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Bente Halvorsen and Runa Nesbakken

A conflict of interests in electricity taxation?
A micro econometric analysis of household behaviour

Abstract:
In conducting economic policy, governments generally face conflicts in various objectives, e.g. between efficiency and equity. In Norway, one objective of energy politics has been to reduce electricity consumption, and several tax increases have been proposed. Whether this objective may be in conflict with objectives of efficiency and equity is the focus in this paper. We discuss the effects on household behaviour of three different electricity tax schemes, one proportional and two non-linear. For each household we estimate the reduction in household electricity consumption. As measures of distributional effects and efficiency effects we estimate compensating variation and excess tax burden from the tax schemes. We find that the non-linear tax scheme targeting high electricity consumption is most preferred in order to reduce consumption and least preferred concerning the objective of minimizing excess tax burden. When considering distributional effects, the ranking of tax schemes depends on the weight placed on different household groups.

Keywords: Household energy consumption; electricity taxation; distributional effects; excess tax burden; compensated variation; tax burden; linear expenditure system.

JEL classification: D12, H22, D39, C31

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Address: Bente Halvorsen, Statistics Norway, Research Department.
E-mail: bente.halvorsen @ssb.no

Runa Nesbakken, Statistics Norway, Research Department.
E-mail: runa.nesbakken@ssb.no

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Statistics Norway
Sales- and subscription service
N-2225 Kongsvinger

Telephone: +47 62 88 55 00
Telefax: +47 62 88 55 95
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1. Introduction

The government will generally face conflicting objectives when conducting economic policy. The most common conflict is between efficiency and distributional effects. The Norwegian political debate regarding taxation of household electricity consumption serves as a good illustration of conflicting objectives. In the Norwegian National Budget for 1999, the government expressed concern that the annual domestic consumption of electricity exceeds the mean production. An increase in the tax on household electricity consumption was proposed to reduce domestic consumption. One of several motivations for reducing electricity consumption was to reduce imports of electricity in order to reduce global CO_2 emissions.[1] However, increasing the electricity tax without simultaneously increasing taxes on fossil fuels may increase emissions since electricity for space heating may be substituted by fossil fuels, as pointed out in the National budget for 2000. A tax increase reduces household consumption possibilities and utility. Thus, the politicians were also concerned about the distributional effects of increased electricity taxation (see e.g. Ministry of Petroleum and Energy, 1998, the white paper on energy No. 29/99 and the national budget for 2000). The focus of this paper is the conflict of interests between the expressed objectives of reduced electricity consumption and distributional effects, as well as efficiency effects.

Micro-economic studies of distributional effects of commodity taxation are not as common as studies of distributional effects of income taxes, but some have been made. Cornwell and Creedy (1996, 1997a and 1997b) discuss welfare effects of introducing a carbon tax on household consumption applying micro data. They develop a method for estimating compensated money measures, both the compensated variation (CV) and the equivalent variation (EV), applying a linear expenditure system

[1] In Norway, electricity is basically produced in hydroelectric power plants. In dry and cold periods with high demand and low supply of electricity Norway imports electricity, among others from Denmark. In Denmark, approximately 60 percent of electricity is produced in gas and coal-based power plants, and windmills produce approximately 20 percent.

(LES). Another tradition of distributional analyses uses micro simulation models to quantify effects of tax reforms. One example in this tradition discussing the consumer response to a commodity tax reform is Symons and Warren (1996).

The literature on the loss of efficiency due to distorting taxes, known as the deadweight loss (DWL) or excess tax burden, is extensive (se e.g. Hausman, 1981, Pauwels, 1986, Slesnick, 1991, Kay, 1980, Ziliak and Kniesner, 1999, Feldstein, 1999, Hausman and Newey, 1995, Breslaw, 1995, Creedy, 1999). In the empirical literature, most studies are using numerical examples instead of estimations on real data (Hausman, 1981, Creedy, 1999). Furthermore, very few *empirical* studies discuss the trade-off between distributional effects and efficiency of tax changes. Correia (1999) discusses this trade-off, both theoretically and empirically, in a dynamic general equilibrium model. She measures the equity by Lorenz dominance of different policies, and calculates the increase in welfare, applying the Pareto criterion, to rank policies according to efficiency. She illustrates this trade-off with several numerical examples of changes in the capital taxation. To our knowledge, no empirical studies have been made calculating the loss of Hicksian consumer surplus due to an increase in commodity taxation based on estimations on real micro data, to measure the trade-off between distributional effects and efficiency.

In this analysis, we apply the approach in Cornwell and Creedy (1997a) calculating the compensating variation (CV) to measure distributional effects of increased electricity taxation. These CVs are used to measure how changes in household utility due to the tax increase depend on the income distribution. We look at three different tax schemes; one proportional and two non-linear. We estimate a LES on cross-sectional micro data of 2410 households. We extend Cornwell and Creedy's (1997a) analysis by calculating the excess tax burden for the mean household due to the tax increase, suggested by Creedy (1999). We also extend Cornwell and Creedy's analysis by calculating the reduction in consumption and increase in household tax burden, both for the mean household and by deciles in the income distribution. This is done to illustrate the potential conflict of interests in household electricity taxation between the objectives of reduced electricity consumption, positive distributional effects and efficiency effects.

The focus of this analysis is the effects of an increase in the electricity tax on household electricity consumption and utility. We do not discuss whether an electricity tax is the optimal instrument to collect revenue or how the government should redistribute the collected revenue. Neither do we discuss how secondary changes in the electricity price due to repercussions in the electricity market and other markets, affect household behaviour and welfare. This analysis may thus be seen as a detailed description of the initial effects on household behaviour of different tax schemes, and how it affects households in different parts of the income distribution.

The paper is organised as follows: In section 2 we describe the theoretical framework for our analysis of household energy expenditures. The methodology for predicting changes in electricity consumption, excess tax burden and distributional effects is presented in section 3. The data set is described in section 4, and the results from the LES estimation follow in section 5. In section 6, we present the predictions of changes in electricity consumption, excess tax burden and distributional effects. A summary of the results is given in section 7, and finally, in section 8, some concluding remarks are made. Mean values for key variables in the data, both for the entire sample and distributed on deciles in the income distribution, and some estimation results are given in the appendix.

