introduction

Residential energy demand amounts to about 30 % of total final energy consumption in Germany. This is similar to other countries in temperate climatic zones. In 2002, households in Germany spent 736 Mio. Euro for heating and hot water supply. This is approximately 6 % of total household consumption (BMWA, 2005). The German energy policy of the last few years can be characterized as an attempt to improve energy-efficiency and to reduce greenhouse gas emissions.

In 2002, to improve energy efficiency in the building sector the regulation for insulation against heat loss (WSchV, 1994) and the regulation for requirements for heating and hot water supply systems (HeizAnlV, 1998) including exhaust-gas limits for oil and gas heating systems were replaced by a regulation combining energy-efficiency requirements for buildings as a whole including insulation, heating and hot water supply systems (EnEV, 2001). Before 2002 the thermal quality of buildings was assessed on the basis of the insulation properties of building components (e.g. window, roof or wall). Each component had to meet a certain standard. Since 2002 the defined maximum calorific values of buildings (based on energy balances) have to be met. This new regulation allows the substitution between a more energy-efficient heating technology and less efficient insulation to fulfil the calorific requirements of the building. The new regulation aims to reduce energy use for heating by 30% for new buildings compared to the old regulations (BMVBW, 2001).[1]

Energy prices were increased in five steps by the introduction of a green tax in 1999 and successively increased until 2003 (Umweltbundesamt, 2002). In 1999 prices for electricity were increased by 1.02 Cent/kWh, prices for heating oil by 2.05 Cent/litre and prices for gas by 0.164 Cent/kWh. In the following 4 years prices for electricity were increased by another 0.26 Cent/kWh each year. Prices for gas were increased in 2003 by 0.202 Cent/kWh. Price increases were further strengthened by price changes on the commodity markets and the developments of exchange rate between Euro and Dollar. Taken together, all this is likely to have affected households' energy consumption.

This paper starts by first examining the determinants of household expenditure on space heating and hot water supply in Germany. We then investigate if different types of households have responded differently to changes in prices for energy. Our hypothesis is that home owners are likely to suffer less from price increases than renters. Landlords will have less of an incentive to improve on energy-efficiency for their rented out accommodation. One reason is that landlords have to bear the costs of improvements themselves and adjustments in rental rates are subject to strict regulations (unless a new tenant moves in). Another reason is that only new buildings fall under the tighter building regulations, and checks on standards are rare.

The data for this exercise are drawn from the German socio-economic panel. This is a survey of private households and individuals providing detailed information on housing, occupational and socio-economic characteristics of households and individuals. For the 1998 and 2003 surveys the panel offers additional information on households heating systems, which is necessary to conduct this analysis.

Econometric analyses of residential energy demand are numerous. An extensive, if somewhat dated, overview is provided by Madlener (1996). The focus of most of these studies is on price and income elasticities to estimate changes in energy demand, mainly for electricity.

[1] For the most recent measures see EnEV (2004). Detailed information on levels and metric efficiency of the regulation is omitted as the new regulation (EnEV) cannot easily be compared with the older regulations (WSchV and HeizAnlV) as discussed above. In addition, many different building characteristics need to be taken into account when calculating the calorific value of a building.

They differ with respect to model application, time period, location and aggregation level of the data chosen. The majority of studies is based on aggregated data on country or regional basis; most studies are for the US. Studies using individual household-level data are relatively rare due to data availability. Dubin and McFadden (1984) were among the first to investigate the choice of energy-using equipment and energy use using micro-level data for the US. More recent studies applying a discrete / continuous modelling framework are Bernard *et al.* (1996), Lee and Singh (1994) and Liao and Chang (2002). For Europe, most of the studies were conducted for Norway (Halvorsen and Larsen (2001), Nesbakken (1999) and Vaage (2000). Baker and Blundell (1991) applied data for the UK.

In our analysis, we model conditional demand only. That is, the decision for consuming energy is not determined by adjustments in technologies but by adjustments in consumptions of energy given the available technology. Previous studies include different sets of demographic and other socio-economic characteristics to explain differences in residential energy demand (see e.g. Branch, 1993; Garbacz, 1983 and 1985; Green, 1987; Hirst *et al.* 1982; Jung, 1993). The age of household members was found significant as well as the size of the household and the minority / majority household type (Poyer and Williams, 1993).

Baker *et al.* (1989) use data from the annual Family Expenditure Survey of Great Britain pooled for 1972 to 1983. Leth-Petersen and Togeby (2001) use panel-data for the period 1984-1995 to estimate the demand for space heating in apartment blocks in Denmark. The focus of the study is on determining the effects of policy measures to reduce energy consumption. The data is not based on the household level, but rather on buildings of more than 1500 m^2. Linderhof (2001) investigates the demand for energy in the Netherlands. Berkhout *et al.* (2004) investigate the ex post impact of an energy tax on Dutch household demand for energy. Rao (submitted) and Gundimeda and Köhlin (submitted) use both micro data to estimate fuel demand elasticities for India. Wu *et al.* (2004) analyse the demand for space heating using micro-level data for Armenia, Moldova and the Kyrgyz Republic.

Our analysis is in line with previous research including a large number of socio-economic and building characteristics that would influence households' energy demand for space heating and hot water supply. In addition, we examine if there is a significant difference between different types of households. To our knowledge, there is only one other study that investigates the energy consumption for space heating in Germany on household level.[2] Schuler *et al*. (2000) use 1988 data for West Germany to examine the extent to which socio-economic variables can explain differences in households' behaviour. Separate regressions are estimated for socio-economic variables and building characteristics. The results are used to evaluate energy efficiency factors from technical simulations.

In contrast, we include both socio-economic and building characteristics in our regressions and care for regional difference in space heating demand. We use information on household expenditure on heating and hot water for the reunified Germany. We also investigate who suffered most from increases in energy prices between 1998 and 2003, home owners or renters, and if regional differences exist. This is another difference to Schuler *et al.* (2000). Unlike most earlier studies using micro-level data, our analysis is not restricted to the demand for electricity. Different energy sources are included. In fact, only few households in Germany use electricity as a primary source for heating, while air conditioning is rare in private homes.

[2] There are earlier studies using micro-level data provided by the statistical office. The drawback of the data is that it covers only three selected types of households (see e.g. Pfaffenberger *et al.*, 1983; and Dennerlein, 1987). Household type 1 includes two-person households receiving pensions or social benefits; household type 2 is a four-person household of blue- and white-collar workers with medium income; household type 3 is a four-person household of white-collar workers and civil servants with higher income.

The remainder of the paper is as follows, the next section describes the data used for the analysis. Section 3 presents and discusses the regression results for different model specifications. In section 4, energy price increases and their effect on household expenditure and consumption for heating and hot water supply are investigated. Section 5 concludes.

2. Data employed

The data used in this study was provided by the German socio-economic panel survey. Since 1984, the survey has provided annual information on housing, on the occupation, employment history and earnings of individuals. In 1990, it was extended to include the former East Germany. In addition to a stable set of core questions, each year the survey focuses on a special topic. In 1998 and 2003 the dataset includes detailed information on the heating and hot water supply systems of households, which is important for the conduct of an analysis on the determinants of household's demand for energy. In order to take advantage of this information the analysis in this paper relies exclusively on the 1998 and 2003 surveys.

