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Evidence on the German Car Fuel Tax

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On the Emissions–Inequality Trade-off in Energy Taxation: Evidence on the German Car Fuel Tax[♦]

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Abstract

By using estimates from an Almost Ideal Demand System (AIDS), we investigate how the German energy tax on car fuels changes the private households' CO_2 emissions, living standards, and post-tax income distribution. Our results show that the tax implies a trade-off between the aim to reduce emissions and vertical equity, which refers to the idea that people with a greater ability to pay taxes should pay more.

JEL codes: C31, D12, D63, H22, H23, I3, K32, Q21

Keywords: energy taxes, environmental taxes, energy demand, emissions, tax incidence, redistribution, inequality

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1 Introduction

Faced with climate change and threats to environmental sustainability, many countries, particularly those in Europe, are redesigning and enhancing their environmental policies to reduce the anthropogenic carbon dioxide emissions (World Nuclear Association, 2011). Despite these changes, residential energy consumption, an important determining factor of CO_2 emissions, has increased in Europe in recent years (The World Bank, 2013). This apparently paradoxical situation calls for thorough investigation of the determinants of household energy demand.

Our study deals with the environmental and distributive effects of the energy tax on car fuels in Germany, a country that places high priority on both environmental protection (International Energy Agency, 2007) and distributive justice. The energy tax on car fuels is charged as a fixed monetary amount per liter and serves as an instrument to reduce households' vehicle emissions, the largest source of CO_2 emissions after the industrial sector (International Energy Agency, 2007). Crucial for the size of the environmental effect is the price elasticity of demand for car fuels: the more elastic the demand, the larger the environmental effect in terms of the CO_2 emissions reduction. Crucial for the distributive effect is the shape of the Engel curve if the expenditure (share) for fuels decreases in income, then vertical equity is at risk, as households with a greater ability to pay will then pay lower taxes relative to income.

The potential emissions-inequality trade-off of energy taxation has become an important issue in environmental economics.[3] As pointed out by Baumol and Oates (1988), by ignoring the emissions-inequality trade-off, "we may either unintentionally harm certain groups in society or, alternatively, undermine the program politically" (p. 235). Most studies investigate the emissions-inequality trade-off in a traditional tax incidence framework, i.e., by quantifying average tax burdens at different points of the income distributions. Only few studies, among them Jorgenson et al. (1992), Oladosu and Rose (2007), and Grösche and Schröder (2014), provide a detailed examination of the redistributive effects using inequality indices (e.g., Gini or Theil index), inequality dominance criteria, or related graphical representations (concentration or Lorenz curves).

We study the potential emissions-inequality trade-off of the German energy tax on car fuels using a demographically scaled Almost Ideal Demand System (AIDS, see Deaton and Muellbauer, 1980, and Ray, 1983). Surprisingly, the redistributive effect of this tax has gained

[3] See Pearson and Smith (1991), Brännlund and Nordström (2004), Wier et al. (2005), Scott and Eakins (2004), Oladosu and Rose (2007), Callan et al. (2008), Fullerton (2008), Grainger and Kolstad (2009), West and Williams III(2004), Jacobsen et al. (2003) or Grösche and Schröder (2014). Studies for Germany include Bach et al. (2002) and Sterner (2012).

little attention so far, although preferences for ecological sustainability and social justice are deeply rooted in German society.[4] Time series of commodity prices and the German Income and Expenditure Survey (IES), a representative household sample, serve as the empirical basis.[5]

Our estimates indicate that an emissions–inequality trade-off exists: The energy tax on car fuels is effective in lowering CO_2 emissions but it is regressive because the tax burden relative to income is a decreasing function of household (equivalent) income.[6] As an example, doubling the tax reduces CO_2 emissions by about 17 percent, but increases the level of inequality in the post-tax income distribution. The redistributive effect, however, is small in quantitative terms. For example, the Gini index increases by about 0.002 percentage points. The effect is moderate because expenditures on fuels make up only a small share of household total expenditures, about 3.75 percent on average. On the other hand, the welfare loss, as captured by the equivalent variation is sizeable: on an annual basis, it amounts to an average of 562 euros. The equivalent variation amounts to 232 euros yearly for the 1st decile and to 961 euros for the 9th decile of the equivalent income distribution.

The paper is structured as follows. Section 2 provides a literature review. Section 3 describes the data and Section 4 the quantitative methods. Section 5 provides the demand system estimates and Section 6 the results from the policy analysis. Section 7 provides a sensitivity analysis, and Section 8 presents the concluding remarks.

2 Literature review

Several studies have investigated potential emissions-inequality trade-offs in environmental taxation. From a technical perspective, the studies can be classified according to three criteria: (a) static one-period vs. dynamic multi-period framework; (b) partial analysis of a single sector vs. total analysis with inter-sector linkages; (c) abstraction from or explicit modeling of behavioral responses.

Because the literature is so extensive, we confine our review to selected works with a framework similar to ours: a one-period partial analysis of the household sector with consideration of behavioral responses. One such study is Brännlund and Nordström (2004)

[4] The move towards ecological sustainability is seen in the subsidization of renewable technologies, emissions regulations, and various environmental taxes. Manifestations of the preference for social justice include Germany’s progressive income tax schedule and comprehensive social security system.

[5] The IES is the only German micro database providing in-depth information on household incomes and expenditures. Based on the demand system estimates, we study how the actual level of the car fuels tax and variations of the tax change the post-tax distribution and CO_2 emissions.

[6] Equivalent income is derived by dividing household income by the modified OECD equivalence scale (see Section 4.3 for details).

using Swedish data. They use the Quadratic Almost Ideal Demand System (QUAIDS) and tax simulations to analyze the consumer responses and welfare effects of a CO_2 tax. The authors find that doubling of the CO_2 tax lowers petrol demand by ten percent.[7] Further, using the compensating variation as assessment criterion, the authors show that low-income households, in relative terms to income, carry a larger share of the tax burden in comparison to high-income households, meaning that the tax is regressive. The compensating variation as percentage of disposable income was found to be 0.55 for the poorest and only 0.33 for the richest households. In a related study, Brännlund and Ghalwash (2008) find that equalization of income will lead to higher emissions in Sweden. They have used the estimates from QUAIDS as well as emissions intensities to investigate the nonlinear nature of the income emissions relationship.

West and Williams III (2004) use a one-period analysis of the US household sector, considering behavioral responses in the framework of a general demand system. They quantify welfare changes and redistributive effects (but not the environmental effect) of the US gasoline tax, and show that it is regressive (except when the revenue is used to fund lump-sum transfers). Using a generalized logit demand system, Dumagan and Mount (1992) find that the welfare effect of carbon tax in the US is non-negligible; the welfare losses increase with income but decrease as proportion of income.

Tiezzi (2005) estimates an AIDS for Italy in order to explore the distributional and welfare effects of a carbon tax. She finds that the welfare loss from an introduction of the carbon tax is non-negligible: 2.32 billion euros over four years. Contrary to many other studies, she finds that the tax burden is progressively distributed across Italian households: the welfare loss as a percentage of expenditures increases with income. However, different from other studies she uses total monthly expenditures as opposed to income as the ordering criterion.

3 Data and data preparation

We use two data sources provided to us by the German Federal Statistical Office. The first data source is the German Income and Expenditure Survey (IES), i.e., representative micro-level household income and expenditure data. The second data source is consumer prices for various expenditure categories.

[7] In a later study, Brännlund et al. (2007) find that in order to keep CO_2 emissions at their initial levels (to neutralize the rebound effect), CO_2 tax should be raised by 130%.

3.1 German Income and Expenditure Survey

The German IES is a cross-sectional household micro database, collected once every five years. Each wave includes a quota sample of about 60,000 German households, for which frequency weights are provided to ensure representativeness (for further information on the data see Bönke et al., 2013, and references therein). The variable spectrum of the data is broad, including socio-economic and demographic characteristics, incomes and other revenues, paid taxes and contributions, inventories, wealth (accumulation). Most importantly for our purposes, IES is the single German database with in-depth information on all kinds of household expenditures—from food and electrical appliances to cars and car fuels.

From the most recent IES waves 1993 to 2008, we have generated a pooled database with time-consistent information. Generating such a pooled database was a challenging task; variables have been added and removed, notation of variables and accounting periods of income or expenditures have changed, et cetera. Details on the pooling strategy can be found in Bönke et al. (2013). Most importantly, we have converted all expenditures to yearly amounts in euros and implemented a symmetric trimming of disposable incomes (lowest and highest percentile of the distribution). Furthermore, households with extreme ratios of total expenditures relative to disposable income are not included in the sample.[8]

The final working sample includes 169,486 households in four cross-sections. The following IES variables are used in the empirical analysis: total expenditures; expenditures for food, electricity, other fuels, and car fuels;[9] disposable income; number and age of household members; and frequency weights.

The core variable for the analysis that follows is expenditure on car fuels. It can be derived from the original IES waves by combining a set of variables, identified by a uniform short notation "ef" (German abbreviation for an identifier) and a serial number. For 1993, expenditure on car fuels is the sum of ef761, ef762, and ef763. For 1998-2008, they it is the sum of ef810, ef299, and ef300. Unfortunately, separate data on gasoline and diesel fuel is available only for 1993, making it impossible to separate the two fuels in the empirical analysis.

Figure 1 represents the development of the expenditure shares over time. The expenditure shares are calculated by dividing a specific good expenditure over total expenditures. Each panel of *Figure 1* shows the 10th, 50th (median), and 90th percentile of the expenditure share for each good. The food share decreased between 1993 and 2003 and increased between 2003

[8]Households belonging to the lowest and highest percentile of the distribution of total expenditures relative to disposable income were excluded from the sample.