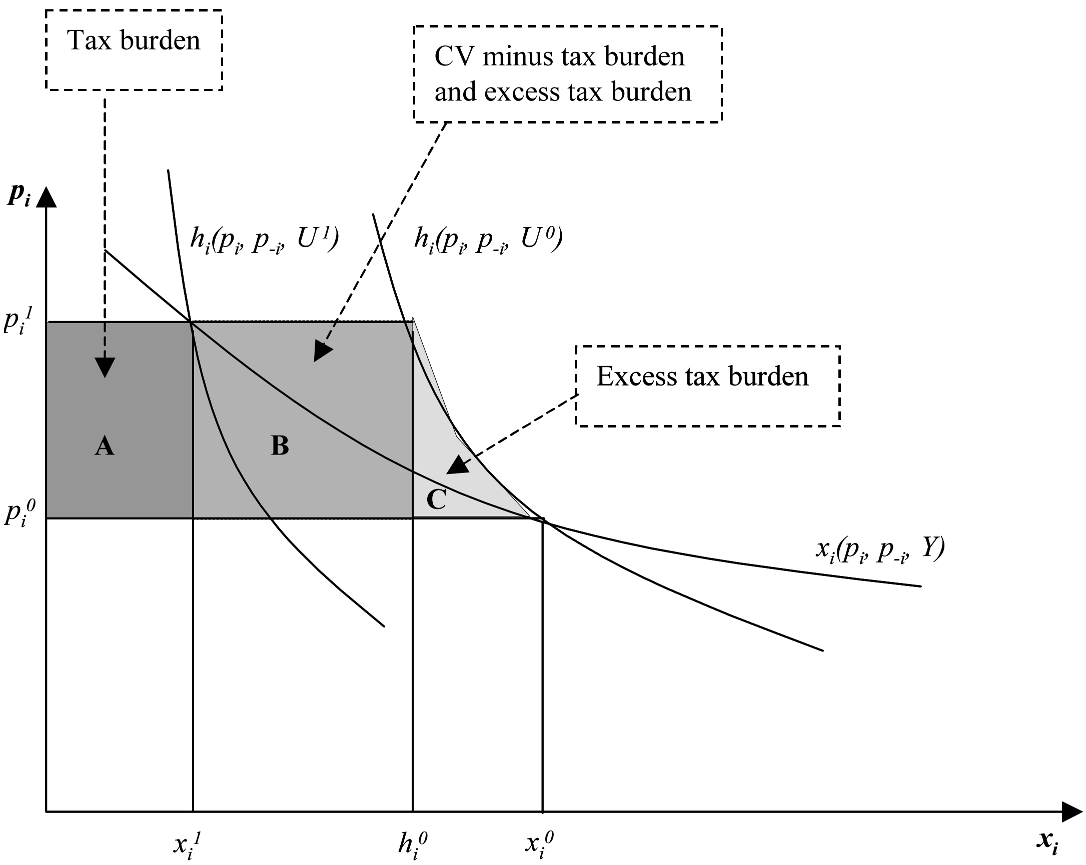
2. Theoretical framework

In order to measure a potential conflict of interests in household electricity taxation, we need to model how the electricity consumption responds to price changes. We start this section by defining the reduction in household electricity demand, compensating variation, increase in tax burden and excess tax burden due to an increase in electricity taxation. Then, we describe the Linear Expenditure System (LES), which is used to calculate the changes in electricity consumption and welfare measures.

2.1 Definitions

To determine the desired level of consumption, we assume that the household maximizes its utility subject to a budget constraint. This optimisation problem gives the household's demand function for all goods and services as a function of all prices and income.

Figure 1. Definition of compensating variation (CV), tax burden and excess tax burden



Source: Mas-Colell et al. (1995) figures 3.1.3 and 3.1.4 (b).

In figure 1, we have illustrated the demand for good i (x_i) as a function of the price of good i (p_i), a vector of prices of all other goods and services (p_{-i}) and income (Y). We have also plotted the Hicksian or compensated demand functions for good i before ($h_i(p_i, p_{-i}, U^0)$) and after ($h_i(p_i, p_{-i}, U^1)$) an increase in the price of good i due to a tax increase. When the price rises from p_i^0 to p_i^1, the demand for the good is reduced from x_i^0 to x_i^1. This quantity effect on the demand for good i (Δx_i) measures how a tax increase will affect the electricity consumption.

We measure the effects on household utility of a tax increase by the compensating variation (CV). The CV is defined as the income compensation necessary for the consumer to maintain the original utility level (U^0) after the price change. This is, by definition, the loss of Hicksian consumer surplus, which is represented by the area under the compensated demand function, i.e. the sum of all shaded areas in figure 1. The CV may be divided into the increase in tax burden (area A), the excess tax burden (area C) and the CV excess of the increase in tax burden and excess tax burden (area B). The increase in tax burden for the consumer is the change in the price of good i, that is the tax increase multiplied with the quantity after the price change (x_i^1). The excess tax burden due to the tax increase (which equals Mas-Colell et al. 1995's DWL) is defined as the loss of compensated variation that may not be compensated by a lump-sum transfer.

Note that we define the excess tax burden in micro. That is, we define the excess tax burden as the deficit that would arise if the government were to compensate the individual households to keep their welfare under the tax equal to her pre tax welfare (see Mas-Colell et al., 1995, figure 3.1.5 or Creedy 1999, pp. 112-113). We do not discuss the excess tax burden in macro, that is, the loss of consumer and producer surplus for all households and firms in the economy as we focus on consumer behaviour.

Note also that the tax revenue from the increase in the electricity tax may be redistributed to the households in many ways. In this analysis, we do not study the effects of redistribution. It may, however, be argued that the excess tax burden is the loss of utility measured in money terms if the entire increase in tax burden and the change in compensated demand times the tax increase (that is, the sum of the A and B area in figure 1) is redistributed to the household as a lump-sum transfer (se e.g. Mas-Colell et al., 1995 or Creedy, 1999 for a discussion).

Note further that the CV measure will normally understate the utility losses for low-income compared to high-income households. To see this, we can write the reduction in indirect utility due to a tax increase (ΔV) as the household CV times the mean marginal utility of income over the price change ($\overline{V}'_Y$), i.e.: $\Delta V = CV \cdot \overline{V}'_Y$ (see e.g. Johansson, 1993 chapter 3.2 for more information). Normally, we assume utility to increase with diminishing returns as income increases, so that the marginal utility of income falls with income. Thus, when comparing a high-income and a low-income household with equal CV, the loss of indirect utility is highest for the low-income household due to a higher marginal utility of income.

Finally, note that a given household income may give rise to a different standard of living across households, depending on the number of household members, age of household members, the level of housing expenses in the area of residence etc. To account for this, an equivalence scale may be used to adjust household income for such factors. Several choices of equivalence scale have been proposed in the literature (see Aaberge and Melby, 1998). We tested the robustness of our analysis to equivalence scale by applying the square root scale, suggested by Atkinson et al. (1995), where household income is corrected for the square root of the number of household members. We found that adjusting income for equivalence scale did not alter the conclusions from our analysis. Thus, these results are not reported here.

2.2 The Linear Expenditure System (LES)

In order to measure the effects of an increase in the electricity tax on household electricity demand, tax burden, CV and excess tax burden, we need estimates of the properties of the demand for electricity. In this analysis, we use the approach suggested by Cornwell and Creedy (1997a), applying the estimates from a LES-estimation to calculate the CV from an electricity tax increase, expanding the analysis by calculating tax burden, excess tax burden and reduction in consumption.

In this model, we focus on the consumption of energy goods only, assuming that the households do not change their labour supply or the consumption of other goods due to an increase in electricity taxation. This implies separability in the consumption of energy and other goods. We focus on the three energy sources of particular relevance in the Norwegian household energy consumption: electricity (*f=1*), kerosene and heating oil (*f=2*) and firewood (*f=3*). We assume that household energy expenditures are given by Stone-Geary functions, resulting in a Linear Expenditure System (LES) representing the consumption of the three energy sources. When estimating demand systems, the covariance matrix will be singular if one good is not used as a reference (see e.g. Greene, 1993). Here, we use the expenditures on firewood as reference.

$$E_f = \gamma_f p_f + \beta_f \left(E - \sum_{m=1}^{3} \gamma_m p_m \right) + \nu_f \, , \tag{1}$$

where E_f is household expenditure on energy source *f*, E is total household energy budget, p_f is the price of energy source *f*. The households' consumption of energy may vary by the number of household members, heating portfolio, stock of electric household appliances, dwelling size, etc. In this analysis, the effects of these household and dwelling characteristics on energy consumption are accounted for by the coefficients γ_f and β_f in the household energy expenditure function (1). That is, the price sensitivity (γ_f) and the budget sensitivity (β_f) are assumed to be linear functions of these characteristics as represented by equation (2):

$$\gamma_f = \gamma_f^0 + \gamma_f^y Y + \sum_{k=1}^{K} \gamma_f^k D_k \quad and \qquad (2)$$
$$\beta_f = \beta_f^0 + \beta_f^y Y$$

where D_k is various household- and dwelling characteristics (see Appendix table A3), *Y* is household income net of taxes, and ν_f is a stochastic error term. We assume the error term to be identical and independently distributed with zero mean and constant variance. γ_f^s and β_f^g (*s=y, 0, ….,K, g=y, 0*) are parameters to be estimated.