In terms of structural attributes the model includes dummy variables describing a property's state of renovation, its date of construction, as well as the type of property (flat, detached house etc). The model controls for the size of the property in square meters, as well as whether the house has central heating, a bath or shower, if it is owner-occupied or a subsidized apartment. Having central heating, a bath or shower is likely to increase household expenditure as it is more strenuous to heat with single stove, and average room temperature would be lower. Further dummy variables indicate the type of heating system: oil, gas, coal (including briquette and wood), electricity, solar, district heating or else (e.g. liquefied gas); and if a new heating system or new windows were installed in the property or if some other modernisation took place in the previous year.

Apart from the many variables indicating dwelling differences outlined above, the regression also controls for a large number of socio-economic characteristics. These include the household size; the number of children in the household; the net household income; the average age of the adult household members; and the number of household members being officially registered as unemployed.

Controls are also included for the size of the town or city in which the property is located. Data on heating degree days, although generally included in other studies, was not provided by the survey (and is available only at high expense). However, the climate in Germany is mostly temperate and not nearly as diverse as for example in Italy or the United States. To capture regional differences, dummy variables indicate in which of the 16 Bundesländer the household lives. A further dummy variable indicates whether observations are drawn from the 1998 or the 2003 survey or from the East or the West of Germany.

A limitation of the data used in the regressions is that no information is offered on energy consumption for space heating; instead, expenditures on energy consumption are recorded. Also, no information is available on efficiency or age of the heating system, the presence of double glazing or other forms of insulation. The variables indicating the state of renovation, the age of the building and if the property is owner occupied might capture some of this information. Owners are more likely to invest in energy-efficient construction, appliances or insulation. Therefore, data for tenants and home owners are analysed together as well as separately. We excluded from our analysis households living in residential homes, student halls or hostels, households receiving social benefits or those paying a reduced rent. For most of these households, expenditures for heating and hot water are included in the monthly rent and are independent of consumption. Households receiving social benefits were excluded as

their rent is partly paid by the government.[3] Also excluded are households with more than one source of heating system except for solar energy. This reduces the number of observations from 16,689 available for analysis to 12,634; 7,547 of them refer to the 2003 survey. The definition of variables included in the analysis is shown in table 1.

Table 1 about here

3. Empirical analysis

The logarithm of monthly expenditures for space heating and hot water supply per square meter was regressed on a number of socio-economic, building and heating characteristics as described above.[4] Note that for home owners, the survey asks for costs of heating and hot water supply in the previous year while tenants are asked for their monthly expenditures for heating and hot water. However, expenditures are mainly based on consumption in the previous year, as the meter is generally read only once a year in Germany. Therefore, information for owner occupied properties and those that are rented should refer to the same period and can be both included in the analysis. The models are estimated using panel-corrected least squares invoked by the <cluster> option in the STATA computer language. This deals with any correlation between disturbances from observations drawn from the same household as well as providing heteroscedasticity-consistent standard errors. The effect is to slightly increase the standard errors of the parameter coefficients.

Table 2 presents regression results for seven different model specifications. The first specification includes all available observations. The RESET test for functional form points to a possible misspecification of this model. Only after experimenting with different kinds of model specifications we noticed that including the variable H_INCL (costs for heating and hot water supply are included in the rent) almost always led to problems of misspecification. Although the meter is read at least once a year, monthly payments are normally not adjusted to differences in consumption but are constant for several years. As a consequence, some households have to make additional payments while others get money back depending on their consumption. Therefore, we reduced the model to exclude these observations from further specifications. Separate regressions are also presented for East and West Germany, for the years 1998 and 2003 as well as owner occupied and rented accommodation. Except for model one (including all 12,634 observations) and model seven (owner occupied accommodation only), the specifications pass the Ramsey RESET test for possible misspecification. Specification seven (home owners) fails to pass only slightly. Excluding the variable H_INCL from model one, the specification passes the RESET test. The estimated coefficients are similar to those presented in table 2.

Table 2 about here

The results suggest, as expected, that there is a strong effect of the kind of heating system on household's expenditures for heating. In particular, it appears that oil and coal heating seem to be less expensive while other forms of energy used for heating (HEAT_ELSE) have the opposite effect. Heating with solar energy has the expected negative effect, but the estimated

[3] Including such households would bias the results. However, limited sensitivity analyses show that the results, including households on social benefits, are very similar to those discussed below

[4] Different transformations of the dependent variable were considered. The semi-logarithm model provided the most consistent results judging by tests for functional form.

coefficients are statistically not significant. However, less than 1% of all households included use solar as an additional source of energy. Properties built before 1980 are more expensive to heat than more recently built ones. This is especially true for properties built in the period after World War II (BUILT_1948 and BUILT_1971). In East Germany, properties built between 1972 and 1980 are more costly to heat. Also, as expected, expenditures are higher for houses than for flats, regardless of the size. In East Germany, agricultural buildings seem to be most expensive to heat.

Heating costs decrease with the size of the property. The presence of central heating, higher household income, more household members,[5] a higher average age of the adult household members and a higher share of unemployed household members increases expenditure on heating. Unemployment is more significant to households in the East while higher income is insignificant there. Living in the East of Germany or having a new heating system decreases expenditures especially for home owners. Unlike most earlier studies, we find a negative relationship between the number of children in a household and the dependent variable. Hirst *et al.* (1981) and Baker *et al.* (1989) found a positive relationship between household energy consumption and the number of children.[6] More recent studies for Norway found no significant relationship. Nesbakken (1999) included the number of children under the age of 16 years and Vaage (2000) included the number of young children in a household. For the Netherlands, Linderhof (2001) found also no significant relationship between young children and the consumption of natural gas. However, his estimates show a negative relationship for the presence of older children in a household. His explanation is that older children are more away from home. In our analysis we include the number of children in households without differentiating between the age groups. The higher the number of children, the more likely older children are present.

The estimated coefficients for household income show an income elasticity ranging from 0.01 to 0.10 depending on model specification. Other studies using different data and different model specifications found income elasticities ranging from –0.27 to 0.61 (Berkhout *et al*., 2004). The majority of studies estimated income elasticities between 0.08 and 0.17 (Baker et al. 1989; Bernhard *et al.*, 1989; Garbacz, 1983; Hirst *et al.* 1981; Nesbakken, 1999 and Poyer and Williamsen, 1993). The above studies are based on household energy consumption.

Dividing the data into owner occupied and rented accommodation shows very similar results. However, some differences show up that can be explained by different characteristics of home owners and renters. The type of building, e.g., are more important to renters than to home owners. However, one feature of the German property market is that owners are more likely to live in a house and renters in a flat: Only 15.8 % of home owners included in the dataset live in flats, while only 17.3 % of renters live in a house. Also, while only 8.2 % of owner occupied dwellings are in cities with more than 500,000 inhabitants, the percentage of rented accommodation is above 20 %. This variable is also positive and significant (GGK_5) in the specification including renters only. If heating costs are included in the rent, expenditures for heating are significantly lower. This confirms that there is normally a delay when costs are adjusted to current prices for energy as discussed above. An alternative interpretation however is that costs for heating are fixed for (some of) those households and independent of consumption. Levinson and Niemann (2004) found evidence that rents are higher when energy costs are included, but the difference is smaller than the cost of the energy used. Unfortunately, the survey gives no information on whether the expenditures are independent of consumption.