[9] The choice of the expenditure categories follows Brännlund et al. (2007).

and 2008. The share of electricity declined slightly from 1993 to 1998 and increased thereafter. The expenditure shares for car fuels and other fuels increased steadily over the entire period under consideration. The mean share of car fuel expenditures over the whole period is 0.038. The share of other goods increased between 1993 and 1998 and declined thereafter.

Figure 1 about here

Figure 2 shows the relationship between the expenditures shares and disposable income. The food share in total expenditures is highest (0.171) for the households belonging to the lowest disposable income deciles and decreases with income; for the richest households it is 0.125. While the electricity share of the poorest households takes 3.5 percent of their total expenditures (m), for the richest households it is only 2.2 percent of m. The expenditure share of other fuels is also decreasing with disposable income. The car fuels expenditure share displays a nonlinear relationship with income: for the households in the 1st income decile it is 0.023; it increases to around 0.045 for the 6th and 7th deciles and then decrease slightly to 0.041 for the 10th decile. In contrast to all the other expenditure shares, the share of other goods is increasing with disposable income.

Figure 2 about here

Tables A1-A4 in the Appendix show the construction of the variables in our empirical analysis. Summary statistics of these variables are provided in *Tables A5-A8* in the Appendix. *Figure A1* provides the kernel density functions for the expenditure shares by household types for 2008. Densities for food and electricity indicate that both goods have characteristics of basic goods: basically all households are report positive expenditure shares.[10] For other fuels and car fuels a substantial fraction of households do not seem to consume the goods, as they have no related expenditures. The densities also indicate some marked differences across household types: particularly, the expenditure shares for food and car fuels increase in household size, whereas the opposite holds for other goods.

[10] The small fraction of households with expenditure shares of zero for electricity can be explained by particular social security instruments that step in once households cannot afford their electricity bills.

3.2 Consumer prices

Because the German Federal Statistical Office is responsible for collecting the IES data and computing consumer prices for various goods, we find the same categorization of consumption aggregates in both data sources.

From the consumer prices and household expenditure data, we derive Stone Price Indices (SPI) for three broad expenditure categories: food, other fuels, and other goods. SPIs reflect differences in consumption patterns across household units.

To derive the SPIs, we follow the approach outlined in Hoderlein and Mihailova (2008). Let $a = 1, \dots, A$ denote the different expenditure categories. An expenditure category can encompass several sub-categories of expenditures, $a_1, \dots, a_S$. The corresponding prices are $p_{a_1}, \dots, p_{a_S}$. The expenditure share of an expenditure category a for household h in period t, $w_{a,h,t}$, is defined as, $w_{a,h,t} = x_{a,h,t} / \sum_a x_{a,h,t}$, with $x_{a,h,t}$ denoting nominal expenditures.

The SPI for category a is, $P_{a,h,t} = \frac{1}{k} \prod_{a_s} (\frac{p_{a_s}}{w_{a_s,h,t}})^{w_{a_s,h,t}}$, with $k = \prod_{a_s} (\overline{w}_{a_s,t})^{-\overline{w}_{a_s,t}}$, and with $\overline{w}_{a_s,t}$ denoting the expenditure share of the reference household in period t. A household with average budget shares is taken as the reference household. Finally, the prices for each category are divided by the lowest price in the base period (1993).

Summary statistics of prices are provided in *Tables A5-A8* in the Appendix. The price of car fuels increased over time during the period under observation; the mean price index in 2008 was 1.552, which represents 83percent increase from the price in 1993. Thus, the increase in car fuel expenditures over the period can be attributed largely to price increases but also to increases in the quantity of fuels consumed.

4 Estimation strategy and policy evaluation criteria

4.1 Demographically scaled AIDS

Our policy analysis steps on a demographically scaled AIDS following Deaton and Muellbauer (1980) and Ray (1983). The starting point for the demand equations is the specification of a function that is general enough to be a second-order approximation to a utility or cost function. Deaton and Muellbauer (1980) chose the Price-Independent Generalized Logarithmic (PIGLOG) preferences, with demands having expenditure shares linear in logarithm of total expenditures. These demands arise from indirect utility function (V), which are linear in logarithm of total expenditures:

$$(1) \quad \ln(V) = \frac{\ln(m) - ln(1 + \rho_1 z_1 + \rho_2 z_2) - \ln(a(p))}{b(p)}.$$

In equation (1), $\ln(m)$ stands for logarithm of total expenditures; the demographic variables z_1 and z_2 represent the number of adults and the number of children in the household; $\ln(a(p))$ represents the cost of subsistence, which takes a translog form:

$$(2)\quad \ln(a\,(p)) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(p_i) + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln(p_i)\ln(p_j).$$

Moreover, $b(p)$ represents the cost of bliss, and is a simple Cobb-Douglas price aggregator:

$$(3)\quad b(p) = \prod_{i=1}^{n} p_i^{\beta_i + \theta_{i1} z_1 + \theta_{i2} z_2}.$$

The PIGLOG preferences can be represented by the expenditure or cost function, which defines the minimum expenditure necessary to attain a specific utility level at given prices. The cost function of a certain household takes the following form:

$$(4)\quad \ln\big(C(V,p)\big) = \ln\big(a(p)\big) + b(p)\ln(V).$$

The demand functions can be derived by price differentiation of equation (4),

$$(5)\quad \frac{\partial \ln(C)}{\partial \ln(p_i)} = \frac{p_i q_i}{C} = w_i,$$

where w_i represents the budget expenditure share of specific good i in total expenditures m. To ease notation, we suppress household and period subscripts in the explanation that follows. The estimable demand system then takes the following form:

$$(6)\quad w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(p_j) + (\beta_i + \theta_{i1} z_1 + \theta_{i2} z_2)\big(\ln(m) - \ln\big(a(p)\big) - \ln(1 + \rho_1 z_1 + \rho_2 z_2)\big) + u_i.$$

The number of goods included in the system is $i = 1, \ldots, n$. The parameters to be estimated include: $\alpha_i, \beta_i, \gamma_{ij}, \rho_i, \theta_i$; α_0 is set at the lowest level of logarithm of total expenditures in the base year; u_i is the error term. Several restrictions are imposed on the parameters in order to ensure homogeneity and symmetry:

$$(7)\quad \sum_i \alpha_i = 1,\ \sum_j \beta_j = 0,\ \sum_k \gamma_{kj} = 0\,, \sum_i \theta_{i1} = \sum_i \theta_{i2} = 0$$

Exogeneity is also required in the estimation of demand systems in order to have consistent and unbiased estimates (see Blundell and Robin (1999) for details) . However, it is virtually impossible for expenditures to be exogenous in a set of demand functions, and thus the exogeneity assumption is likely to be violated (LaFrance, 1991). In particular, the budget shares of the commodities are likely to be jointly determined with total expenditures, making total expenditures endogenous in the budget equations. Endogenity is problematic as it may induce inconsistent parameter estimates.[11] Moreover, LaFrance (1991) finds evidence that the endogeneity significantly impacts the demand parameter estimates. In order to treat the endogeneity problem, we follow the augmented regression technique of Blundell and Robin (1999). The error term can be rewritten as,

$$(8)\ u_i = \nu_i v + \varepsilon_i,$$

and it can be safely assumed that $E(\varepsilon_i|m) = 0$. Here v represents the residual from the reduced-form equation for $\ln(m)$. Time trend, income, income squared, prices, and demographic variables are included in the equation explaining $\ln(m)$. All the variables included in the reduced-form equation are statistically significant (see *Table A9* in the Appendix). Using the residuals from the reduced-form equation as explanatory variables in the budget share equations allows us to correct for the potential endogeneity.

In order to obtain the income and price elasticities, equation (6) needs to be differentiated with respect to $\ln(m)$ to obtain income elasticity, and with respect to $\ln(p_j)$ to derive the price elasticity,

$$(9)\quad \varepsilon_i = \frac{\mu_i}{w_i} + 1, \text{ where}$$

$$(10)\quad \mu_i \equiv \frac{\partial w_i}{\partial \ln(m)} = \beta_i + \sum_{k=1}^{2} \theta_{ik} z_k .$$

Equation (9) represents the income elasticity of demand. Goods with positive income elasticity are normal goods; otherwise they are Giffen goods. Income elasticity lower than one indicates necessities, whereas elasticity greater than one is a sign of luxury goods.

The uncompensated price elasticity is calculated according to,

[11] According to Dhat et al. (2003), any inference based on such estimates would be invalid.

$$(11)\quad \varepsilon_{ij}^{u} = \frac{\mu_{ij}}{w_i} - \delta_{ij}, \text{ where}$$

$$(12)\quad \mu_{ij} \equiv \frac{\partial w_i}{\partial \ln(p_j)} = \gamma_{ij} - \mu_i(\alpha_j + \textstyle\sum_{k=1}^{n} \gamma_{jk} \ln(p_k)),$$

and δ_{ij} is the Kroneker delta, $\delta_{ij} = 1$ for $i = j$ and 0 otherwise.

The compensated price elasticity is calculated as:

$$(13)\quad \varepsilon_{ij}^{c} = \varepsilon_{ij}^{u} + \varepsilon_i w_j.$$

The own-price elasticity should have a negative sign. If ε_{ij}^{c} is lower than one, the demand for the good is inelastic. If ε_{ij}^{c} is higher than one, demand is price-elastic. Negative cross-price elasticity indicates complementary goods, whereas positive cross-price elasticity indicates substitute goods.