Since the total energy budget (*E*) is endogenous to households, we estimate an instrument to avoid simultaneity problems. The instrument is given by:

$$E = \sum_{f=1}^{3} F_f p_f = a_0 + a_1 Y + \sum_{c=1}^{C} a_{2c} K_c + \varepsilon \ , \qquad (3)$$

We assume that the instrument for the energy budget is a linear function of household income net of taxes, household characteristics (K_c) (different from the characteristics included in D_k) and a stochastic error term (ε). We assume the error term to have the same characteristics as the error terms in the expenditure functions.

The instrument is estimated applying the Ordinary Least Square method. The predictions from this estimation are inserted into the expenditure system (1) and (2), which is estimated by simultaneous

Maximum Likelihood estimation applying the MINIMIZE procedure in Limdep to minimize the negative log-likelihood function.

3. How to measure conflicting objectives

In this section, we discuss how to apply estimates from the expenditure system in (1) and (2) to calculate the change in electricity consumption, the distributional effects and excess tax burden, in order to illustrate the potential conflict of objectives in increased electricity taxation.

3.1 Reduced electricity consumption

From equation (1), we find that the partial derivative of the electricity *expenditure* with respect to the electricity price is given by: $\frac{\partial E_1}{\partial p_1} = (1-\beta_1)\gamma_1$. Solving this with respect to the marginal effect on electricity *consumption* of a price change, using $\frac{\partial E_1}{\partial p_1} = \frac{\partial F_1}{\partial p_1} p_1 + F_1$, gives: $\frac{\partial F_1}{\partial p_1} = \frac{(1-\beta_1)\gamma_1 - F_1}{p_1}$.

The predicted change in household electricity consumption in tax scheme j ($\Delta\hat{F}_{1j}$) is calculated as the estimated marginal quantity effect ($\partial\hat{F}_1 / \partial p_1$) multiplied by the mean change in the electricity price in tax scheme j ($\Delta\overline{p}_{1j}$).

$$\Delta\hat{F}_{1j} = \frac{(1-\hat{\beta}_1)\hat{\gamma}_1 - F_1}{\hat{p}_1} \Delta\overline{p}_{1j} \ , \tag{4}$$

For a proportional tax scheme, the mean price change ($\Delta\overline{p}_{1j}$) equals the marginal price change. This is, however, not true for non-linear tax schemes, as not all consumption is subject to a price increase. The mean price change is calculated by multiplying the tax increase by the proportion of household electricity consumption affected by the tax scheme. In order to calculate $\hat{\beta}_1$ and $\hat{\gamma}_1$, and thus the change in electricity consumption, we use the LES-estimates from a simultaneous estimation of the expenditure system (equations 1 and 2).

3.2 Distributional effects

The distributional effects of the tax schemes depend on how the tax increase affects households in different parts of the income distribution. When discussing welfare effects of tax increases, the media and politicians often focus on the increase in households' electricity expenditure, that is, the increase in tax burden. However, the value of the household’s utility loss is larger than the tax burden. As illustrated by figure 1, the total loss of compensated utility originates from increased tax burden (area Ain figure 1) and reduced consumption (the sum of the B and C areas in figure 1). Therefore, we look at the distribution of the entire CV as well as the increase in tax burden.

Compensating variation[2]

The household's CV is calculated applying the method suggested by Cornwell and Creedy (1997a) and Creedy (1999), using the properties of the LES to calculate the expenditure function before and after the tax increase. The predicted Compensating Variation (CV) in tax scheme *j* for the individual household is given by:

$$CV_j = A^0\left[\frac{A_j^1}{A^0}+\frac{B_j^1}{B^0}\left(\frac{E^0}{A^0}-1\right)\right]-E^0 \tag{5}$$

where

$$A^0=\sum_{f=1}^{3}p_f\hat{\gamma}_f,\;\; A_j^1=(p_1+\Delta p_{1j})\hat{\gamma}_1+\sum_{f=2}^{3}p_f\hat{\gamma}_f,$$
$$B^0=\prod_{f=1}^{3}\left(\frac{p_f}{\hat{\beta}_f}\right)^{\hat{\beta}_f} \;\; and \;\; B_j^1=\left(\frac{(p_1+\Delta p_{1j})}{\hat{\beta}_1}\right)^{\hat{\beta}1}\cdot\prod_{f=2}^{3}\left(\frac{p_f}{\hat{\beta}_f}\right)^{\hat{\beta}_f} \tag{6}$$

[2] See e.g. Cornwell and Creedy (1997a) pp. 594 - 598 for more information on calculating compensated money measures based on estimates from a LES. See also Deaton and Muellbauer (1980) for a discussion of welfare effects in the LES.

We denote the situation before the tax increase by superscript 0 and after the tax increase by superscript 1. E is expenditures on electricity, oil and wood. $\Delta\overline{p}_{1j}$ represents the mean electricity price change due to tax scheme j, i.e. the tax increase multiplied with the share of consumption over the limit of exemption. The estimated parameters for the mean household are used to estimate the parameters β_f and γ_f, which in turn are inserted into (6) to give an estimate of the CV for the mean household in each tax scheme. This estimate is multiplied by the share of households being affected by the tax to take into account that not all households are exposed to a utility loss. Thus, we calculate the loss of utility as the CV for the mean household and the mean affected household.

Increase in tax burden

The maximum household tax burden is the price change due to the tax increase multiplied by initial consumption. However, when the tax increases, the household may want to substitute consumption of oil or wood for electricity consumption in order to reduce its utility losses. Thus, the tax burden after the household have changed their consumption of electricity is less or equal to the maximum tax burden.

The increased tax burden in tax scheme j for each individual household (TB_j) after changes in consumption is given by:

$$TB_j = \Delta p_{1j}\left[\left(F_1 + \Delta\hat{F}_{1j}\right) - \vec{F}_{1j}\right], \tag{7}$$

where $F_1 + \Delta\hat{F}_{1j}$ is the electricity consumption after the tax increase. Only electricity consumption exceeding the limit $\vec{F}_{1j}$ is affected by tax scheme j. Thus, $\left(\left(F_1 + \Delta\hat{F}_{1j}\right) - \vec{F}_{1j}\right)$ is the amount of electricity consumption affected by the tax increase in scheme j.[3] For the proportional tax scheme, the limit of exemption from tax increase equals zero.

CV divided by income

As discussed in section 2.1, the CV measure will understate the utility loss in low-income compared to high-income households. Thus, when comparing two households with a given CV, the utility loss is larger for households with low income than for high-income household. In order to emphasize the importance of income on utility, we also look at how the CV divided by household net income is distributed over deciles in the income distribution.

3.3. Efficiency effects

In this analysis, we focus on a possible conflict of interests in electricity taxation regarding the change in consumption, distributional effects and efficiency effects. Here, we measure the efficiency effects by the excess tax burden in tax scheme j, defined in section 2.1. The excess tax burden in tax scheme j is calculated as the predicted CV minus the compensated demand after the tax increase for the original utility level multiplied by the tax increase in tax scheme j (for an illustration, see figure 1):

$$ETB_j = CV_j - \hat{h}_{1j}\left(p_1 + \Delta p_{1j}, U^0\right)\Delta p_{1j} \tag{8}$$

where $\hat{h}_{1j}\left(p_1 + \Delta p_1, \hat{U}^0\right) = \hat{\gamma}_1 + U^0\left(\frac{p_1 + \Delta p_{1j}}{\hat{\beta}_1}\right)^{\hat{\beta}_1 - 1} \cdot \prod_{k=2}^{3}\left(\frac{p_k}{\hat{\beta}_k}\right)^{\hat{\beta}_k}$, $\hat{U}^0 = \prod_{f=1}^{3}\left(F_f - \hat{\gamma}_f\right)^{\hat{\beta}_f}$ and $\sum_{f=1}^{3}\beta_f = 1$.[4]

The excess tax burden is thus a money measure for the permanent utility loss due to a change in

[3] In some cases, the predicted electricity consumption after the tax increase is lower than the limit of exemption. In these cases, the predicted increase in tax burden is set to zero.