[5] The household size effect could have been removed by normalizing the dependent variable to population. However, this procedure would not lead to consistent results as most independent variables are measured at the level of the household or housing unit and cannot be transformed in per capita terms.

[6] Baker *et al.* (1989) included children under 5 years only.

The variable OWNER indicates that households with property are likely to spend less money on heating compared to home renters. An interpretation is that owners are more likely to improve the conditions of their houses than are tenants. This is further confirmed by the variables measuring the condition of the property (RENOV). Better conditions include better insulation, energy-efficient construction and appliances which reduces expenditures on heating. This is more relevant to renters than to home owners. Over 80 % of home owners state the condition of their property as good. Less than one per cent indicates that the property needs complete renovation and none report that the property is ready for demolition. Interestingly, whereas in the 1998 specification the RENOV variables are all highly significant, none of them is significant in 2003. This might point at improvements in properties' conditions between 1998 and 2003. Other studies including the status of ownership of accommodation found that home owners consume more energy than tenants do (see Baker *et al.* 1989; Vaage, 2000 and Berkhout *et al*., 2004). However, the number of variables describing the property is rather limited in the above studies. Also, in Germany, landlords are responsible for introducing energy related technology, while tenants have to pay the energy bill.

The variables which indicate whether or not the household has a bath or a shower, whether the property is a council house or whether it has new windows (a form of insulation) are not significant. Dummy variables for some Federal States are significant indicating regional differences (market segmentation). Expenditures in 2003 are significantly higher compared to 1998. Between 1998 and 2003 consumer prices for energy have increased by more than 20 % (Statistisches Bundesamt, 2004) in Germany due to price increases on the commodity markets, the trend of the exchange rate between Euro and Dollar and the consequences of the German green tax on energy.

Note that we also tried specifications that included the kind of hot water supply system. The regression results are almost identical to those omitting this information. Including observations with more than one heating system does not significantly alter the results.

Differences in data, study area and regression specification makes a comparison with other studies difficult. While most other studies use household energy consumption as an endogenous variable, this information was unfortunately not provided by the dataset. However, the overall results seem to confirm what most others have found before: a significant influence of households socio-economic characteristics and building characteristics on residential energy demand.

4. Increase in prices for energy and household expenditure

The last few years have shown a considerable increase in energy prices and in particular in consumer energy prices in Germany. Between 1998 and 2004, prices for a barrel of crude oil tripled from $ 12.34 to $ 36.02 (see BMWA, 2005). In this period, household expenditures on a litre of heating oil almost doubled (from € 22.10 to € 40.32 per 100 litre). Prices for gas rose from € 0.28 to € 0.43 per m^3. Electricity prices increased less pronouncedly from € 0.15 to € 0.17 per kWh. Heating and hot water supply systems of households in owner occupied properties and those in rented accommodation might have different rates of energy-efficiency and might, therefore, be affected differently by price increases. As mentioned above, home owners are more likely to have more energy-efficient systems.

In Germany, mainly oil, gas and electricity are used for residential space heating and hot water supply. In our dataset, more than 80 % of households use one of the above energy sources for heating. About 54 % use gas, 40 % use oil and only 6 % use electricity for heating. Also, the above sources of energy are more prevalent in owner occupied properties

(92.1%) than in rented accommodation (72.1%). As renters are more likely to live in cities with more inhabitants, district heating is more common. In our dataset, about 23 % of rented accommodation rely on district heating compared to only 3 % of owner occupied properties. However, we restrict our analysis to the two sources oil and gas because data is more readily available and the number of observations is more sufficient.

Table 3 shows the regression results for the seven different model specification discussed above. Separate regression results are presented for households heating with either gas or oil. Two additional explanatory variables were added providing information on energy prices for 1998 and 2003 for heating oil and gas. The information was taken from BMWA (2005). Between 1998 and 2003 prices for gas increased on average by 14.9 Cent per m^3 and for heating oil by 14.1 Cent per litre. To save space, the estimates for coefficients other than those relating to the different prices for energy or if the property was modernized (heating, windows or other) are omitted but these can be obtained from the author on request. The results are very similar to those discussed above.

Table 3 about here

A doubling of gas or heating oil prices increases household expenditures for those households with gas or oil heating systems by 40 to 50 % on average with oil heating being slightly more expensive. Also, while increases in gas prices seem to raise household expenditure in Western Germany more, increases in oil prices seem to be more costly to households in Eastern Germany. In general, price increases lead to higher expenditures for households in owner occupied accommodation compared to households in rented accommodation. Interestingly, using solar energy for heating decreases expenditures for energy significantly by about 14 %. This is especially true for households heating with oil. Also, modernisation in the form of a new heating system significantly reduces expenditures for those households heating with gas. Other forms of modernisation (indicated by the variable ELSE_NEW) are found to be significant for households heating with oil.

Another general feature of the results is that households in rented accommodation are likely to spend more on heating regardless of the energy source, building type, household characteristics etc. If the prices for gas or oil were to double, expenditures for households in owned accommodation would rise slower compared to households in rented accommodation. This can be seen by comparing the estimated coefficients for OWNER for the first five model specifications. However, for East Germany, this relationship is less clear. The estimated coefficient for OWNER in model specification 3 (East sample) is not significant. One explanation might be that since the reunification great efforts had been made for rehabilitation of all types of residential buildings. As a result, today most rented accommodation offers double glazing, insulation and new heating systems.

Overall, the results confirm our hypothesis that a significant difference in expenditures for heating and hot water supply exists between households in rented or owner occupied accommodation. However, the results also suggest that this difference is likely to become smaller over time. Price increases seem to be generally more costly to home owners (compare specifications 6 and 7) and last year's price increases show a diminishing benefit compared to households in rented accommodation (compare specifications 4 and 5). The results suggest that owners are still more likely to have installed energy-efficient heating and hot water supply systems (comparing the coefficients for OWNER for the model specifications).

Although landlords have less of an incentive to improve the conditions of their rented accommodation they seem to have invested in more energy-efficient systems; last year's price

increases show a diminishing benefit for home owners. Reasons for this might be the introduction of tighter exhaust-gas limits for gas and oil heating systems or the introduction of limits for heat loss for accommodation (independent of ownership) by the implementation of a new regulation in 2002 as discussed above (EnEV, 2001). This hypothesis can only partly be confirmed by our analysis. No modernisation variable is found significant in the specification that includes renters only (specification 6). However, in the specification including data for 2003 only (specification 5) the variable indicating a new heating system (HEAT_NEW) is highly significant for households heating with gas; the variable ELSE_NEW is only significant for households heating with oil. Another explanation might be that modernisation took place between 1998 and 2001. This information is not covered by our data set; only information on whether modernisation took place in the previous year (either in 1997 or 2002) is available. Nevertheless, the difference between households in rented or owner occupied accommodation still exists and future energy prices are likely to rise further. An energy policy targeting those groups of people might be beneficial not only to households in rented accommodation, but might increase energy-efficiency further.

There are few studies estimating price elasticities for energy sources other than electricity. Berkhout *et al.* (2004), Baker *et al.* (1989), Green (1987) and Linderhof (2001) offer estimates on price elasticities for gas ranging from –0.44 to –0.19. A doubling of the price for gas would reduce the consumption by 19 to 44 %.