4.2 The energy tax on car fuels

In Germany, two taxes are levied on top of the producer price of car fuels: the energy tax and the value-added tax. The energy tax is a quantity tax charged per liter. It differs between gasoline and diesel fuel. The tax base of the value-added tax is the fuel price per liter including the energy taxes. Hence, for our period of investigation, 2008, the end consumer price of car fuels takes the form:[12]

$$(14)\quad P_g = \left(PP_g + CM_g + ET_g\right) * (1 + VAT) = (0.525 + 0.655) * (1.19) = 1.400$$

$$(15)\quad P_d = (PP_d + CM_d + ET_d) * (1 + VAT) = (0.650 + 0.470) * (1.19) = 1.333$$

P_g and P_d stand for the consumer price of gasoline and diesel; PP_g and PP_d represent the price of the product (the import price of gasoline or diesel); CM_g and CM_d denote the contribution margins (this part covers the expenses of the mineral oil groups and their profits plus costs of the emergency storage fund); ET denotes the energy tax[13] (since 1999 it also includes the green tax; the tax rate is different for the different fuels: $ET_g = 0.470\ euros/liter$ and

[12] See Federal Ministry of Finance, 2014.

[13] The energy tax is imposed on the basis of the Energy Tax Act of 15 July 2006. See Energy Tax Act, Federal Ministry of Justice and Consumer Protection, 2014. The energy tax was called the mineral oil tax (*Mineraölsteuer*) until 2006.

$ET_d = 0.655\ euros/liter$); VAT denotes the value added tax[14] (19 percent levied on the total price including the energy tax).

Because in the IES we cannot distinguish between diesel and gasoline from 1998 and on, we have constructed a weighted average for the end user price on car fuels, using the consumption shares of gasoline and diesel in total car fuel consumption in 2008 as weights (0.73 and 0.27, respectively[15]). A weighted average was constructed in the same way for the energy tax.

4.3 Policy evaluation criteria

To explore the environmental and redistributive effects of the German energy tax on car fuels, we follow Banks et al. (1997). Basically, expenditure functions, indirect utility function, subsistence, and bliss levels (all of these functions were introduced in Section 4.1) are derived for different levels of the tax.

Using these estimates, we assess how the tax impacts the demand for car fuels and related emissions. The environmental criterion involves comparisons of the car-related CO_2 emissions for the status quo tax rate and variations in the tax rate following Brännlund et al. (2007). More precisely, the status quo CO_2 emissions are calculated by multiplying the carbon factor of car fuels (θ) with the initial quantity of the good (q^0): $E^0 = \theta q^0$. The after-tax emissions are: $E^1 = \theta q^1$.

To understand the distributional effects of the tax, an indicator of material welfare is required to rank the households. A widely accepted indicator is equivalent income, which represents income adjusted for the differences in the material needs of households of different composition (number of adults and children). The OECD equivalence scale is used for this adjustment. It is defined as:

$$(16)\quad \text{Equivalence scale} = 1 + 0.5 * \text{adults} + 0.3 * \text{children}.$$

After having sorted the households in increasing order of equivalent income, we compute the welfare changes due to the tax on car fuels along the distribution. To do so, we make use of the following measures:

1. Changes in tax burdens due to a change in the tax rate, $\Delta t = (ET^1 - ET^0)q^1$.

[14] The Value Added Tax is imposed on the basis of the Value Added Tax Act of 15 July 2006. See Value Added Tax Act, Federal Ministry of Justice and consumer protection, 2014.

[15] See Statista, 2014.

2. Equivalent variation (EV), $EV = e\,(p^1, V^1) - e\,(p^0, V^1)$. EV is the amount of money that a household is willing to give up in order to avert the price change.

3. Inequality indices. We use two well-established indices, the Gini index, G, and the Theil index, T. More inequality always means a higher index.

5 Demand System Estimates

The AIDS includes the expenditure shares of the following five categories: food, electricity, other fuels, car fuels, and an aggregate of other goods. A demographically scaled version is estimated using the numbers of adults and children as explanatory variables.

Table 1 summarizes the mean income elasticity of all the expenditure categories.[16] The lower and upper bounds of 95 percent confidence intervals are also included in the table. The income elasticities show that food, electricity, other fuels, and car fuels are normal and necessity goods. A one percent increase in income will lead to 0.752 percent increase in the demand for car fuels. Similar interpretations can be made for the other elasticities. The aggregate of other goods is normal but a luxury good (income elasticity is higher than 1).

Table 1 about here

Table 2 includes the own-price and cross-price elasticities of the five expenditure categories in the demand system. Food is almost price-elastic (-0.950) for the average German household. The cross-price elasticities reveal that food and electricity are substitute goods. Food demand would increase by 0.029 percent if the price of electricity increased by one percent. Food is a complementary good to other fuels and also to car fuels.

Household demand for electricity in Germany is price-inelastic with own-price elasticity of -0.787. Electricity and other fuels are substitute goods; similarly, electricity and car fuels are substitutes. Demand for other fuels is also price-inelastic (-0.566). Other fuels and car fuels are found to be substitutes (0.155). Electricity and other goods are found to be complement goods. Car fuel demand is found to be price-inelastic in Germany (-0.165). Finally, car fuels and other goods are complementary goods, with negative cross-price elasticity (-0.514). Demand for other goods is price-elastic; a 1.049 percent fall in demand for other goods is

[16] Further details on the AIDS coefficient estimates can be found in Table A10 in the Appendix.

caused by one percent increase in the good's own price. Our elasticities estimates are to some extent comparable to the estimates of Kohn and Missong (2003) and Beznoska (2014) [17].

Looking at the coefficients of the demographic variables provides some interesting insights (see *Table A10* in the Appendix). Our reference household is a single adult household without children. Households with two adults have 96.41 percent higher costs than households with one adult. Adding one child adds 40.98 percent to the overall costs of the family. Moreover, the statistical significance of the thetas confirms that allowing the scale to vary with prices permits for substitution responses and provides a better model fit.

Table 2 about here

6 Policy analyses

To understand the emissions-inequality trade-off of the German energy tax on car fuels, we first characterize the status quo, that is, the situation in 2008. In 2008, the energy tax on car fuels amounted to 0.606 euros per liter of car fuel. *Table 3* presents the key figures on emissions, tax burdens, and inequality indices for the post-tax distributions. All the numbers relate to a period of one year. The average household produces car-related emissions of 2.073 tons of CO_2 and pays 523 euros in energy tax on car fuels. The level of inequality in the post-tax equivalent income distribution, as captured by the Gini index (Theil index), is 0.266 (0.115).

Table 3 about here

Departing from the status quo, we assess two alternative scenarios: one scenario in which the tax is zero and a second scenario where it is doubled. The results are summarized in *Table 4.* In the zero-tax scenario, CO_2 emissions increase to 2.319 tons per household, a 12 percent emission increase compared with the 2008 status quo. The average monetary welfare gain due to the reduction of the tax burden,[18] as captured by the equivalent variation, is 682 euros, and the Gini and the Theil indices indicate a moderate reduction of inequality (by about 0.003 points). This is because poorer households spend a larger proportion of their income on car

[17] Kohn and Missong (2003) estimate a non-demographic QUAIDS for broad number of goods categories in Germany for the years 1988-1993, while Beznoska (2014) estimates a non-demographic AIDS for Germany for energy, mobility and leisure for the years 1998-2008.

[18] Note that the equivalent variation does not capture potential welfare losses from rising emissions.

fuels than richer households. In the scenario where the tax is doubled, the EV indicates a welfare loss[19] of 562 euros, and both inequality indices indicate a slight inequality increase.

Car fuels consumption and consequently emissions decrease to 1.726 tons per household, which would represent 17 percent lower emissions than in the 2008 status quo. Austin and Dinan (2005) find the gasoline tax as an efficient policy instrument for achieving great immediate gasoline savings, by encouraging people to drive less and eventually to buy more fuel efficient cars.

Table 4 about here

To better understand how changes in the tax rate impact “rich” and “poor” households, *Figures 2* and *3* provide the decile-specific average changes in CO_2 emissions, tax burdens, and equivalent variations.

The zero-tax scenario is summarized in *Figure 3*. As can be seen from the upper left graph, emissions increase for all the deciles and exhibit an inverse u-shaped relationship. The emissions increase starts at 0.179 tons for the poorest households, grows to 0.291 tons for the households in the middle of the equivalent income distribution, and declines to 0.151 tons for the richest households. The percentage increase in emissions, however, is decreasing over the deciles. It appears that the tax cut makes more poor households start to drive cars, and hence the percentage increase in emissions is largest for them. Lowering the tax therefore means that demand increases for all households and in particular for those that did not consume in the initial situation. The initial non-consumers are most frequently found in the lowest equivalent income deciles; namely 33 percent of all car fuels non-consumers in 2008 are in the first decile, 17 percent in the second, 11 percent in the third, and so on. The tax cut will not drastically alter the car fuel consumption patterns or the emissions amounts of the rich households. The upper right panel represents the changes in the tax burdens in euros. The tax relief is smallest for the poorest households (260 euros) and largest for the richest households (826 euros). The same holds for the equivalent variations; the welfare gain is largest for the richest.

Figure 3 about here

[19] All the welfare results derived from the EV are reconfirmed by the CV. The respective results are provided in the Appendix (see *Table A11* and *Figure A2*).

Figure 4 refers to the scenario where the tax is doubled. In terms of emission reductions, the effect is smallest for the poorest households (-0.183 t) and largest for the richest households (-0.505 t). However, the percentage change in CO_2 emissions is largest for the poor and decreases as equivalent income increases. Thus, the largest car-related emissions reductions, and consumption reductions, would come from the poorest households. The tax burden increases across the deciles (168 euros for the poorest and 571 euros for the richest decile), and the same holds for the equivalent variation as measure of welfare loss in this case (277 euros for poorest and 895 euros for the richest decile). Galinato and Yoder (2010) find that a Pigovian tax on motor fuels increases the welfare of consumers in the US, but only when the tax revenue collected is recycled. Increasing the tax means that demand drops for all households except for those that have zero consumption in the status quo. As already mentioned, these households are particularly frequent in the lower deciles of the distribution.