[4] See Deaton and Muellbauer (1980), p. 42 for more information.

relative prices when it is assumed that the increase in tax burden is redistributed to the household as a lump-sum transfer.

If the motivation for the tax increase is purely fiscal, and the tax increase is not designed to reduce efficiency losses in the economy, the initial loss of consumers surplus, and thus the loss of efficiency due to the tax increase (before any secondary effects on the electricity price due to repercussions in the market), is the sum of all excess tax burdens for all households in the economy. If the motivation for the tax increase is correcting externalities, the aggregated excess tax burden minus benefits resulting from an internalisation of externalities will measure the efficiency effects of the tax schemes.

4. The data

All analyses presented in this paper are based on a pooled sample of 2410 separate households for the years 1993 and 1994, randomly drawn from the Norwegian population in accordance with Statistics Norway's standard sampling procedure. Our main data source is Statistics Norway's annual Survey of Consumer Expenditure (SCE) (see Statistics Norway, 1996). The SCE provides detailed information about household electricity expenditures, expenditures on other energy sources, heating equipment and household characteristics, such as dwelling size, type of dwelling etc. Information on income for all household members in the survey is obtained from the Directorate of Taxes' tax assessment registers. Income is measured as taxable income reported in the tax return net of taxes and deductions. Social security, child support etc. are not included in the income concept. Municipal electricity prices are obtained from the Norwegian Water Resources and Energy Directorate, and regional prices for firewood, kerosene and heating oil are obtained from the price survey used to calculate the Norwegian Consumer Price Index.

5. Results from the estimation

Before presenting the predictions from our analysis, we give a brief description of the results from the simultaneous estimation of the LES system on energy, presented in table 1.[5] In the first column, we present the estimated coefficients, in the second column we present the T-values and in the last column we present the P-values, that is, the probabilities of falsely rejecting the hypothesis of no effect. The first section of table 1 shows the estimated parameters in the expenditure function for electricity, and the second section shows the estimated parameters in the expenditure function for heating oil and kerosene. The parameters in the expenditure function for firewood are not estimated explicitly, but can be calculated implicitly from the estimated parameters assuming that the demand functions are in accordance with economic theory.[6] Finally, we present the estimated standard deviations of expenditures on electricity, heating oil and kerosene.

Looking at the electricity expenditures in part 1B of table 1, we find that the price sensitivity of electricity demand (γ_1) increases significantly with the number of rooms with electric floor heating, number of electric heaters, number of heaters based on fuel oil and kerosene, individual central heating based on fuel oil, individual central heating based on electricity, number of drying tumblers and dish washers, net floor space, number of persons in the household and the fixed electricity fee. The reason why the price sensitivity of the electricity demand increases with the stock of heating equipment based on fuel oil and kerosene is probably that these households have the opportunity of substitution in heating their dwelling. More electric appliances also increase price sensitivity, as the potential for "saving" electricity increases. Furthermore, we find that the price sensitivity of the electricity demand (γ_1) decreases significantly with household income, common central heating system, living in a block of flats, number of children younger than 16 and electricity bill paid by

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[5] Results from the estimation of the instrument for the energy budget in (3) are presented in Appendix table A2.

[6] See e.g. Deaton and Muellbauer, 1980, for more information.

others. Having small children in the household increases the necessity to heat the residence in the cold period of the year, making the consumption less sensitive to price changes. We also see from part 1A of table 1 that the sensitivity of electricity expenditures due to changes in the energy budget decreases with household income, that is, the estimate of β_1^y in equation (2) is negative. This result is as expected, since we assume that the marginal utility of consumption decreases with income.

The price sensitivity of expenditures of fuel oils (γ_2) is estimated to depend significantly on number of electric heaters, wood stoves and stoves for oil and kerosene, individual central heating based on oil and net floor space (see part 2B of table 1). The sensitivity of oil expenditures due to changes in the energy budget (β_2) also decreases with household income (see part 2A of table 1).

Table 1. Results from a simultaneous Maximum Likelihood estimation of a linear expenditure system on energy. 1993-94

Variable	*Coefficient*	*T-value*	*P-value*
1. Electricity expenditures (in 1000 NOK)			
A. (β_1) Energy budget effects:			
Constant	0.576	15.54	0.000
Household net income (10 000 NOK)	-0.002	-2.39	0.017
B. (γ_1) Price effects:			
Constant	-7.529	-2.68	0.007
Household net income (10 000 NOK)	-0.056	-1.83	0.067
Number of rooms with electric floor heating	1.871	7.73	0.000
Number of electric heaters	0.914	8.09	0.000
Number of heaters based on fuel oil and kerosene	2.592	3.19	0.001
Number of heaters based on fuel wood	-0.116	-0.33	0.743
Individual central heating system based on oil (dummy)	3.273	1.37	0.172
Common central heating system (dummy)	-11.250	-3.80	0.000
Individual central heating system based on electricity (dummy)	5.882	3.13	0.002
Number of drying tumblers	2.354	3.09	0.002
Number of dishwashing machines	3.626	4.20	0.000
Living in a block of flats (dummy)	-3.955	-2.12	0.034
Net floor space	0.081	8.20	0.000
Number of persons in the household	2.447	5.39	0.000
Number of children under age 16	-1.171	-2.32	0.021
Fixed electricity fee, regular household tariff	0.003	2.35	0.019
Electricity bill paid by employer or others (dummy)	-6.426	-2.28	0.023
2. Expenditures on heating oil and kerosene (in 1000 NOK)			
A. (β_2) Budget effects:			
Constant	0.049	3.26	0.001
Household net income (10 000 NOK)	-0.001	-2.56	0.011
B. (γ_2) Price effects:			
Constant	-0.032	-0.59	0.558
Household net income (10 000 NOK)	-0.000	-0.48	0.628
Number of rooms with electric floor heating	-0.010	-1.47	0.141
Number of electric heaters	-0.013	-4.16	0.000
Number of stoves based on fuel oil and kerosene	0.368	17.43	0.000
Number of stoves based on fuel wood	-0.029	-3.30	0.001
Individual central heating system based on oil (dummy)	1.425	34.84	0.000
Common central heating system (dummy)	0.059	1.10	0.273
Individual central heating system based on electricity (dummy)	0.011	0.35	0.727
Living in a block of flats	-0.082	-1.18	0.238
Net floor space	0.001	4.88	0.000
Number of persons in the household	0.010	0.90	0.370
Number of children under age 16	-0.016	-1.06	0.288
3. Expenditures on firewood (in 1000 NOK)			
A. (γ_3) Price effects:			
Constant	0.000	0.00	0.997
4. Standard deviations for energy expenditures (in 1000 NOK)			
Electricity	3.370	119.88	0.000
Heating oil and kerosene	1.272	138.10	0.000

All expenditures and prices are measured in 1994 NOK. 1 US$ is approximately 8.5 NOK.

6. Predictions

By applying the estimates reported in table 1, combined with mean values for all independent variables,[7] we are able to calculate estimates for β_f and γ_f in equation (2). These estimates are then applied to predict the reduction in electricity consumption, CV, tax burden and excess tax burden for the mean household in the different tax schemes, both for the entire sample and by deciles in the income distribution.