Garbacz (1985) and Gillingham and Hagemann (1984) report a short-run elasticity for fuel oil space heating of -1.56 and –1.09 respectively (-1.81 and –1.34 respectively including water heating) for the US.

So far, our analysis has been based on expenditures for space heating. The numbers are therefore not readily comparable. The estimates above suggest that households expenditures on gas would increase by 37 to 55%, if prices double. Expenditure for oil would increase by 32 to 67%, if oil prices double. To make our data comparable we divided household expenditure by the respective price of energy. Information on energy prices for 1998 and 2003 for heating oil and gas was again taken from BMWA (2005).We are aware that the calculated variable is only a very rough approximation of energy consumption as fixed costs are not accounted for and energy prices differ over Germany, but data is not readily available for an exact calculation.

Table 4 shows the results for our seven different model specifications discussed above. Again, separate regression results are presented for households heating either with gas or oil.

Table 4 about here

The results indicate that the estimated oil and gas price elasticities based on our approximated energy consumption for households in Germany are comparable at the higher end to those of other studies, which used more appropriately measured consumption data for other countries. Our elasticity for fuel oil space heating range between -2.03 and –1.68 respectively; price elasticities for gas range from –0.63 to –0.44. In general, a similar pattern to that described above for the other variables emerges when using consumption data rather than data on household expenditure.

In a further step we tried to combine the consumption data for household heating either with gas or oil in one regression using information on the energy content of the two sources. This would allow a direct comparison of heating services and remove the differences related solely

to fuel choice. Unfortunately, the Ramsey RESET test points to problems of misspecification for almost all specifications. Therefore, the results are not presented here.

5. Conclusion

The paper investigates the determinants of household expenditure on space heating and hot water supply in Germany. Estimates derived from the regressions suggest that household expenditure is significantly lower for owner occupied accommodation. Those households have therefore suffered less from last year's increase in energy prices compared to those in rented accommodation. One reason might be that home owners are more likely to have invested in energy-efficient heating and hot water supply systems. Tenants have little control over home improvement. Also, landlords have less of an incentive to improve the conditions of their rented out accommodations, as their tenants foot the energy bill and rent control is strong. Our results also suggest that this difference is likely to become smaller over time. Nevertheless, improvements in energy efficiency would not only reduce household expenditure for space heating but can help to reduce greenhouse gas emission reductions as well.

The models we specify have a reasonable goodness of fit and our results on the whole mainly confirm those of previous studies using different data and regions. Nevertheless, this analysis needs to be extended in several ways. First, our analysis was restricted to household expenditure on heating and hot water supply. It would be interesting to see if our results would change if energy consumption (in physical units) would be used as the dependent variable instead. We tried such a specification by dividing expenditures by energy prices. Although, the calculated energy consumption can only be regarded as a rough estimate of the true consumption we find the results comparable to those of other studies using better data for other countries. Second, the dataset offered no information on age or efficiency of heating systems installed. This should have an effect on energy consumption and expenditures. Third, information about whether households had a green electricity provider was not available. Expenditures should be significantly higher. However, the current number of households with green energy is small (about 1.3 % of all German households; Wüstenhagen and Bilharz, in press). Fourth, energy prices in Germany differ. The regional dummy variables captures this, but prices differ even within these regions. All this is deferred to future research.

References

Baker, P. and R. Blundell, 1991, The microeconometric approach to modelling energy demand: Some results for UK households, Oxford Review of Economic Policy 7, 54-76.

Baker, P., Blundell, R. and J. Micklewright, 1989, Modelling household energy expenditures using micro-data, The Economic Journal 99, 720-738.

Bernard, J.-T., Bolduc, D. and D. Bélanger, 1996, Quebec residential electricity demand: a microeconomic approach, Canadian Journal of Economics XXIX, 92-113.

Berkhout, P.H.G., Ferrer-I-Carbonell, A. and J.C. Muskens, 2004, The ex post impact of an energy tax on household energy demand, Energy Economics 26, 297-317.

BMWA, 2005, Energiedaten – Nationale und International Entwicklung, Stand 22.2.2005, Bundesministerium für Wirtschaft und Arbeit, Berlin.

BMVBW, 2001, Energieeinsparverordnung: Eine gute Entscheidung für Klima und Bauwirtschaft, Pressemitteilung vom 07.03.2001 vom Bundesministerium für

Wirtschaft und Technologie und vom Bundesministerium für Verkehr, Bau und Wohnungswesen, Berlin.

Branch, E.R., 1993, Short run income elasticities of demand for residential electricity using consumer expenditure survey data, Energy Journal 14, 111-121.

Dennerlein, R. K.-H., 1987, Residential Demand for Electrical Appliances and Electricity in the Federal Republic of Germany, Energy Journal 8, 69-86.

Dubin, J.A. and D.L. McFadden, 1984, An Econometric Analysis of Residential Electric Appliance Holdings and Consumption, Econometrica 52, 345-362.

EnEV, 2001, Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (EnEV) vom 16. November 2001.

EnEV, 2004, Bekanntmachung der Neufassung der Energieeinsparverordnung (EnEV) vom 2. Dezember 2004, Bundesgesetzblatt 2004 Teil I Nr. 6 vom 7.12.2004, Bonn, pp. 3144-3162.

Garbacz, C., 1983, A model of residential demand for electricity using a national household sample, Energy Economics 5, 124-128.

Garbacz, C., 1985, Residential fuel oil demand: a micro-based national model, Applied Economics 17, 669-674.

Gillingham, R. and R.P. Hagemann, 1984, Household demand for fuel oil, Applied Economics 16, 475-482.

Green, R.D., 1987, Regional variations in US consumer response to price changes in home heating fuels: the Northeast and the South, Applied Economics 19, 1261-1268.

Gundimela, H. and G. Köhlin, submitted, Fuel demand elasticities for energy and environmental policies: Indian sample survey evidence, Energy Economics.

Halvorsen, B. and B.M. Larsen, 2001, The flexibility of household electricity demand over time, Resource and Energy Economics 23, 1-18.

HeizAnlV, 1998, Heizungsanlagen-Verordnung - Verordnung über energiesparende Anforderungen an heizungstechnischen Anlagen und Warmwasseranlagen, Neufassung vom 4. Mai 1998, Bundesgesetzblatt Teil I 1998 S. 851.

Hirst, E., Goeltz, R. and J. Carney, 1982, Residential energy use – Analysis of disaggregated data, Energy Economics 4, 74-82.

Jung, T.Y., 1993, Ordered logit model for residential electricity demand in Korea, Energy Economics 15, 205-209.

Lee, R.-S. and N. Singh, 1994, Patterns in residential gas and electricity consumption: an econometric analysis, Journal of Business and Economic Statistics 12, 233-241.

Leth-Petersen, S. and M. Togeby, 2001, Demand for space heating in apartment blocks. Measuring effects of policy measures aiming at reducing energy consumption, Energy Economics 23, 387-403.

Levinson, A. and S. Niemann, 2004, Energy use by apartment tenants when landlords pay for utilities, Resource and Energy Economics 26, 51-75.

Liao, H.-C. and T.-F. Chang, 2002, Space-heating and water-heating energy demands of the aged in the US, Energy Economics 24, 267-284.

Linderhof, V. G. M., 2001, Household demand for energy, water and the collection of waste: a microeconometric analysis, Ph.D. dissertation, University of Groningen, Labyrint Publication, Capelle a/d IJssel.