Figure 4 about here

The previous analysis has indicated the presence of an emissions–inequality trade-off: increasing the energy tax on car fuels lowers emissions but increases inequality in the post-tax income distribution. The intensity of the trade-off is described in *Figure 4*. It provides emission and inequality levels as a function of the tax rate, and the quintessence of the two relationships: the intensity of the trade-off. In the status quo, total car-related emissions of the German households are 77.7 Megatons (Mt) and the Gini index is 0.267.[20] Increasing (lowering) the tax by 50 percent lowers (increases) emissions by 8.9 percent (9.7 percent) but increases (decreases) the Gini index by 0.4 percent (0.4 percent). Policy makers are yet to decide how to weigh environmental goals against equality concerns to determine an optimal tax level.

Figure 5 about here

7 Sensitivity analysis

Our main results rely on a demographically scaled version of the AIDS. We have also estimated an unscaled version that is less general to examine the sensitivity of the elasticities from the scaled version. As expected, the scaled version provides a better fit to the data: the

[20] The relationship between the Theil index and emissions is depicted in Figure A3, and the patterns are the same as with the Gini index.

R^2 is higher in the demographic system for all goods except for other fuels (see *Table 5)*. The income and price elasticities of the two models are rather close (see *Table 5)*.

Table 5 about here

As another robustness check, we allow for price and income elasticities to differ across income levels. Here we resort to the demographic specification of the demand system. *Table 6* shows the elasticities for each quartile of the equivalent income distribution. Overall, the estimated income elasticities do not differ substantially across quartiles. Critical for our policy analysis is the price elasticity of demand for car fuels. The results are that households at the top of the distribution respond to an increase in the price of car fuels with a stronger reduction in fuel demand than households at the bottom of the distribution. Using the quartile-specific elasticities would therefore imply an intensification of the estimated emissions-inequality trade-off.

Table 6 about here

8 Conclusion

Understanding household energy demand is integral part of German energy policy. Our analysis sheds light on an important instrument for reducing CO_2 emissions in Germany: the energy tax on car fuels. In particular, we study how the tax alters the household demand for car fuels, associated emissions, and the distribution of post-tax income.

Our estimates indicate the presence of an emissions-inequality trade-off: an increase in the tax rate lowers CO_2 emissions but increases inequality in the distribution of post-tax income. Unfortunately, other environmental policies in Germany also produce undesired regressive effects. For example, in a recent study, Grösche and Schröder (2014) assess the redistributive effects of the promotion of renewables in the electricity mix through a feed-in tariff and find that it is regressive.

References

Austin, D., Dinan, T., 2005. Clearing the Air: The Costs and Consequences of Higher CAFE Standards and Increased Gasoline Taxes. Journal of Environmental Economics and Management 50, 562–582.

Bach, S., Kohlhaas, M., Meyer, B., Praetorius, B., Welsch, H., 2002. The Effects of Environmental Fiscal Reform in Germany: A Simulation Study. Energy Policy, 30, 803-811.

Banks, J., Blundell, R., Lewbel, A., 1997. Quadratic Engel Curves and Consumer Demand. The Review of Economics and Statistics, 79, 527-539.

Baumol, W.J., Oates, W.E., 1988. The Theory of Environmental Policy. New York: Cambridge University Press, 2nd Edition.

Blundell, R., Robin, J.M., 1999. Estimation in Large and Disaggregated Demand Systems: An Estimator for Conditionally Linear Systems. Journal of Applied Econometrics 14, 209-232.

Beznoska, M., 2014. Estimating a Consumer Demand System of Energy, Mobility and Leisure. A Microdata Approach for Germany. Freie University Berlin Discussion Paper 08/2014.

Callan, T., Lyons, S., Scott, S., Tol, R.S.J., Verde, S., 2009. The Distributional Implications of a Carbon Tax in Ireland. Energy Policy, 37, 407-412.

Bönke, T., Schröder, C., Werdt, C., 2013. Compiling a Harmonized Database from Germany's 1978 to 2003 Sample Surveys of Income and Expenditure. Wirtschafts- und Sozialstatistisches Archiv, 7, 135-168.

Brännlund, R., Ghalwash, T., 2008. The Income–Pollution Relationship and the Role of Income Distribution: An Analysis of Swedish Household Data. Resource and Energy Economics, 30, 369- 387.

Brännlund, R., Nordström, J., 2004. Carbon Tax Simulations Using a Household Demand Model. European Economic Review, 48, 211- 233.

Brännlund, R., Ghalwash, T., Nordström, J., 2007. Increased Energy Efficiency and the Rebound Effect: Effects on Consumption and Emissions. Energy Economics, 29, 1-17.

Deaton, A., Muellbauer, J., 1980. An Almost Ideal Demand System. The American Economic Review, 70, 312-326.

Dhar, T., Chavas, J.P., Gould, B.W., 2003 . An Empirical Assesment of Endogeneity Issues in Demand Analysis for Differentiated Products. . American Journal of Agricultural Economics, 85, 605-617.

Dumagan, J.C., Mount, T.D., 1992. Measuring the Consumer Welfare Effects of Carbon Penalties. Energy economics, 14, 82–93.

Federal Ministry of Finance, 2014. [Basic Knowledge of the Price of Gasoline and its Development]. Available online: <http://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Steuern/Steuerarten/spritpreis.html > (in German).

Federal Ministry of Justice and Consumer protection, 2014. [Energy Tax Act]. Available online: <http://www.gesetze-im-internet.de/energiestg/index.html>(in German).

Federal Ministry of Justice and Consumer protection, 2014. [Value Added Tax Act]. Available online: <http://www.gesetze-im-internet.de/ustg_1980/index.html>(in German).

Fullerton, D., 2009. Distributional Effects of Environmental and Energy Policy: An Introduction. *Distributional Effects of Environmental and Energy Policy*. Ed. Don Fullerton. Aldershot, UK: Ashgate.

Galinato, G.J., Yoder, J.K., 2010. An Integrated Tax-Subsidy Policy for Carbon Emissions. Resource and Energy Economics, 32, 310-326.

Grainger, C.A., Kolstad, C.D., 2009. Who Pays a Price on Carbon?. Environmental and Resource Economics, 46, 359-376.

Grösche, P., Schröder, C., 2014. On the Redistributive Effects of Germany's Feed-In Tariff. Empirical Economics, 46, 1339-1383.

Hoderlein, S., Mihaleva, S., 2008. Increasing the Price Variation in a Repeated Cross Section. Journal of Econometrics, 147, 316-325.

Jacobsen, H.K., Birr-Pedersen, K., Wier, M., 2003. Distributional Implications of Environmental Taxation in Denmark. Fiscal Studies, 24, 477-499.

Jorgenson, D.W., Slesnik, D.T., Wilcoxen, P.J.,1992. Carbon Taxes and Economic Welfare. Brookings Papers on Economic Activity, Microeconomics, 393-431.

Kohn, K., Missong, M., 2003. Estimation of Quadratic Expenditure Systems Using German Household Budget Data. Jahrbücher für Nationaloekonomie und Statistik 4/2003, 422-448.

Kratena, K., Meyer, I., Wüger, M., 2009. A Combination of Aggregate and Individual Household Analysis. WIFO Working Papers No. 334.

Labandeira, X., Labeaga, J., Rodriguez, M., 2006. A Residential Energy Demand System for Spain. The Energy Journal, 27, 87-111.

LaFrance, J., 1991. When is Expenditure “Exogeneous” in Separable Demand Models. Western Journal of Agricultural Economics, 16(1), 49-62.

Lin, C.-Y. C., Prince, L., 2013. Gasoline Price Volatility and the Elasticity of Demand for Gasoline. Energy Economics 38, 111–117.

Oladosu, G., Rose, A., 2007. Income Distribution Impacts of Climate Change Mitigation Policy in the Susquehanna River Basin Economy. Energy Economics, 29, 520-544.

Pearson, M., Smith, S. 1991. Open Access publications from University College London, University College London. Available online: < http://discovery.ucl.ac.uk>

Ray, R., 1983. Measuring the Cost of Children: An Alternative Approach. Journal of Public Economics 22, 89-102.

Scott, S., Eakins, J., 2004. Carbon Taxes: Which Households Gain or Lose? ERTDI Report Series No.20, Environmental Protection Agency, Johnstown Castle.

Statista, 2014. [Car fuels consumption of German private households in the period from 2000 to 2008]. Available online: <http://de.statista.com/statistik/daten/studie/73902/umfrage/pkw---kraftstoffverbrauch-der-privaten-haushalte-in-deutschland> (in German)

Sterner. T., 2012. Distributional Effects of Taxing Transport Fuel. Energy Policy 41, 75-83.

Tafare, K., Taffesse, A.S., Tamru, S., Tafera, N., Paulos, Z., 2010. Food Demand Elasticities in Ethipia: Estimates Using Household Income Consumption Expenditure (HICE) Survey Data. ESSP II Working paper 11.

Tiezzi, S., 2005. The Welfare Effects and the Distributive Impact of Carbon Taxation on Italian Households. Energy Policy 33, 1597–1612.

The German Mobility Panel, 2014. [Statistics and Time series] Available online: <http://mobilitaetspanel.ifv.uni-karlsruhe.de/en/downloads/statistiken-und-zeitreihen/index.html>(in German)

The International Energy Agency, 2007. Energy Policy of Germany. Available online: <http://www.iea.org/Textbase/npsum/Germany2007SUM.pdf>

The World Bank, 2013. Household Final Consumption Expenditure (Percentage of GDP). Available online: < http://data.worldbank.org/indicator/NE.CON.PETC.ZS

West, S., Williams III, R., 2004. Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes. Journal of Environmental Economics and Management, 47, 535-558.