We start this section by describing the tax schemes. Then, we present some predictions for the mean household. Next, we look in more detail on the distribution of the number of households affected by the tax schemes, the predicted reduction in electricity consumption, CVs and tax burdens over deciles in the income distribution.

6.1. The tax schemes

The current electricity tax for Norwegian households is proportional to the electricity consumption. In 1993 and 1994, which are the years for which we have data, the electricity tax was 4.85 øre per kWh net of VAT on average (1 cent is approximately 8.5 øre). The tax amounted to about 12 percent of the electricity price for household consumers.

In this paper, we consider three different tax schemes for households, one proportional and two non-linear. The reason for looking at the non-linear alternatives is that such tax schemes were proposed to reduce potential negative distributional effects of an increase in the electricity tax (see the white paper on energy No. 29/99). In the proportional tax scheme (tax scheme 1), we assume that the electricity tax increases with 6.15 øre/kWh (5 øre/kWh net of VAT), which represents a 14.5 percent increase in the

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[7] Mean values for all dependent and independent variables, both for the entire sample and by deciles in the income distribution, are presented in Appendix table A1.

electricity price. In tax scheme 2, the tax increase on electricity consumption exceeding 10 000 kWh per household is 10.46 øre/kWh including VAT. For consumption below the limit, the electricity tax is unchanged. In tax scheme 3, the limit of exemption is 25 000 kWh per household, and the tax increases with 42.93 øre/kWh including VAT for consumption exceeding this limit.

Tax schemes 2 and 3 are constructed such as to yield the same tax revenue as tax scheme 1 with the initial electricity consumption. That is, the total tax burden is equal in all tax schemes when assuming no changes in electricity consumption due to the tax increase. Since the households are likely to change their electricity consumption when the electricity price changes, the actual tax revenues of tax schemes 1, 2 and 3 will differ *ex post*.

6.2. Predictions for the mean household

Table 2 sums up the predictions for the mean household with respect to reduced electricity consumption, distributional effects and excess tax burden. In our sample, only 41 percent of the households are affected by tax scheme 3, while 90 percent and 98 percent are affected by tax schemes 2 and 1 respectively, see table 3.[8] Since not all households are affected by the tax increases, the predictions presented in table 2 are both for the mean household and the mean *affected* household.

[8] The reason why not all households are affected by the proportional tax scheme is that some households are registered with a zero expenditure on electricity for various reasons. For instance, some households have their electricity bill paid by their employer or other persons, whereas some households have their electricity expenses included in their rent.

Table 2. Main results for the mean household in the sample

	Tax scheme		
	1	*2*	*3*
Reduced electricity consumption (kWh)	1 935	1 976	2 174
Reduced electricity consumption for *affected* households (kWh)	1 976	2 183	5 309
Compensating variation (NOK)	1 388	1 418	1 416
Compensating variation for *affected* households (NOK)	1 418	1 566	3 457
Increased tax burden (NOK)	1 286	1 228	505
Increased tax burden for *affected* household (NOK)	1 313	1 356	1 249
Excess tax burden (NOK)	1.63	1.79	3.23
Excess tax burden (NOK) for *affected* households	1.66	1.98	7.89
Excess tax burden per increase in tax burden (%)	0.13	0.15	0.64

1 US$ is approximately 8.5 NOK.

The reductions in electricity consumption for the mean household and for the mean affected household in each of the three tax schemes are reported in the first two rows of the table. The predicted reduction in consumption is largest for tax scheme 3 (2 174 kWh), which follows from a large reduction in consumption for the households being affected by the tax (5 309 kWh). Thus, tax scheme 3 is preferable when the objective is to reduce household electricity consumption. The predicted reduction in electricity consumption for the mean household as share of initial electricity consumption ranges from 8.3 percent in tax scheme 1 to 9.3 percent in tax scheme 3.

When comparing the utility loss measured by the CV in the three tax schemes, we find that the estimated CV for the mean household is lowest in tax scheme 1. When looking at the *affected* households only, there are large differences in the estimated CVs between tax schemes. The large CV, which occurs in tax scheme 3, is more than twice as high as in tax scheme 2 and 1. This is mainly due to the large reduction in electricity consumption for the affected households in this tax scheme.

The increase in average tax burden for the mean household is NOK 505 in tax scheme 3, while the increase in tax burden is much higher for the other two tax schemes. This is due to larger reductions of electricity consumption in tax scheme 3 than in tax scheme 1 and 2. When looking at the *affected* households only, the differences in increased tax burden between tax schemes are smaller. If the objective is to minimise the increase in tax burden, tax scheme 3 is preferable to the other two when looking at both the mean household and the mean affected household. Compared to the increase in tax burden of NOK 1 249 for the mean affected household in tax scheme 3, the reduction in consumption of 5 309 kWh represents a reduction in the initial tax burden (i.e. before the change in consumption) of NOK 1853. That is, if the household did not reduce electricity consumption due to the tax increase, the increase in tax burden would have been NOK 3 102 for the mean affected household in tax scheme 3 and not NOK 1 249.

In the last three lines of table 2, we report the predicted increase in excess tax burden for the mean and mean affected household, and the excess tax burden as a share of the increase in household tax payments (in percent). The excess tax burden is the loss of utility that cannot be regained by a redistribution of tax revenue. Thus, the excess tax burden per tax burden illustrates the permanent loss of utility measured in monetary terms for each NOK collected in tax revenue. The predicted excess tax burden for the mean household is smallest for tax scheme 1, which makes the proportional tax scheme preferable when aiming to minimize the excess tax burden. If we look at the estimated excess tax burden for the mean *affected* household, the difference between the tax schemes is enhanced. When looking at the excess tax burden as share of tax revenue, the proportional tax scheme is even more preferable as compared to the non-linear schemes, as the cost of collecting one NOK in revenue is 4.9 times higher in tax scheme 3 than in tax scheme 1. This large difference is due to the large reduction in consumption in tax scheme 3, as most households reduce their consumption towards the limit of exemption, making both the tax burden lower and the excess tax burden higher in the non-linear tax scheme with highest tax.

6.3. Variations over the income distribution

In the previous section, we presented predictions for the entire sample. However, when discussing distributional effects, it is of importance how the tax schemes affect households in different parts of the income distribution. We start by describing the share of households affected by the three tax schemes and how these households change their consumption as a response to the tax increase. Then we look at how the predicted CVs and tax burdens are distributed over income. Finally, we adjust the CV for household income to take into account that the utility loss of a one NOK increase in expenditures is larger for low-income households compared to high-income households.

Distribution of affected households and reduced electricity consumption

Table 3 shows the share of households affected by the tax schemes in different parts of the income distribution. In the first three columns of table 4, the resulting reductions in electricity consumption for the mean households by deciles in the income distribution are presented. Then, in the last three columns of table 4, we present the predicted reductions in consumption for the mean *affected* households by deciles in the income distribution.