Madlener, R., 1996, Econometric analysis of residential energy demand: a survey, Journal of Energy Literature II 2, 3-32.

Nesbakken, R., 1999, Price sensitivity of residential energy consumption in Norway, Energy Economics 21, 493-515.

Pfaffenberger, W., Meyer-Renschhausen, M. and O. Hohmeyer, 1983, Energy conservation by private households in the Federal Republic of Germany: The efficacy and distributional effects of energy policy, Journal of Economic Psychology 3, 285-298.

Poyer, D.A. and M. Williams, 1993, Residential energy demand: additional empirical evidence by minority household type, Energy Economics 15, 93-100.

Rao, M.N., submitted, Engel elasticity for energy carriers in India: An indirect approach, Energy Economics.

Statistisches Bundeamt, 2004, Preise: Verbraucherpreisindizes für Deutschland, Fachserie 17/Reihe 7, Januar 2004, Statistisches Bundesamt, Wiesbaden.

Schuler, A., Weber, C. and U. Fahl, 2000, Energy consumption for space heating of West-German households: empirical evidence, scenario projections and policy implications, Energy Policy 28, 877-894.

Umweltbundesamt, 2002, Ökosteuer – sparen oder zahlen? Umweltbundesamt, Berlin.

Vaage, K., 2000, Heating technology and energy use: a discrete / continuous choice approach to Norwegian household energy demand, Energy Economics 22, 649-666.

WSchV, 1994, Wärmeschutzverordnung - Verordnung über einen Energiesparenden Wärmeschutz bei Gebäuden, in der Fassung der Bekanntmachung vom 16. August 1994, Bundesgesetzblatt Teil I 1994 S. 2121.

Wu, X., Lampietti, J. and A.S. Meyer, 2004, Coping with the cold: space heating and the urban poor in developing countries, Energy Economics 26, 345-357.

Wüstenhagen, R. and M. Bilharz, in press, Green energy market development in Germany: effective public policy and emerging customer demand, Energy Policy.

Table 1. Definition of variables included in the regressions

Variable	Definition
EXP_SQ	Monthly expenditure for space heating and hot water per square meter (Cent per square metre)
SQM	Dwelling size in square metre
HEAT	Heating system (oil, gas, coal (including wood and briquette), electricity, solar, municipal heat distribution or else (i.e. liquid gas)): unity or zero
NEW	Modernisation in last year (new central heating, new windows or other): unity or zero
TYPE	Building type (agricultural building, single or double house, terrace house, flat in building with 3 to 4 flats, flat in building with 5 to 8 flats, flat in building with 9 or more flats, flat in high rise building or else): unity or zero
BUILT	Vintage class (before 1919, 1919-1948, 1949-1971, 1972-1980, 1981-1990, 1991 or later): unity or zero
RENOV	Condition of property (good, needs renovation, needs complete renovation, ready for demolition): unity or zero
GGK	Community size (less than 2000, 2000-20000, 20000-100000, 100000-500000, more than 500000 inhabitants): unity or zero
OWNER	Unity if property is owned, zero otherwise
AGE	Average age of adult household members
HHGR	Household size
CHILD	Number of children in household
INCOME	Household net income (in EURO)
UNEMPL	Share of household members being registered as unemployed
C_HEAT	Unity if property has central heating, zero otherwise
BATH	Unity if property has a bath or shower, zero otherwise
H_INCL	Unity if costs for heating and hot water are included in the rent, zero otherwise
SOCIAL	Unity if the property is a council house, zero otherwise
YEAR	Unity if the observations are drawn from the 2003 survey, zero otherwise
STATE	Federal State (Schleswig-Holstein, Hamburg, Lower Saxony, Bremen, North Rhine-Westphalia, Hesse, Rhineland-Palatinate and Saarland, Baden-Wuerttemberg, Bavaria, Berlin, Brandenburg, Mecklenburg Western-Pommerania, Saxony, Saxony-Anhalt, Thuringia): unity or zero
EAST	Federal States belonging to Eastern Germany (Berlin is matched to the West German sample): unity or zero

Source: German socio-economic panel

Table 2. The results of the regression

Dependent variable = logarithm of monthly expenditures for heating and warm water (in Cent/m^2)

Variable[1]	All Coefficient	West Coefficient	East Coefficient	1998 Coefficient	2003 Coefficient	Renter Coefficient	Owner Coefficient
CONSTANT	5.50E+00*	5.54E+00*	6.83E+00*	5.95E+00*	5.48E+00*	5.65E+00*	5.62E+00*
HEAT_OIL	-1.29E-01*	-1.45E-01*	-1.30E-01	-1.26E-01**	-1.46E-01***	-8.87E-02***	-2.21E-01**
HEAT_GAS	-5.22E-02***	-6.06E-02	-6.47E-03	-5.83E-03	-7.28E-02	-5.27E-03	-1.18E-01
HEAT_DIS	-3.47E-02	-4.05E-02	-2.74E-02	-3.18E-03	-3.94E-02	1.44E-02	-7.49E-02
HEAT_ELEC	1.80E-02	2.95E-02	-4.78E-02	4.47E-02	9.59E-03	7.79E-02	-5.85E-02
HEAT_SOL	-5.33E-02	-1.72E-02	-3.36E-02	-2.81E-02	-2.91E-02	1.50E-01	-5.02E-02
HEAT_COAL	-3.97E-01*	-4.85E-01*	-3.04E-01**	-3.30E-01*	-5.03E-01**	-1.86E-01*	-5.89E-01*
HEAT_ELSE	1.45E-01*	9.99E-02	2.08E-01	1.84E-01**	1.39E-01	5.71E-01*	4.80E-02
STATE_1	6.54E-02***	8.27E-02	(dropped)	4.76E-03	1.64E-01**	2.02E-01**	-1.19E-01***
STATE_2	(dropped)	6.02E-02	(dropped)	-1.62E-02	1.62E-01**	(dropped)	(dropped)
STATE_3	-3.62E-02	-4.01E-02	(dropped)	-1.60E-01	7.32E-02	2.64E-02	-2.21E-01*
STATE_4	-4.07E-02	(dropped)	(dropped)	(dropped)	(dropped)	2.16E-01***	-2.28E-01**
STATE_5	-3.49E-02	-3.41E-02	(dropped)	-1.74E-01	9.12E-02	6.00E-02	-2.27E-01*
STATE_6	-6.23E-03	-3.24E-02	(dropped)	-1.13E-01	5.69E-02	2.23E-02	-2.12E-01*
STATE_7	1.19E-02	9.67E-03	(dropped)	-1.40E-01	1.35E-01***	4.94E-02	-1.71E-01*
STATE_8	1.88E-02	1.37E-02	(dropped)	-1.38E-01	1.48E-01***	1.63E-01**	-1.88E-01*
STATE_9	2.60E-02	2.08E-02	(dropped)	-1.30E-01	1.53E-01**	1.12E-01***	-1.64E-01*
STATE_10	-6.33E-03	-2.46E-02	(dropped)	-1.39E-01	6.55E-02	1.22E-02	-2.27E-01*
STATE_11	-3.31E-02	(dropped)	-1.04E-02	1.79E-02	-1.77E-02	-4.71E-02	-6.30E-03
STATE_12	1.49E-02	(dropped)	2.74E-02	9.29E-02***	-7.31E-03	1.19E-01**	-1.46E-02
STATE_13	6.08E-02**	(dropped)	4.03E-02	4.91E-02	4.01E-02	1.82E-02	4.08E-02
STATE_14	4.64E-02***	(dropped)	4.13E-02	6.81E-02	3.58E-02	1.42E-01**	1.01E-02
STATE_15	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)
TYPE_AGR	2.55E-01**	2.59E-01***	(dropped)	3.69E-01*	1.04E-01	3.12E-01**	1.58E-01
TYPE_HOUSE	2.64E-01**	2.70E-01**	-4.29E-02**	3.75E-01*	9.20E-02	3.57E-01*	1.32E-01
TYPE_TERR	1.91E-01***	1.79E-01	-8.90E-02	3.02E-01*	7.03E-03	3.15E-01*	4.52E-02
TYPE_FLAT4	1.35E-01	1.04E-01	-1.50E-01	1.90E-01**	-4.17E-02	2.74E-01*	-8.51E-03