Wier, M., Birr-Pedersen, K., Jacobsen, H.K., Klok, J., 2005. Are CO_2 Taxes Regressive? Evidence from the Danish Experience. Ecological Economics, 52, 239-251.

World Bank, 2014. Gini index. Available online: <http://data.worldbank.org/indicator/SI.POV.GINI>

World Nuclear Association, 2011. Policy Responses to climate change. Available online: <http://www.world-nuclear.org/info/Energy-and-Environment/Policy-Responses-to-Climate-Change/>

Figures and Tables

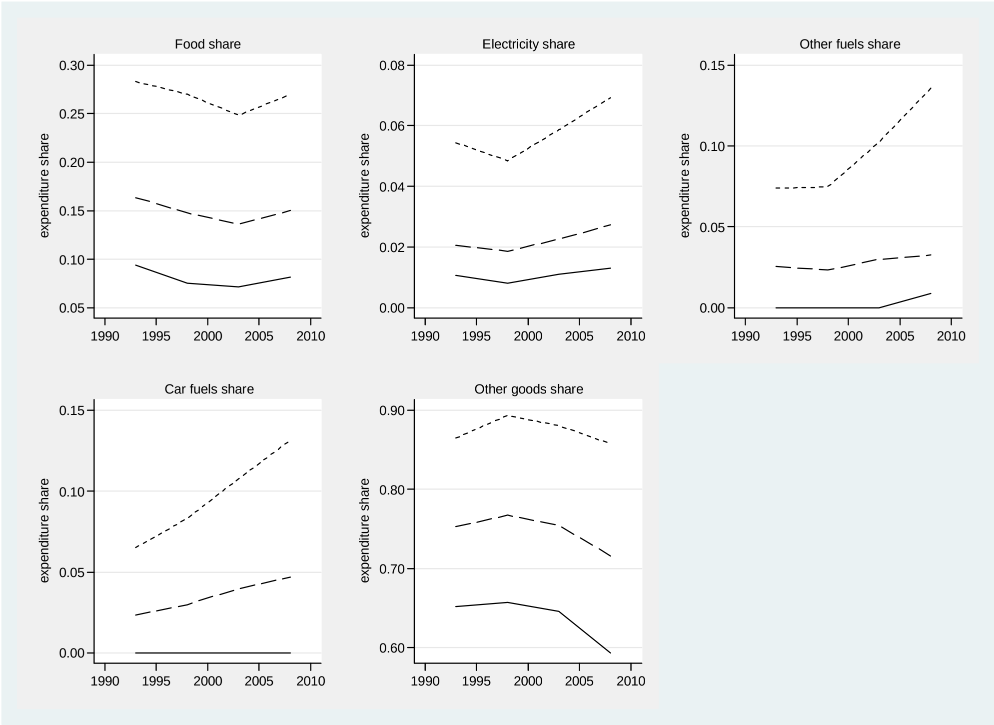

Figure 1. Development of expenditure shares over time

Note. Median values of expenditure shares and 10th and 90th percentile are given. Database is IES, 1993-2008.

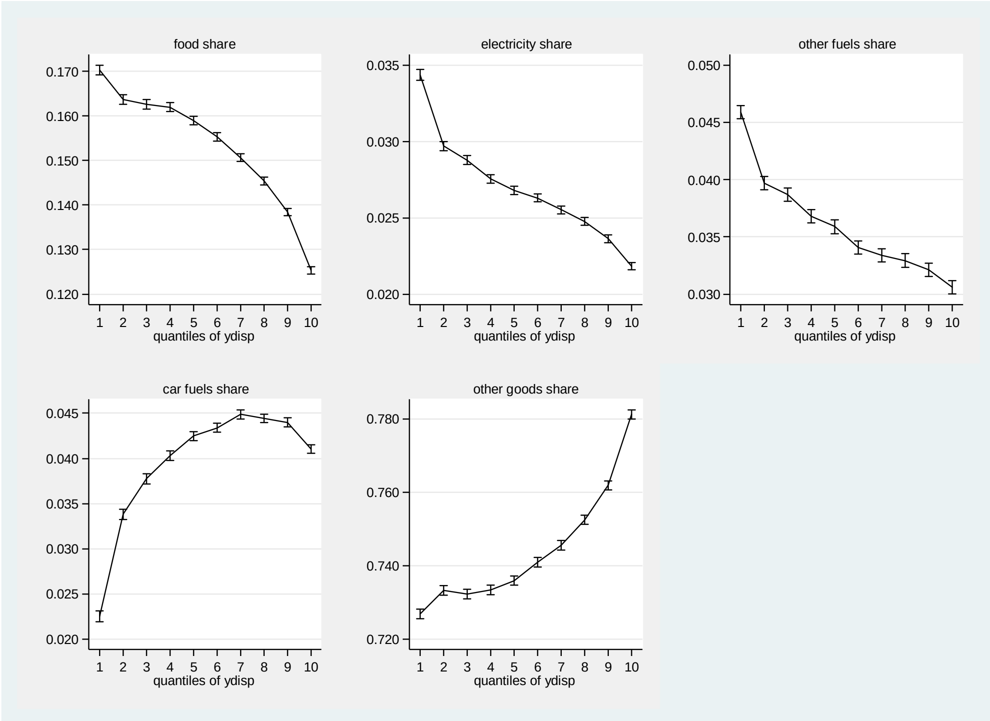

Figure 2. Expenditure shares and disposable income.

Note. Average values of variables and lower and upper bound of 95% confidence intervals are presented. Database is IES 2008.

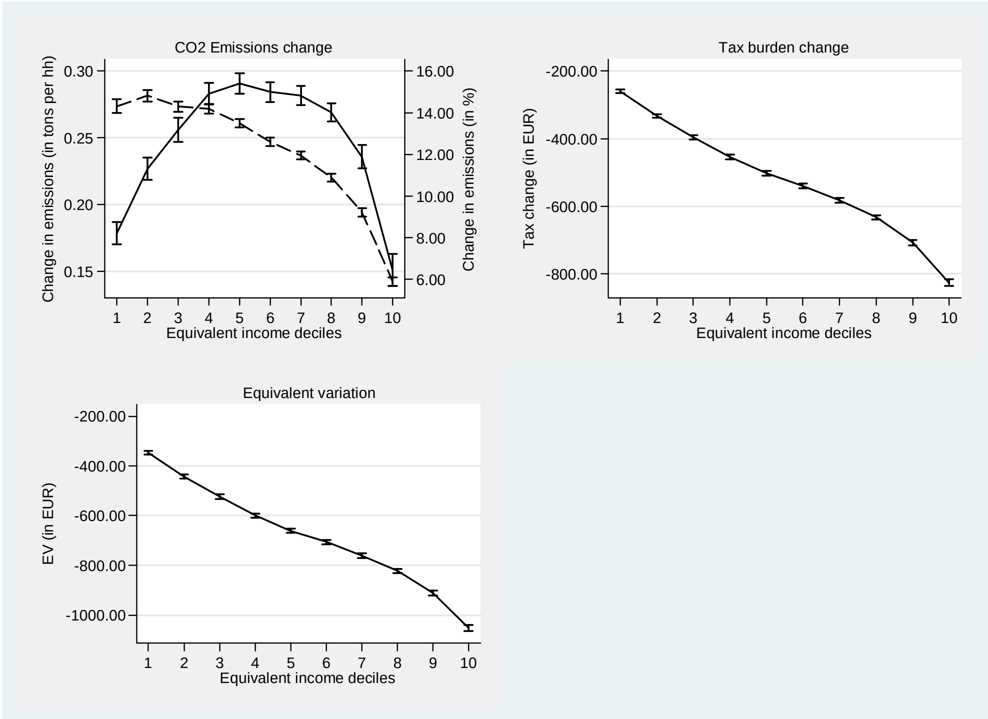

Figure 3. Reduction of energy tax to zero

Note. Average values of variables and lower and upper bound of 95% confidence intervals are presented. Database is IES 2008.

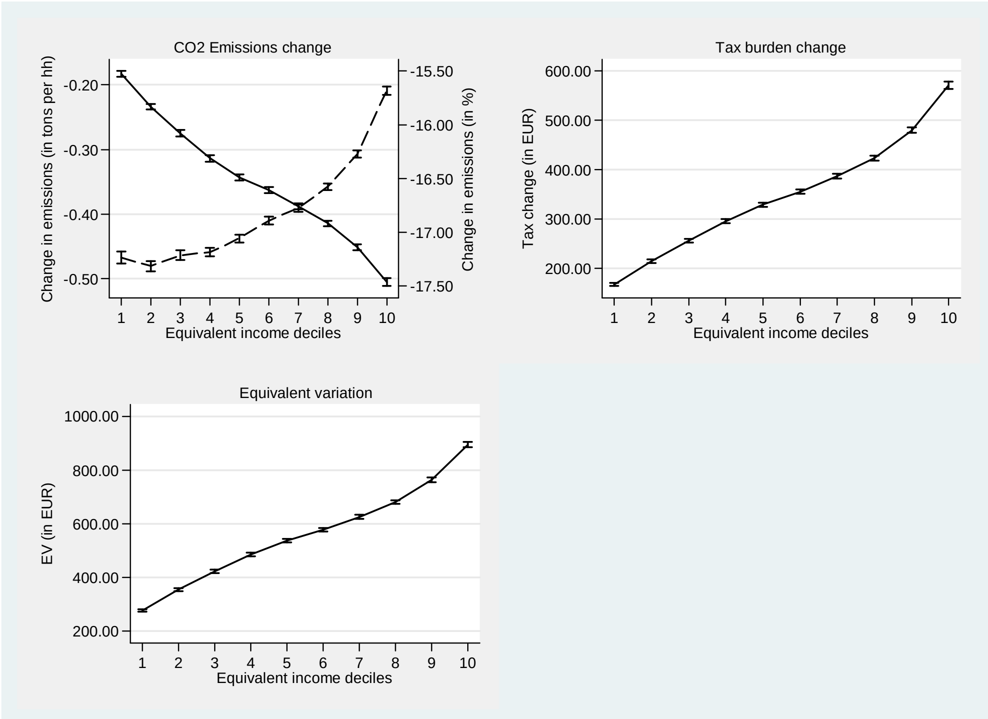

Figure 4. Doubling of the energy tax

Note. Average values of variables and lower and upper bound of 95% confidence intervals are presented. Database is IES 2008.