Table 3. Share of affected households in the sample and by deciles over the income distribution. Percent

Deciles	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Tax scheme 1	96	96	97	98	97	99	99	99	99	99	98
Tax scheme 2	76	84	88	94	92	93	94	95	93	97	90
Tax scheme 3	17	25	27	35	39	43	50	51	56	67	41

Table 4. Predicted reduction in electricity consumption for the mean and mean affected household, for the entire sample and by deciles in the income distribution. kWh

	Predicted reduction in electricity consumption (kWh) for the mean household in tax scheme…			*Predicted reduction in electricity consumption (kWh) for the mean affected household in tax scheme…*		
	1	*2*	*3*	*1*	*2*	*3*
Mean for all observations	1 935	1 976	2 174	1 976	2 183	5 309
Deciles:						
1	1 663	1 373	1 025	1 728	1 799	6 023
2	1 723	1 532	1 162	1 798	1 828	4 667
3	1 902	1 778	1 559	1 959	2 031	5 779
4	1 942	1 925	1 773	1 974	2 053	5 026
5	1 877	1 904	1 807	1 933	2 066	4 633
6	1 868	1 937	2 053	1 892	2 093	4 805
7	2 010	2 112	2 149	2 035	2 252	4 317
8	2 044	2 201	2 482	2 061	2 326	4 863
9	2 046	2 274	3 021	2 072	2 435	5 433
10	2 273	2 726	4 714	2 292	2 807	7 013

Looking at table 3, we see that there is a tendency for the share of affected households to increase by income, in particular for tax scheme 3. Furthermore, looking at table 4, we see that the mean household in high-income deciles reduces electricity consumption more than mean households in low-income deciles, and that this tendency is most clear for tax scheme 3. This is mainly because the share of households affected increases with income. When *affected*, the differences between deciles in reduced electricity consumption are relatively small and with a less clear tendency for increase by income (see the last three columns of table 4). Thus, on average for the entire sample, tax scheme 3 target high-income households better with respect to reduced electricity consumption, than tax schemes 1 and 2. However, if we look at the affected households only, there is no clear tendency of increased predicted reduction in electricity consumption by income in tax scheme 3.

Distribution of compensating variation

Figure 2a shows how the predicted CV for the mean household is distributed over deciles in the income distribution, whereas figure 2b shows how the predicted compensating variation for the mean affected household is distributed over income.

Figure 2a. Distribution of the total compensating variation due to increased electricity taxation on different deciles in the income distribution. NOK

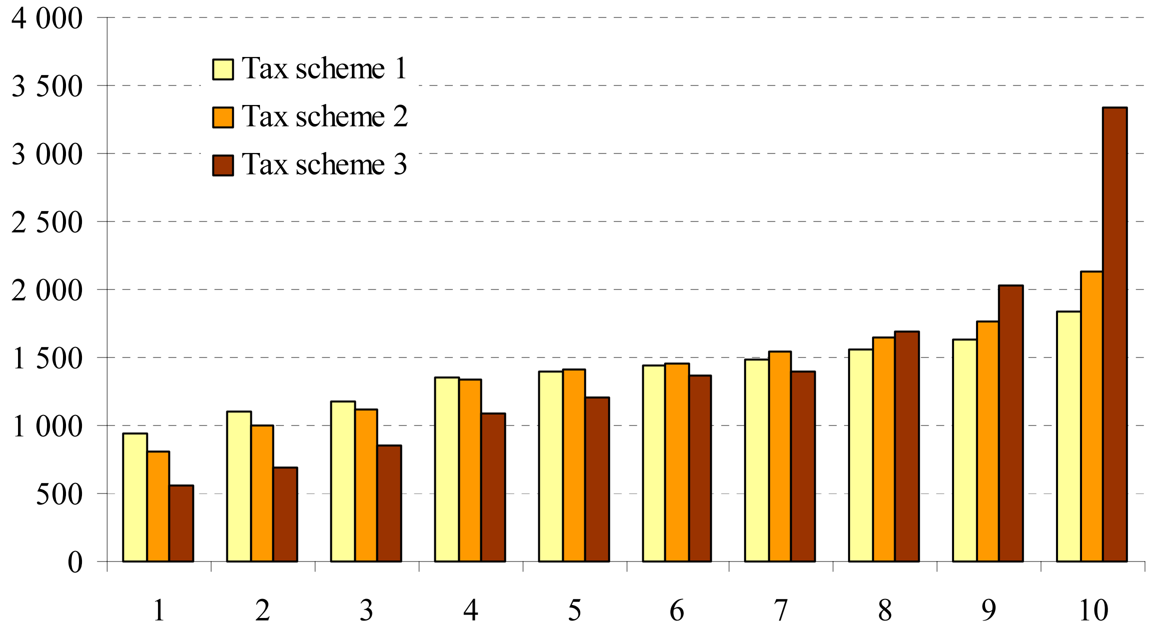
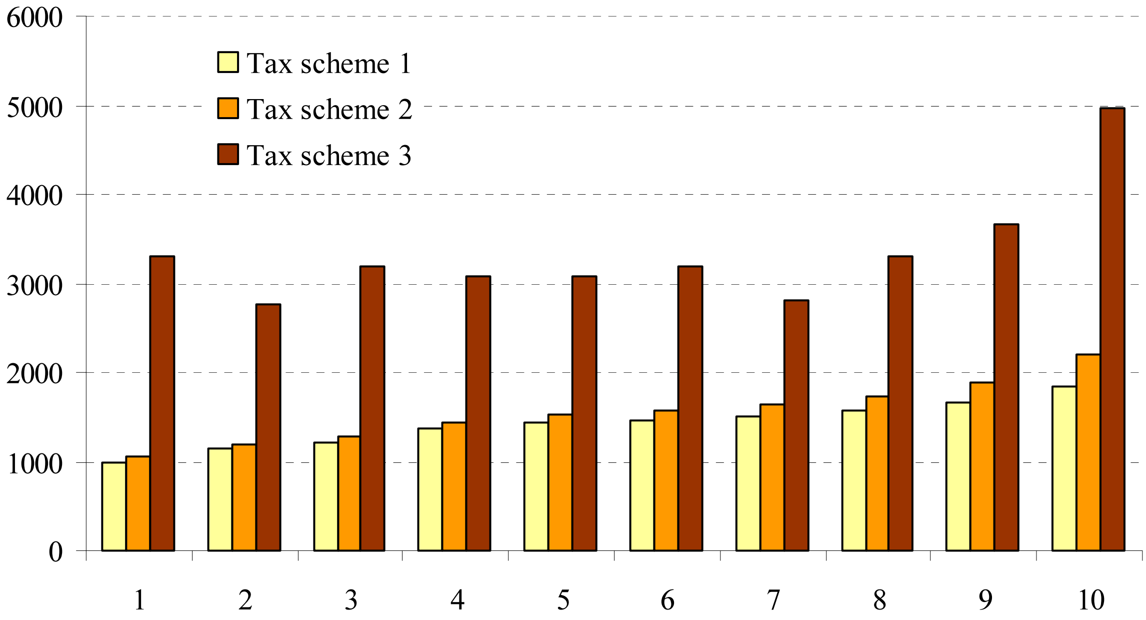


Figure 2b. Distribution of the total compensating variation for *affected* households due to increased electricity taxation on different deciles in the income distribution. NOK



The predicted CV for the mean household increases unambiguously with income, and this trend is clearer for tax scheme 3 than for the two other tax schemes. That is, the required income compensation in order to sustain initial utility, and thus the utility loss, increases more with income in tax scheme 3 compared to the other two tax schemes. Thus tax scheme 3 seems to give more positive distributional effects than the other tax schemes. The reason is that it mainly affects high-income households (see table 3) and that there is a tendency for high-income households to reduce electricity consumption more on average than low-income households in this tax scheme (see table 4). Thus, when looking at the CV for the mean household by deciles in the income distribution, tax scheme 3 is preferable to the two others for distributional reasons.

However, when discussing the distributional effects of a tax increase, it is also of interest to view the effects on the affected households, in particular in the lower parts of the income distribution. Figure 2b shows the predicted CV for the mean *affected* household in different income deciles. The predicted

CV, and thus the level of utility loss, is clearly higher in tax scheme 3 than in the other two tax schemes for all deciles. This means that affected low-income households also have a large utility loss in tax scheme 3 compared to the other tax schemes, and this loss is at the same level as for more wealthy households. Besides this, the difference in utility loss between low-income and high-income households in tax scheme 3 is smaller than in figure 2a, making the clear positive distributional effects of the non-linear tax alternative more uncertain. When comparing welfare effects for affected households only, tax schemes 1 and 2 are preferred to 3.