TYPE_FLAT8	7.29E-02**	3.81E-02	-3.22E-01*	1.55E-01***	-1.70E-01	2.38E-01**	-2.18E-01
TYPE_FLAT9	5.09E-02	1.37E-02	-2.90E-01*	1.47E-01	-1.88E-01	2.30E-01**	-2.04E-01
TYPE_HIGH	5.63E-02	-1.22E-02	-4.50E-01**	1.24E-01	-2.67E-01	2.08E-01***	-2.45E-01
TYPE_ELSE	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)
BUILT_1918	1.25E-01*	1.62E-01*	1.43E-01*	8.03E-02**	2.19E-01*	2.96E-02	2.06E-01*
BUILT_1948	1.29E-01*	1.70E-01*	1.86E-01*	1.13E-01*	2.27E-01*	3.10E-02	2.36E-01*
BUILT_1971	1.19E-01*	1.83E-01*	1.50E-01*	1.14E-01*	2.30E-01*	6.26E-02**	2.28E-01*
BUILT_1980	1.18E-01*	1.52E-01*	2.13E-01*	1.22E-01*	1.92E-01*	3.31E-02	2.15E-01*
BUILT_1990	6.50E-02*	8.33E-02*	1.57E-01*	-5.90E-03	1.62E-01*	5.48E-03	1.40E-01*
BUILT_1991	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)
GGK_1	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)
GGK_2	-9.44E-04	7.04E-04	1.25E-02	8.48E-03	-7.96E-03	2.09E-02	-3.48E-03
GGK_3	1.41E-02	1.14E-02	3.00E-02	1.98E-02	-5.74E-03	5.35E-02	-5.48E-04
GGK_4	1.35E-02	2.99E-02	-2.15E-02	4.14E-02	-5.74E-03	9.23E-02**	-1.99E-02
GGK_5	2.63E-02	2.05E-02	(dropped)	3.01E-02	2.90E-03	1.13E-01**	-3.52E-02
RENOV_1	-2.09E-01**	-2.24E-01	-3.25E-01	-5.50E-01*	-1.90E-01	-2.26E-01***	-9.93E-02
RENOV_2	-1.78E-01***	-1.82E-01	-2.90E-01	-5.04E-01*	-1.54E-01	-1.98E-01	-4.89E-02
RENOV_3	-1.18E-01	-1.31E-01	-2.06E-01	-4.19E-01*	-1.31E-01	-1.50E-01	(dropped)
RENOV_4	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)
LOG_INC	6.03E-02*	7.42E-02*	2.39E-02	5.48E-02*	7.43E-02*	1.04E-02	9.53E-02*
LOG_HHGR	9.30E-02*	9.49E-02*	1.22E-01*	7.90E-02*	1.13E-01*	1.27E-01*	8.52E-02*
LOG_AGE	1.00E-01*	1.36E-01*	1.14E-01**	1.07E-01*	1.61E-01*	1.05E-01*	1.54E-01*
LOG_CHILD	-7.67E-02*	-8.67E-02*	-6.23E-02	-7.81E-02**	-7.66E-02*	-5.57E-02	-8.32E-02*
UNEMPL	6.47E-02*	-2.06E-02	1.04E-01**	6.29E-02	3.29E-02	-1.93E-02	7.12E-02***
C_HEAT	3.93E-02***	3.28E-02	9.67E-02***	3.93E-02	8.05E-02**	4.30E-02	1.05E-01**
BATH	1.86E-02	-4.50E-02	1.24E-01	3.38E-02	9.61E-03	-4.40E-02	3.21E-02
OWNER	-1.30E-01*	-1.41E-01*	-5.94E-02	-1.82E-01*	-8.03E-02*	(dropped)	(dropped)
LOG_SQM	-4.49E-01*	-4.90E-01*	-6.57E-01*	-5.10E-01*	-5.32E-01*	-4.52E-01*	-5.61E-01*
SOCIAL	5.91E-03	3.96E-02	2.92E-02	3.73E-02	4.03E-02	1.59E-02	(dropped)
H_INCL	-1.90E-02***	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)
YEAR	-1.83E-01*	-2.40E-01*	-2.00E-01*	(dropped)	(dropped)	-1.61E-01*	-2.75E-01*
EAST	3.77E-02	(dropped)	(dropped)	-7.53E-02	1.48E-01***	7.00E-02	-1.27E-01**
HEAT_NEW	-5.60E-02**	-3.34E-02	-1.17E-01**	-4.88E-02	-5.78E-02	-4.00E-02	-5.75E-02***

WIND_NEW	1.38E-02	5.74E-03	-7.89E-03	-1.92E-02	2.81E-02	6.44E-03	-8.74E-04
ELSE_NEW	-1.74E-02	-3.51E-02***	-2.33E-02	-4.18E-02	-1.99E-02	1.34E-02	-4.19E-02**
No. Obs	12,634	7,286	1,765	3,543	5,508	2,869	6,182
R-Squared	19.43	22.29	26.87	21.61	20.86	17.26	24.53
RESET test (P>F)	0.0000	0.2299	0.2052	0.1779	0.4751	0.1055	0.0055

*Source: Own calculation. Significance at one-percent level is indicated by *, significance at five-percent level is indicated by ** and significance at ten-percent level is indicated by ***.*

[1] *LOG indicates that the logarithm of the variable was used.*

Table 3. Changes in household energy expenditure caused by energy price increases

Dependent variable =logarithm of monthly expenditures for heating and warm water (in Cent/m^2)