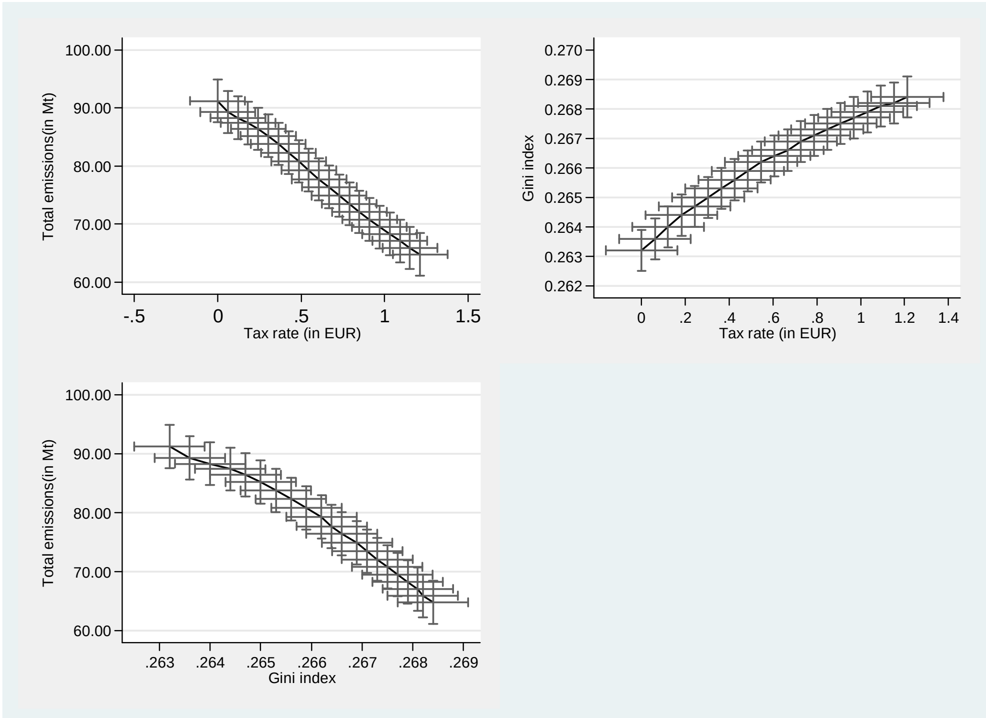

Figure 5. The relationship between tax rate, emissions, and inequality

Note. Average values of total emissions (and Gini index) and lower and upper bound of 95% confidence intervals are presented. Database is IES 2008.

Table 1. Income elasticities

Expenditure category	*Income elasticity*
Food	0.503
	[0.469; 0.537]
Electricity	0.540
	[0.538; 0.542]
Other fuels	0.707
	[0.706; 0.708]
Car fuels	0.752
	[0.751; 0.754]
Other goods	1.140
	[1.139; 1.141]

Note. Average values of the coefficient estimates and lower and upper bound of 95% are provided. Database is IES, 1993-2008.

Table 2. Price elasticities (uncompensated)

	Food	*Electricity*	*Other fuels*	*Car fuels*	*Other goods*
Food	-0.950	0.029	-0.027	-0.054	0.499
	[-0.953; -0.947]	[0.027; 0.032]	[-0.028; -0.025]	[-0.057; -0.052]	[0.466; 0.531]
Electricity	0.165	-0.787	0.204	0.076	-0.198
	[0.164; 0.166]	[-0.788; -0.786]	[0.203; 0.205]	[0.075; 0.077]	[-0.199; -0.197]
Other fuels	-0.147	0.148	-0.584	0.163	-0.288
	[-0.146; -0.148]	[0.147; 0.149]	[-0.586; -0.582]	[0.162; 0.164]	[-0.289; -.287]
Car fuels	-0.241	0.045	0.143	-0.165	-0.534
	[-0.242; -0.240]	[0.044; 0.046]	[0.142; 0.144]	[-0.166; -0.164]	[-0.536; -0.532]
Other goods	0.004	-0.023	-0.028	-0.043	-1.050
	[0.003; 0.005]	[-0.024; -0.022]	[-0.029; -0.027]	[-0.044; -0.042]	[-1.051; -1.049]

Note. Average values of the coefficient estimates and lower and upper bound of 95% confidence intervals are provided. Database is IES, 1993-2008.

Table 3. Status quo

	Tax rate (in euros/l)	*Emissions (in tons)*	*Tax burden (in euros)*	*Gini index*	*Theil index*
Status	0.606	2.073	523. 459	0.266	0.115
quo	[0.524; 0.688]	[2.062; 2.084]	[520.675; 526.243]	[0.265; 0.267]	[0.114; 0.116]

Note. Average values of the variables and 95% lower and upper confidence intervals are provided. Database is IES, 2008.

Table 4. Tax simulations with zero energy tax on car fuels and 100% tax increase

	Tax rate (in euros/l)	*Emissions (in tons)*	*Tax burden (in euros)*	*EV (in euros)*	*Gini index*	*Theil index*
No tax	0	2.319	0	-682.649	0.263	0.112
		[2.307; 2.331]		[-686.228; -679.069]	[0.262; 0.264]	[0.111; 0.113]
Double tax	1.212	1.726	871.654	561.566	0.268	0.116
	[1.130; 1.294]	[1.717; 1.735]	[866.956; 876.351]	[558.547; 564.585]	[0.267; 0.269]	[0.115; 0.117]

Note. Average values of the variables and lower and upper bound of 95% confidence intervals are provided. Database is IES, 2008.

Table 5. Comparison of Base and Demographic System estimates

	Base	*Demographic*
Income elasticities		
Food	0.824	0.503
	[0.823; 0.825]	[0.469; 0.537]
Electricity	0.622	0.540
	[0.621; 0.623]	[0.538; 0.542]
Other fuels	0.567	0.707
	[0.565; 0.569]	[0.706; 0.708]
Car fuels	1.101	0.752
	[1.100; 1.102]	[0.751; 0.754]
Other goods	1.063	1.140
	[1.062; 1.064]	[1.139; 1.141]
Price elasticities		
Food	-1.143	-0.950
	[-1.142; -1.144]	[-0.953; -0.947]
Electricity	-0.663	-0.787
	[-0.664; -0.662]	[-0.788; -0.786]
Other fuels	-0.731	-0.584
	[-0.732; -0.730]	[-0.586; -0.582]
Car fuels	-0.195	-0.165
	[-0.196; -0.194]	[-0.166; -0.164]
Other goods	-1.028	-1.050
	[-1.029; -1.027]	[-1.051; -1.049]
Goodness-of- fit measure (R^2)		
Food share	0.868	0.892
Electricity share	0.707	0.712
Other fuels share	0.507	0.498
Car fuels share	0.602	0.611
Other goods share	0.457	0.525

Note. Average values of the variables and lower and upper bound of 95% confidence intervals are provided. Database is IES, 1993-2008.

Table 6. Elasticities by equivalent income classes

Equivalent income quartiles	*0- 25%*	*25-50%*	*50-75%*	*75-100%*
Income elasticities				
Food	1.115	1.178	1.187	0.650
	[1.114; 1.116]	[1.177; 1.179]	[1.186; 1.188]	[0.645; 0.655]
Electricity	0.861	0.908	0.822	0.471
	[0.860; 0.862]	[0.907; 0.909]	[0.821; 0.823]	[0.469; 0.473]
Other fuels	0.707	0.728	0.589	0.129
	[0.706; 0.708]	[0.727; 0.729]	[0.588; 0.590]	[-0.496; 0.755]
Car fuels	1.483	1.162	0.949	0.383
	[1.474; 1.492]	[1.161; 1.163]	[0.948; 0.950]	[0.377; 0.388]
Other goods	0.965	0.968	0.9912	1.140
	[0.964; 0.966]	[0.967; 0.969]	[0.990; 0.992]	[1.139; 1.141]
Price elasticities				
Food	-1.227	-1.271	-1.316	-1.027
	[-1.228; -1.226]	[-1.272; -1.270]	[-1.317; -1.315]	[-1.028; -1.026]
Electricity	-0.932	-0.833	-0.868	-0.612
	[-0.933; -0.931]	[-0.834; -0.832]	[-0.869; -0.867]	[-0.613; -0.611]
Other fuels	-0.636	-0.821	-0.829	-0.493
	[-0.637; -0.635]	[-0.822; -0.820]	[-0.830; -0.828]	[-0.766; -0.219]
Car fuels	-0.041	-0.227	-0.278	-0.426
	[-0.055; -0.029]	[0.228; -0.226]	[-0.279; -0.277]	[-0.432; -0.421]
Other goods	-0.896	-0.909	-0.933	-1.049
	[-0.897; -0.895]	[-0.910; -0.908]	[-0.934; -0.932]	[-1.050; -1.048]

Note. Average values of the variables and lower and upper bound of 95% confidence intervals are provided. Database is IES, 1993-2008.