Distribution of increased tax burden

In figure 3a, we show how the predicted increase in tax burden for the mean household is distributed over the deciles in the income distribution. We see from the figure that total tax burden increases with income for all tax schemes. The increase in tax burden is lowest for tax scheme 3 at the same time as the progression over income is strongest for this alternative, making tax scheme 3 preferable if income levelling is considered most important.

Figure 3a. Distribution of the total increase in tax burden due to increased electricity taxation on different deciles in the income distribution. NOK

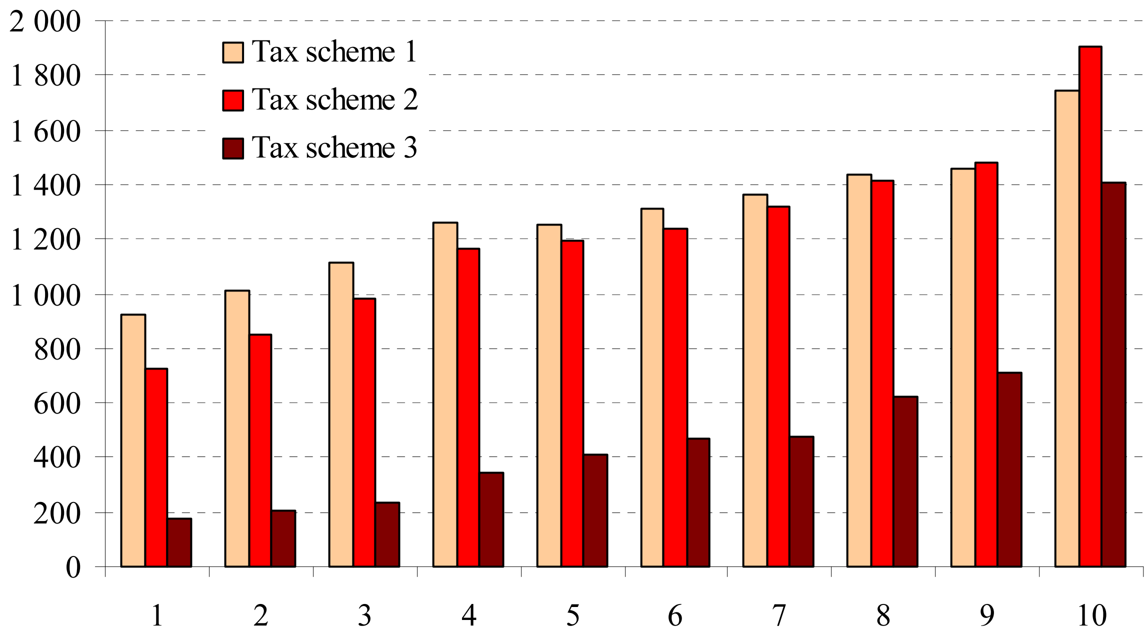


Figure 3b. Distribution of the total increase in tax burden for *affected* households due to increased electricity taxation on different deciles in the income distribution. NOK

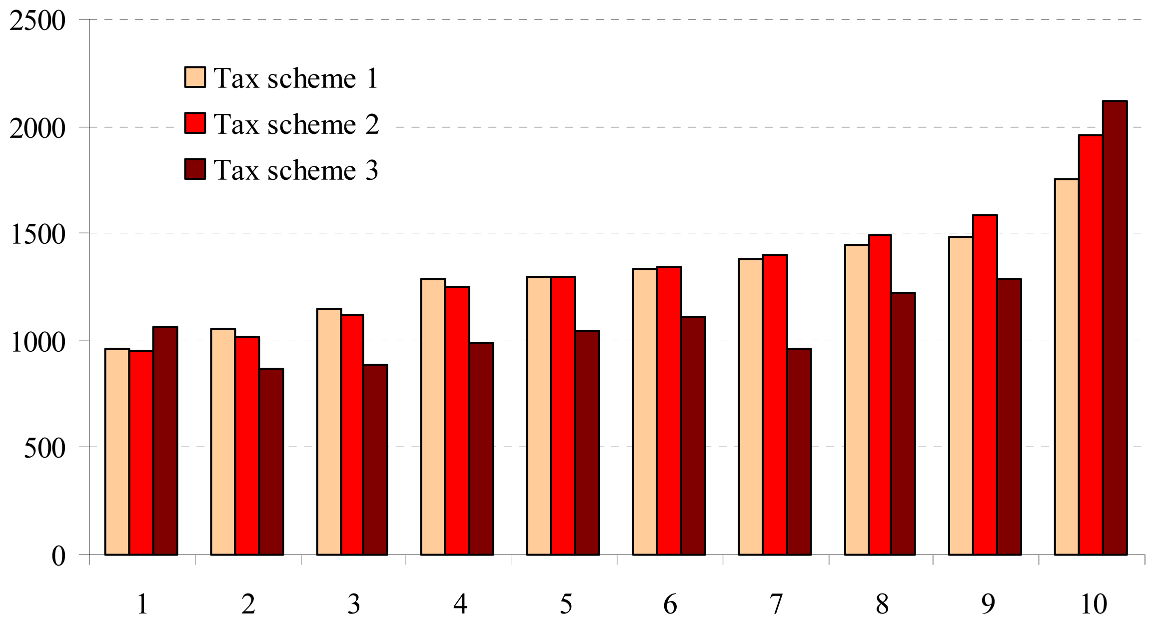


Figure 3b shows how the predicted increase in tax burden for the mean *affected* household varies over the income distribution. The tax burden increases by income deciles for tax schemes 1 and 2. Furthermore, we see that the increase in predicted tax burden for affected households in tax scheme 3 shows a less distinct trend over the income distribution. Thus, tax scheme 3 is preferable when looking at the predictions for the mean household, while the conclusion is not as distinct when looking at the mean affected household.

Distribution of CV relative to income

Based on evidence so far, it seems that tax scheme 3 has better distributional properties than the other tax schemes in most cases. However, comparing a low-income household and a high-income household with equal CV, the loss of utility will normally be higher in the low-income than in the high-income household (se the discussion of the marginal utility of income in section 2.1). In tax scheme 3, the predicted CV for the mean *affected* household in the 10th decile is about 1.5 times as high as for the mean affected household in the 1st decile (see figure 2b), while mean income is calculated to be more than 8 times higher for households in the 10th decile than for households in the 1st decile. Thus, the increase in tax burden is much heavier to bear for low-income households than for high-income households.

Figure 4a illustrates how the predicted CV for the mean household relative to household income (net of income taxes) varies by deciles in the income distribution. The figure shows that no tax schemes have positive distributional effect, in contrast to the conclusions from the previous analysis. For tax schemes 1 and 2, the figure indicates that the estimated utility loss, measured by the predicted CV as share of household net income, weighs heaviest in the lower parts of the income distribution. The ranking of tax schemes with respect to their distributional properties is, however, not altered, as tax scheme 3 is approximately neutral with respect to distributional effects.