Variable[1]	All Coefficient	West Coefficient	East Coefficient	1998 Coefficient	2003 Coefficient	Renter Coefficient	Owner Coefficient
LOG_PRICE_GAS	0.4301*	0.4967*	0.4213*			0.3738*	0.5558*
OWNER	-0.1183*	-0.1368*	-0.0548	-0.1579*	-0.0862*		
HEAT_NEW	-0.0791**	-0.0793***	-0.1601**	-0.0724	-0.1484*	-0.0566	-0.1176**
WIND_NEW	-0.0070	-0.0100	-0.0095	-0.0713***	0.0510	0.0221	-0.0320
ELSE_NEW	-0.0098	-0.0281	-0.0358	-0.0180	-0.0370	-0.0360	-0.0305
No. Obs	5,577	3,525	866	1,601	2,790	1,474	2,917
R-Squared	17.78	20.02	28.22	19.00	21.10	18.57	22.05
RESET test (P>F)	0.3029	0.8122	0.9799	0.3893	0.1959	0.4060	0.0057
LOG_PRICE_OIL	0.4863*	0.5794*	0.6510*			0.3287*	0.6753*
OWNER	-0.1050*	-0.1252*	0.0400	-0.2054*	-0.0322		
HEAT_NEW	0.1744	0.0100	0.0896	0.1744	-0.0165	0.1632	0.0264
WIND_NEW	0.0019	0.0119	-0.0153	0.0019	0.0747	0.0152	0.0109
ELSE_NEW	-0.0416***	-0.0647**	-0.0275	-0.0416	-0.0670***	0.0515	-0.0568**
No. Obs	4,148	2,717	467	1,252	1,932	688	2,496
R-Squared	22.64	25.16	39.75	26.94	20.19	16.96	30.12
RESET test (P>F)	0.0007	0.3710	0.2057	0.6626	0.3815	0.3355	0.0834

*Source: Own calculation. Significance at one-percent level is indicated by *, significance at five-percent level is indicated by ** and significance at ten-percent level is indicated by ***.*

[1] *LOG indicates that the logarithm of the variable was used.*

Table 4. Changes in household energy consumption caused by energy price increases

Dependent variable = logarithm of monthly consumption of gas or oil for heating and warm water (in m3/sqm, l/sqm)

Variable[1]	All Coefficient	West Coefficient	East Coefficient	1998 Coefficient	2003 Coefficient	Renter Coefficient	Owner Coefficient
LOG_PRICE_GAS	-0.5699*	-0.5033*	-0.5787*			-0.6262*	-0.4442*
OWNER	-0.1183*	-0.1368*	-0.0548	-0.1579*	-0.0862*		
No. Obs	5,577	3,525	866	1,601	2,790	1,474	2,917
R-Squared	22.00	22.93	30.68	19.00	21.10	25.15	21.50
RESET test (P>F)	0.9713	0.6376	0.2319	0.3893	0.1959	0.1429	0.0079
LOG_PRICE_OIL	-1.8730*	-1.7799*	-1.7083*			-2.031*	-1.6840*
OWNER	-0.1050*	-0.1252*	0.0400	-0.2054*	-0.0322		
No. Obs	4,148	2,717	467	1,252	1,932	688	2,496
R-Squared	59.35	56.32	62.48	26..94	20.19	62.27	54.23
RESET test (P>F)	0.0063	0.0636	0.0112	0.6626	0.3815	0.2265	0.4052

*Source: Own calculation. Significance at one-percent level is indicated by *.*

[1] *LOG indicates that the logarithm of the variable was used.*

Working Papers

Research Unit Sustainability and Global Change

Hamburg University and Centre for Marine and Atmospheric Science

Rehdanz, K. (2005), *Determinants of residential space heating expenditures in Germany*, **FNU-66** (forthcoming)

Ronneberger, K., R.S.J. Tol and U.A. Schneider (2005), *KLUM: A simple model of global agricultural land use as a coupling tool of economy and vegetation*, **FNU-65** (submitted)

Tol, R.S.J. (2005), *The Benefits of Greenhouse Gas Emission Reduction: An Application of* FUND, **FNU-64** (submitted)

Röckmann, C., M.A. St.John, F.W. Köster, F.W. and R.S.J. Tol (2005), *Testing the implications of a marine reserve on the population dynamics of Eastern Baltic cod under varying environmental conditions*, **FNU-63** (submitted)

Letsoalo, A., J. Blignaut, T. de Wet, M. de Wit, S. Hess, R.S.J. Tol and J. van Heerden (2005), *Triple Dividends of Water Consumption Charges in South Africa*, **FNU-62** (submitted)

Zandersen, M., Termansen, M., Jensen,F.S. (2005), *Benefit Transfer over Time of Ecosystem Values: the Case of Forest Recreation*, **FNU-61** (submitted)

Rehdanz, K., Tol, R.S.J. and Wetzel, P. (2005), *Ocean Carbon Sinks and International Climate Policy*, **FNU-60** (submitted)

Schwoon, M. (2005), *Simulating The Adoption of Fuel Cell Vehicles*, **FNU-59** (submitted)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2005), *The Impact of Climate Change on Domestic and International Tourism: A Simulation Study*, **FNU-58** (submitted)

Bosello, F., R. Roson and R.S.J. Tol (2004), *Economy-wide estimates of the implications of climate change: Human health*, **FNU-57** (submitted, *Ecological Economics*)

Hamilton, J.M. and M.A. Lau (2004) *The role of climate information in tourist destination choice decision-making*, **FNU-56** (forthcoming, Gössling, S. and C.M. Hall (eds.), Tourism and Global Environmental Change. London: Routledge)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2004), *The impact of climate on holiday destination choice*, **FNU-55** (submitted, *Climatic Change*)

Bigano, A., J.M. Hamilton, M. Lau, R.S.J. Tol and Y. Zhou (2004), *A global database of domestic and international tourist numbers at national and subnational level*, **FNU-54** (submitted)

Susandi, A. and R.S.J. Tol (2004), *Impact of international emission reduction on energy and forestry sector of Indonesia*, **FNU-53** (submitted)

Hamilton, J.M. and R.S.J. Tol (2004), *The Impact of Climate Change on Tourism and Recreation*, **FNU-52** (submitted)

Schneider, U.A. (2004), *Land Use Decision Modelling with Soil Status Dependent Emission Rates*, **FNU-51** (submitted)

Link, P.M., U.A. Schneider and R.S.J. Tol (2004), *Economic impacts of changes in fish population dynamics: the role of the fishermen's harvesting strategies*, **FNU-50** (submitted)

Berritella, M., A. Bigano, R. Roson and R.S.J. Tol (2004), *A General Equilibrium Analysis of Climate Change Impacts on Tourism*, **FNU-49** (submitted, *Tourism Management*)

Tol, R.S.J. (2004), *The Double Trade-Off between Adaptation and Mitigation for Sea Level Rise: An Application of* FUND, **FNU-48** (submitted, *Mitigation and Adaptation Strategies for Global Change*)

Erdil, Erkan and Yetkiner, I. Hakan (2004), *A Panel Data Approach for Income-Health Causality*, **FNU-47**

Tol, R.S.J. (2004), *Multi-Gas Emission Reduction for Climate Change Policy: An Application of* FUND, **FNU-46** (forthcoming, *Energy Journal*)

Tol, R.S.J. (2004), *Exchange Rates and Climate Change: An Application of* FUND, **FNU-45** (submitted, *Climatic Change*)

Gaitan, B., Tol, R.S.J, and Yetkiner, I. Hakan (2004), *The Hotelling's Rule Revisited in a Dynamic General Equilibrium Model*, **FNU-44** (submitted)

Rehdanz, K. and Tol, R.S.J (2004), *On Multi-Period Allocation of Tradable Emission Permits*, **FNU-43** (submitted)

Link, P.M. and Tol, R.S.J. (2004), *Possible Economic Impacts of a Shutdown of the Thermohaline Circulation: An Application of* FUND, **FNU-42** (*Portuguese Economic Journal*, **3**, 99-114)

Zhou, Y. and Tol, R.S.J. (2004), *Evaluating the costs of desalination and water transport*, **FNU-41** (forthcoming, *Water Resources Research*)