Appendix

Table A1. Identifiers of the underlying original IES 1993 variables

Original IES variables in each category	*Content*
Food and beverages (no alcohol, no tobacco)	
ef109	Food, beverages and tobacco
ef644	Other beverages, tobacco
Electricity	
ef705	Electricity
Other fuels	
ef707	Gas
ef709	Liquid fuels
ef711	Hard coal
ef713	Coke
ef715	Lignite
ef718	District heating, hot water
Car fuels	
ef761	Gasoline
ef762	Diesel
ef763	Consumables for motor vehicles and bicycles

Note. Database is IES 1993.

Table A2. Identifiers of the underlying original IES 1998 variables

Original IES variables in each category	*Content*
Food and beverages (no alcohol, no tobacco)	
ef125	Food, Beverages, Tobacco
ef740	Tobacco
Electricity	
ef770	Electricity (tenant/subtenant)
ef771	Electricity (owner)
ef772	Electricity (benefits in kind)
Other fuels	
ef773	Gas (tenant/subtenant)
ef774	Gas (owner)
ef775	Gas (benefits in kind)
ef776	Liquid fuels (tenant/subtenant)
ef777	Liquid fuels (owner)
ef778	Liquid fuels (benefits in kind)
ef779	Solid fuels (tenant/subtenant)
ef780	Solid fuels (owner)
ef781	Solid fuels (benefits in kind)
ef782	District heating (tenant/subtenant)
ef783	District heating (owner)
ef784	District heating (benefits in kind)
Car fuels	
ef810	Fuels and lubricants for private vehicles

Note. Database is IES 1998.

Table A3. Identifiers of the underlying original IES 2003 variables

Original IES variables in each category	*Content*
Food and beverages (no alcohol, no tobacco)	
ef51	Food and beverages
Electricity	
ef258	Electricity (incl. solar energy)
Other fuels	
ef259	Gas
ef260	Heating oil
ef261	Other fuels
ef262	District heating, warm water
Car fuels	
ef299	Fuels and lubricants

Note. Database is IES 2003.

Table A4. Identifiers of the underlying original IES 2008 variables

Original IES variables in each category	*Content*
Food and beverages (no alcohol, no tobacco)	
ef61	Food and beverages
Electricity	
ef251	Electricity (incl. solar energy)
Other fuels	
ef252	Gas
ef253	Heating oil
ef254	Coal, wood, and other solid fuels
ef255	District heating, hot water
Car fuels	
ef300	Fuels and lubricants

Note. Database is IES 2008.

Table A5. Descriptive statistics for 1993

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
disp. inc.	38378	33630.450	17749.480	7016.458	105893.200
t. expenditures	38378	26732.410	13139.430	3488.475	138006.000
food exp.	38378	4338.383	2399.318	2556.453	47433.570
electricity exp.	38378	601.557	4356.844	0.000	8141.812
other fuels exp.	38378	701.997	5169.145	0.000	13367.220
car fuels exp.	38378	698.220	5816.776	0.000	6959.194
other exp.	38378	20392.250	11219.500	1221.674	126590.700
food share	38378	0.172	0.066	0.000	0.616
electricity sh.	38378	0.026	0.018	0.000	0.286
other fuels sh.	38378	0.033	0.026	0.000	0.349
car fuels sh.	38378	0.025	0.023	0.000	0.230
other goods sh.	38378	0.744	0.076	0.317	0.978
ln(p_food)	38378	1.285	0.115	0.993	1.681
ln(p_elect)	38378	1.201	0.000	1.201	1.201
ln(p_otherfuel)	38378	0.945	0.129	0.384	1.222
ln(p_carfuel)	38378	0.848	0.000	0.848	0.848
ln(p_othergood)	38378	1.212	0.087	0.049	1.640
Adults	38378	2.036	0.831	1.000	8.000
children	38378	0.595	0.960	0.000	6.000

Note. Database is IES 1993.

Table A6. Descriptive statistics for 1998

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
disp. inc.	47747	38462.200	20493.800	7454.636	124794.100
t. expenditures	47747	29171.110	17187.370	3675.714	215394.200
food exp.	47747	4087.903	2.067.809	4090.335	23813.930
electricity exp.	47747	570.083	4.102.481	0.000	7415.777
other fuels exp.	47747	691.718	7.366.757	0.000	16563.810
car fuels exp.	47747	940.144	7.681.655	0.000	10872.110
other exp.	47747	22881.260	15783.510	2164.336	207614.400
food share	47747	0.155	0.069	0.000	0.525
electricity sh.	47747	0.024	0.017	0.000	0.283
other fuels sh.	47747	0.030	0.029	0.000	0.383
car fuels sh.	47747	0.031	0.029	0.000	0.353
other goods sh.	47747	0.760	0.085	0.347	0.983
ln(p_food)	47747	1.347	0.004	1.062	1.755
ln(p_elect)	47747	1.193	0.000	1.193	1.193
ln(p_otherfuel)	47747	0.951	0.122	0.527	1.304
ln(p_carfuel)	47747	0.960	0.000	0.960	0.960
ln(p_othergood)	47747	1.343	0.098	0.153	1.713
Adults	47747	2.021	0.815	1.000	8.000
children	47747	0.568	0.912	0.000	6.000

Note. Database is IES 1998.

Table A7. Descriptive statistics for 2003

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
disp. inc.	41046	41307.400	22416.890	7612.000	131484.000
t. expenditures	41046	27869.260	16098.570	3206.515	232843.300
food exp.	41046	3650.286	1909.102	32.000	21440.000
electricity exp.	41046	662.423	4840.913	0.000	10064.000
other fuels exp.	41046	930.854	1082.000	0.000	23628.000
car fuels exp.	41046	1201.276	9895.956	0.000	11424.000
other exp.	41046	21424.420	14489.550	2470.718	225339.300
food share	41046	0.144	0.061	0.001	0.571
electricity sh.	41046	0.028	0.019	0.000	0.350
other fuels sh.	41046	0.038	0.038	0.000	0.518
car fuels sh.	41046	0.041	0.037	0.000	0.360
other goods sh.	41046	0.749	0.083	0.319	0.982
ln(p_food)	41046	1.386	0.122	1.081	1.756
ln(p_elect)	41046	1.312	0.000	1.313	1.312
ln(p_otherfuel)	41046	1.238	0.065	0.931	1.378
ln(p_carfuel)	41046	1.276	0.000	1.276	1.276
ln(p_othergood)	41046	1.373	0.074	0.084	1.708
Adults	41046	1.997	0.824	1.000	8.000
children	41046	0.440	0.826	0.000	6.000

Note. Database is IES 2003.

Table A8. Descriptive statistics for 2008

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
disp. inc.	42315	40989.970	22710.660	7504.000	129240.000
t. expenditures	42315	26306.320	14525.560	3111.000	213739.000
Food	42315	3847.322	2037.563	28.000	21924.000
electricity	42315	755.444	5664.706	0.000	11620.000
other fuels	42315	1203.773	1716.214	255.000	29391.000
car fuels	42315	1398.887	1223.770	0.000	13376.000
other goods	42315	19100.890	12446.150	1812.000	201304.000
food exp.	42315	0.158	0.066	0.001	0.595
electricity exp.	42315	0.034	0.023	0.000	0.372
other fuels exp.	42315	0.049	0.052	0.001	0.634
car fuels exp.	42315	0.049	0.045	0.000	0.531
other exp.	42315	0.710	0.094	0.100	0.975
ln(p_food)	42315	1.512	0.172	1.195	1.868
ln(p_elect)	42315	1.566	0.000	1.566	1.566
ln(p_otherfuel)	42315	1.662	0.044	1.134	1.907
ln(p_carfuel)	42315	1.552	0.000	1.553	1.553
ln(p_othergood)	42315	1.389	0.063	0.181	1.751
Adults	42315	1.933	0.807	1.000	8.000
children	42315	0.358	0.749	0.000	6.000

Note. Database is IES 2008.

Table A9. The reduced form equation for ln (m)

Varable	*Coefficient*
Year	0.284***
ln(disp. inc)	0.001*
ln((disp. inc)^2)	0.337***
ln(p_food)	-0.023
ln(p_elect)	0.261
ln(p_otherfuel)	-0.011
ln(p_carfuel)	-1.336***
ln(p_othergood)	-0.719***
adults	0.070***
children	0.026*
constant	4.436***

Note. Authors' calculations; Database is IES 1993-2008.
*significant at 10%, **significant at 5%, *** significant at 1%.