Lau, M. (2004), *Küstenzonenmanagement in der Volksrepublik China und Anpassungsstrategien an den Meeresspiegelanstieg*,**FNU-40** (submitted, *Coastline Reports*)

Rehdanz, K. and Maddison, D. (2004), *The Amenity Value of Climate to German Households*, **FNU-39** (submitted)

Bosello, F., Lazzarin, M., Roson, R. and Tol, R.S.J. (2004), *Economy-wide Estimates of the Implications of Climate Change: Sea Level Rise*, **FNU-38** (submitted)

Schwoon, M. and Tol, R.S.J. (2004), *Optimal CO_2-abatement with socio-economic inertia and induced technological change*, **FNU-37** (submitted)

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J. (2004), *The Effects of Climate Change on International Tourism*, **FNU-36** (submitted)

Hansen, O. and R.S.J. Tol (2003), *A Refined Inglehart Index of Materialism and Postmaterialism*, **FNU-35** (submitted)

Heinzow, T. and R.S.J. Tol (2003), *Prediction of Crop Yields across four Climate Zones in Germany: An Artificial Neural Network Approach*, **FNU-34** (submitted, *Climate Research*)

Tol, R.S.J. (2003), *Adaptation and Mitigation: Trade-offs in Substance and Methods*, **FNU-33** (submitted, *Environmental Science and Policy*)

Tol, R.S.J. and T. Heinzow (2003), *Estimates of the External and Sustainability Costs of Climate Change*, **FNU-32** (submitted)

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J. (2003), *Climate change and international tourism: a simulation study*, **FNU-31** (forthcoming, *Global Environmental Change*)

Link, P.M. and R.S.J. Tol (2003), *Economic impacts of changes in population dynamics of fish on the fisheries in the Barents Sea*, **FNU-30** (submitted)

Link, P.M. (2003), *Auswirkungen populationsdynamischer Veränderungen in Fischbeständen auf die Fischereiwirtschaft in der Barentssee*, **FNU-29** (*Essener Geographische Arbeiten*, **35**, 179-202)

Lau, M. (2003), *Coastal Zone Management in the People's Republic of China – An Assessment of Structural Impacts on Decision-making Processes*, **FNU-28** (submitted)

Lau, M. (2003), *Coastal Zone Management in the People's Republic of China – A Unique Approach?*, **FNU-27** (*China Environment Series*, Issue 6, pp. 120-124; http://www.wilsoncenter.org/topics/pubs/7-commentaries.pdf)

Roson, R. and R.S.J. Tol (2003), *An Integrated Assessment Model of Economy-Energy-Climate – The Model Wiagem: A Comment*, **FNU-26** (forthcoming, *Integrated Assessment*)

Yetkiner, I.H. (2003), *Is There An Indispensable Role For Government During Recovery From An Earthquake? A Theoretical Elaboration*, **FNU-25**

Yetkiner, I.H. (2003), *A Short Note On The Solution Procedure Of Barro And Sala-i-Martin for Restoring Constancy Conditions*, **FNU-24**

Schneider, U.A. and B.A. McCarl (2003), *Measuring Abatement Potentials When Multiple Change is Present: The Case of Greenhouse Gas Mitigation in U.S. Agriculture and Forestry*, **FNU-23** (submitted)

Zhou, Y. and Tol, R.S.J. (2003), *The Implications of Desalination to Water Resources in China - an Economic Perspective*, FNU-22 (*Desalination*, **163** (4), 225-240)

Yetkiner, I.H., de Vaal, A., and van Zon, A. (2003), *The Cyclical Advancement of Drastic Technologies*, **FNU-21**

Rehdanz, K. and Maddison, D. (2003) *Climate and Happiness*, **FNU-20** (*Ecological Economics*, **52** 111-125)

Tol, R.S.J., (2003), *The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, **FNU-19** (*Energy Policy*, **33** (16), 2064-2074).

Lee, H.C., B.A. McCarl, U.A. Schneider, and C.C. Chen (2003), *Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation*, **FNU-18** (submitted).

Schneider, U.A. and B.A. McCarl (2003), *Implications of a Carbon Based Energy Tax for U.S. Agriculture*, **FNU-17** (submitted).

Tol, R.S.J. (2002), *Climate, Development, and Malaria: An Application of* FUND, **FNU-16** (forthcoming, *Climatic Change*).

Hamilton, J.M. (2003), *Climate and the Destination Choice of German Tourists*, **FNU-15** (revised and submitted).

Tol, R.S.J. (2002), *Technology Protocols for Climate Change: An Application of* FUND, **FNU-14** (forthcoming, *Climate Policy*).

Rehdanz, K (2002), *Hedonic Pricing of Climate Change Impacts to Households in Great Britain*, **FNU-13** (forthcoming, *Climatic Change*).

Tol, R.S.J. (2002), *Emission Abatement Versus Development As Strategies To Reduce Vulnerability To Climate Change: An Application Of* FUND, **FNU-12** (forthcoming, *Environment and Development Economics*).

Rehdanz, K. and Tol, R.S.J. (2002), *On National and International Trade in Greenhouse Gas Emission Permits*, **FNU-11** (forthcoming, *Ecological Economics*).

Fankhauser, S. and Tol, R.S.J. (2001), *On Climate Change and Growth*, **FNU-10** (*Resource and Energy Economics*, **27**, 1-17).

Tol, R.S.J. and Verheyen, R. (2001), *Liability and Compensation for Climate Change Damages – A Legal and Economic Assessment*, **FNU-9** (*Energy Policy*, **32** (9), 1109-1130).

Yohe, G. and R.S.J. Tol (2001), *Indicators for Social and Economic Coping Capacity – Moving Toward a Working Definition of Adaptive Capacity*, **FNU-8** (*Global Environmental Change*, **12** (1), 25-40).

Kemfert, C., W. Lise and R.S.J. Tol (2001), *Games of Climate Change with International Trade*, **FNU-7** (*Environmental and Resource Economics*, **28**, 209-232).

Tol, R.S.J., W. Lise, B. Morel and B.C.C. van der Zwaan (2001), *Technology Development and Diffusion and Incentives to Abate Greenhouse Gas Emissions*, **FNU-6** (submitted, *International Environmental Agreements*).

Kemfert, C. and R.S.J. Tol (2001), *Equity, International Trade and Climate Policy*, **FNU-5** (*International Environmental Agreements*, **2**, 23-48).

Tol, R.S.J., Downing T.E., Fankhauser S., Richels R.G. and Smith J.B. (2001), *Progress in Estimating the Marginal Costs of Greenhouse Gas Emissions*, **FNU-4**. (*Pollution Atmosphérique – Numéro Spécial: Combien Vaut l'Air Propre?*, 155-179).

Tol, R.S.J. (2000), *How Large is the Uncertainty about Climate Change?*, **FNU-3** (*Climatic Change*, **56** (3), 265-289).

Tol, R.S.J., S. Fankhauser, R.G. Richels and J.B. Smith (2000), *How Much Damage Will Climate Change Do? Recent Estimates*, **FNU-2** (*World Economics*, **1** (4), 179-206)

Lise, W. and R.S.J. Tol (2000), *Impact of Climate on Tourism Demand*, **FNU-1** (*Climatic Change*, **55** (4), 429-449).