Table A10. Coefficient estimates of the demographic demand system

	Whole sample	*Quartiles of equivalent income distribution*			
Coefficient		*0-25%*	*25-50%*	*50-75%*	*75-100%*
α_1	0.1469***	0.1803***	0.1460***	0.1279***	0.1427***
α_2	0.0262***	0.0352***	0.0299***	0.0296***	0.0264***
α_3	0.0378***	0.0448***	0.0438***	0.0470***	0.0401***
α_4	0.0448***	0.0344***	0.0431***	0.0502***	0.0547***
β_1	-0.0680***	0.0265***	0.0353***	0.0311***	-0.0537***
β_2	-0.0121***	-0.0056***	-0.0033***	-0.0055***	-0.0097***
β_3	-0.0126***	-0.0121***	-0.0104***	-0.0152***	-0.0094***
β_4	-0.0010***	0.0211***	0.0073***	-0.0035***	-0.0223***
γ_{11}	-0.0036***	-0.0400***	-0.0400***	-0.0417***	-0.0105***
γ_{12}	0.0025***	0.0017**	-0.0019*	-0.0023***	0.0018***
γ_{13}	-0.0066***	0.0054***	0.0085***	0.0112***	-0.0030***
γ_{14}	-0.0109***	0.0039***	-0.0004	-0.0024**	-0.0048***
γ_{22}	0.0052***	0.0019	0.0043***	0.0032***	0.0091***
γ_{23}	0.0049***	0.0094***	0.0075***	0.0079***	0.0016***
γ_{24}	0.0015***	0.0059***	0.0021***	-0.0006	-0.0007
γ_{33}	0.0141***	0.0120***	0.0055***	0.0049***	0.0113***
γ_{34}	0.0053***	-0.0033***	0.0087***	0.0113***	0.0094***
γ_{44}	0.0324***	0.0352***	0.0305***	0.0289***	0.0232***
ρ_1	0.9641***	0.1426***	0.1424***	0.1418***	0.8517***
ρ_2	0.4098***	0.1414***	0.1384***	0.0346*	0.2057***
θ_{11}	-0.0027***	-0.0033***	-0.0044***	-0.0038***	0.0031***
θ_{21}	0.0002*	0.0011***	0.0007***	0.0011***	-0.0028***
θ_{31}	0.0019***	0.0014***	0.0011***	0.0020***	-0.0067***
θ_{41}	-0.0062***	-0.0029***	-0.0005***	0.0014***	-0.0035***
θ_{21}	-0.0059***	-0.0023***	-0.0044***	-0.0019***	0.0066***
θ_{22}	0.0001	0.0009***	0.0003***	0.0000	-0.0009***
θ_{32}	0.0016***	0.0010***	0.0004***	-0.0002	-0.0033***
θ_{42}	-0.0041***	-0.0028***	-0.0009***	0.0000	-0.0012***
ν_1	0.0095***	-0.0790***	-0.0977***	-0.0923***	-0.0146***
ν_2	-0.0033***	-0.0141***	-0.0132***	-0.0097***	0.0003
ν_3	0.0018***	-0.0026***	0.0015***	0.0088***	0.0103***
ν_4	-0.0047***	-0.0220***	-0.0218***	-0.0166***	0.0043***

Note. Authors' calculations; Database is IES 1993-2008. *significant at 10%, **significant at 5%, *** significant at 1%.

Table A11. Compensating variation with zero energy tax and 100% tax increase

	Tax rate (in EUR/l)	*CV (in EUR)*
No tax	0	-667.099
		[-670.619; -663.579]
Double tax	1.212	573.495
	[1.130; 1.294]	[570.424; 576.566]

Note. Average values of the variables and lower and upper bound of 95% confidence intervals are provided. Database is IES, 2008.

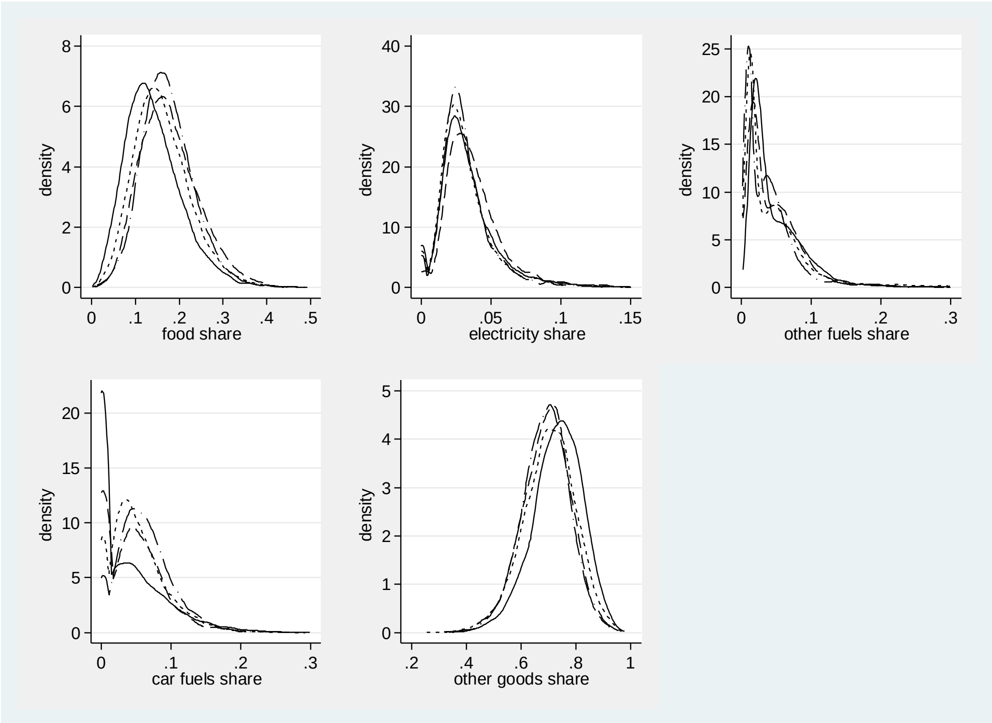

Figure A1. Density functions for the expenditure shares

Note. Database is IES, 2008. Solid line: household type 1- single adults; dashed line: household type 2 - single parents; dotted line: household type 3 - two adults no children; dashed and dotted line: household type 4 - two and more adults with children.

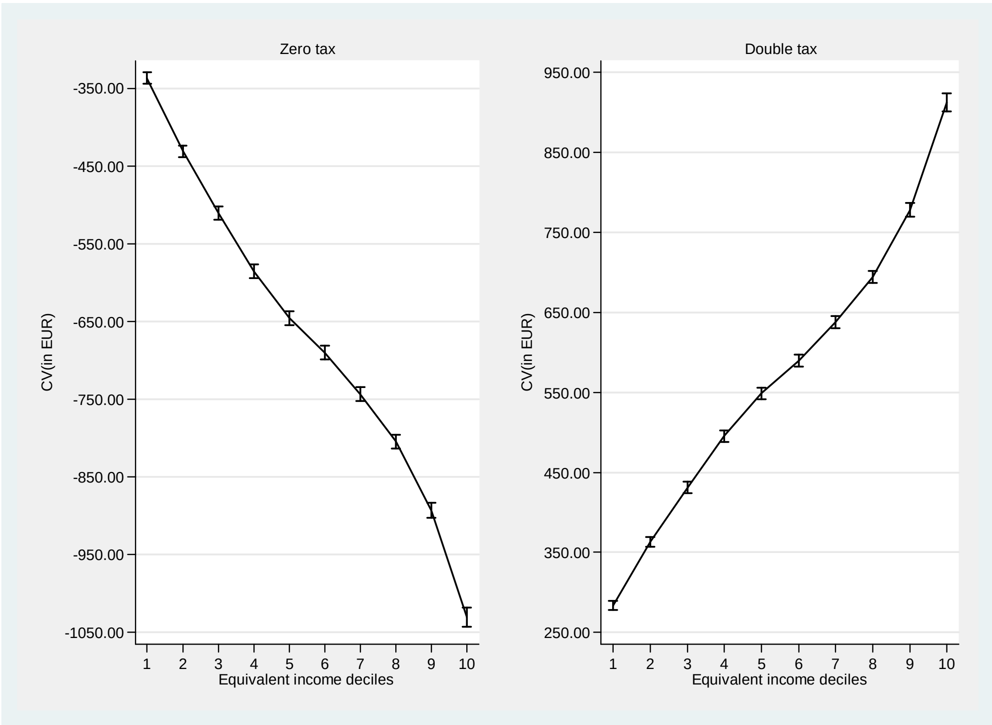

Figure A2. Compensating variation

Note. Average values of CV and lower and upper bound of 95% confidence intervals are provided. Database is IES, 2008.

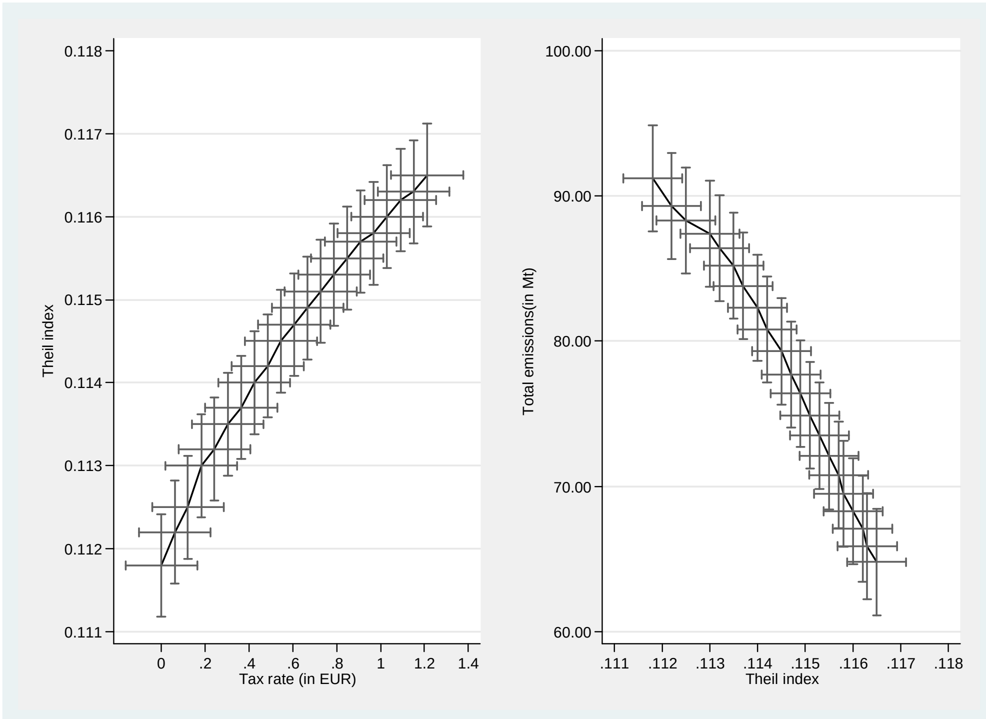

Figure A3. The relationship between tax rate, emissions, and Theil index

Note. Average values of the inequality index and total emissions; as well as lower and upper bound of 95% confidence intervals are provided. Database is IES, 2008.

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