Figure 4a. Compensating variation per household income due to increased electricity taxation by deciles in the income distribution. Percent

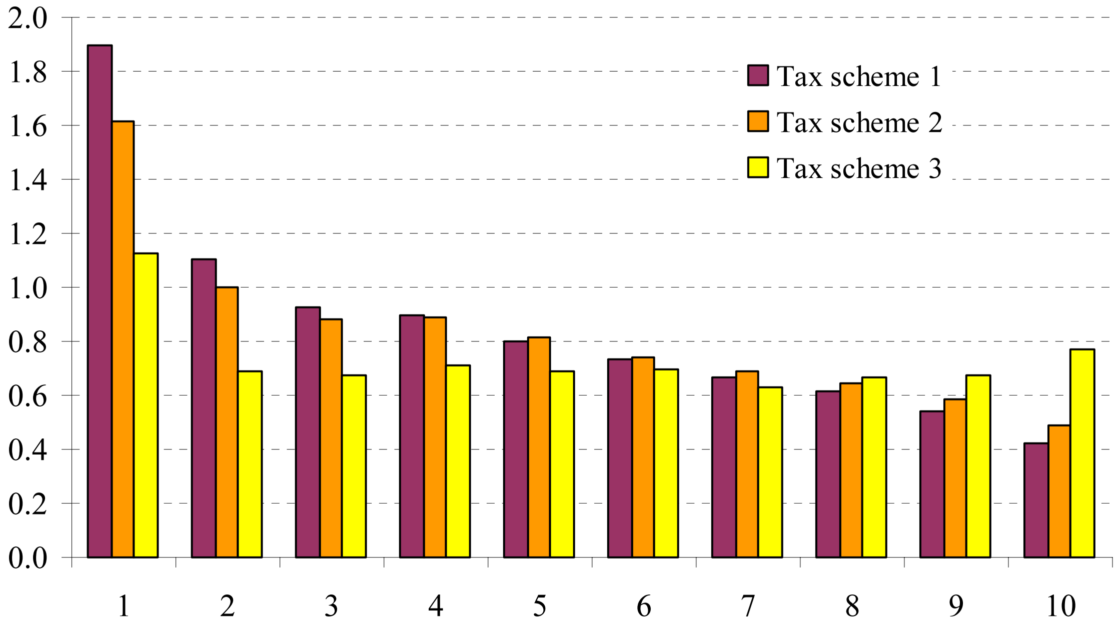
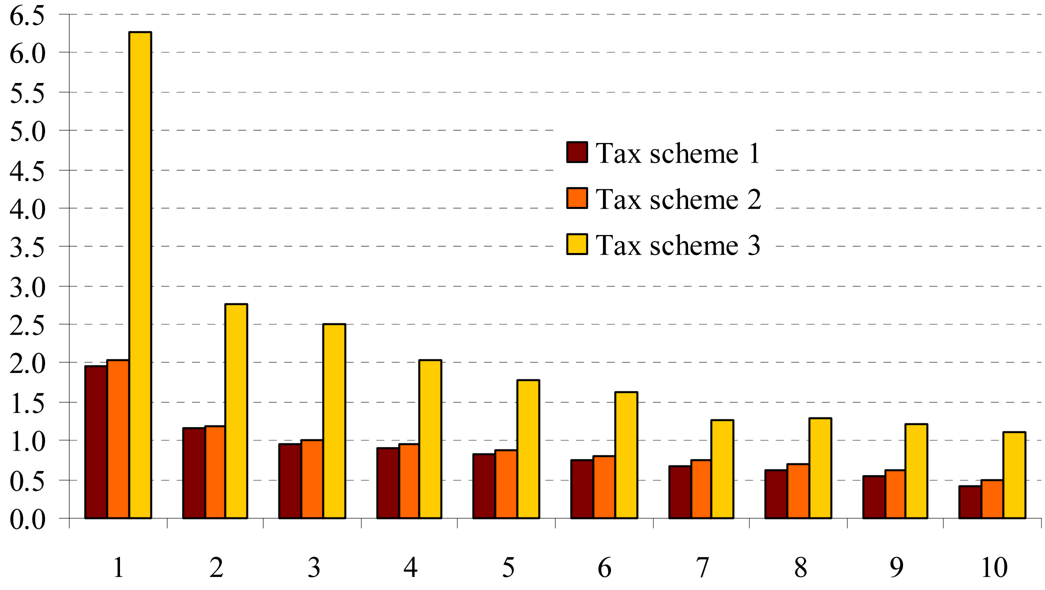


Figure 4b. Compensating variation per household income for *affected* households due to increased electricity taxation by deciles in the income distribution. Percent



It is, however, important to notice that even among the ten percent of households in the sample having lowest income, 17 percent of the households use more electricity than the level of exemption in tax scheme 3 and are heavily affected by the tax increase (see table 3). From figure 2b we saw that the utility loss, measured by the predicted CV for the mean *affected* household, is as large for affected households in this low-income decile as for the households in the 8th decile. Thus, when considering effects of different tax schemes, one has to remember that even though average results for an income group may be satisfactory, the results for individual households may be unsatisfactory.

Figure 4b shows the predicted CV relative to net income for the mean *affected* household by deciles in the income distribution. Tax scheme 3 now turns out to be the least preferable tax scheme. This is because the estimated utility loss for the mean affected household, as measured by the predicted CV in percent of household net income, is higher in tax scheme 3 than in the other two tax schemes. This result is valid for all deciles, and the burden is particularly heavy for households in the 1st income decile.

7. Summary

In table 5 we give a summary of our results in sections 6.2 and 6.3. The different political objectives, and the measures of these objectives, are presented in the first column. The preferred tax schemes for different objectives are presented in the second and third columns for the mean household and for the mean *affected* household, respectively.

Table 5. Preferred tax scheme for the mean household and the mean affected household depending on different objectives

	Mean household	***Mean affected household***
1. Reduced electricity consumption	*Tax scheme 3* High-income households reduce most	*Tax scheme 3* No trend in reduction by income decile
2. Distributional effects: *a) Compensating Variation*	*Tax scheme 3* Positive distributional effects	*Tax scheme 1 and 2* Lower level of CVs than in tax scheme 3, and larger relative difference in CVs of low-income vs. high-income deciles
b) Increase in Tax Burden	*Tax scheme 3* Lowest tax revenues	*Tax scheme 3, but not obvious* This is because the differences between tax schemes are relatively small and the increase in tax burden is largest for tax scheme 3 for decile 1
c) CV/Income	*Tax scheme 3* Approximately neutral as regards distributional effects in tax scheme 3. Negative distributional effects of other tax schemes	*Tax scheme 1 and 2* Negative distributional effects for all tax schemes
3. Efficiency effects:[a] *Excess Tax Burden*	*Tax scheme 1*	*Tax scheme 1*

[a] This is a gross effect, i.e. it is not taken into account any positive efficiency effects which follow if the motivation of the tax increase is to reduce initial efficiency losses.

Looking at table 5, we see that whether there is a conflict between the objectives between reduced electricity consumption, distributional effects and efficiency effects from an increase in the electricity tax depends on whether wee look at the effects on the *mean* or the *mean affected* household. Furthermore, the level of conflicting objectives depends on the motivation for the proposed tax increase. This is in particular true when looking at the effects on the *mean* household only (second column in table 5).

If the tax increase is purely fiscally motivated, there is a conflict of interests between the objectives of reduced electricity consumption and distributional effects and the objective of efficiency. Since tax scheme 3 target households with high electricity consumption, it is preferred as a means of reducing electricity consumption for the *mean* household. Tax scheme 3 is also preferable when considering distributional effects for the *mean* household, as the number of affected households in tax scheme 3 increases with income. However, tax scheme 3 represents the highest loss of efficiency as measured by excess tax burden for the *mean* household. The proportional tax scheme (tax scheme 1) gives the lowest excess tax burden. However, if the motivation for increasing the electricity tax was to reduce initial efficiency problems, e.g. due to global emissions, the conflict of interests is reduced or eliminated. Thus, it is an empirical question whether the non-linear tax scheme targeting high electricity consumption is preferred when considering the net effect on efficiency.

When considering the *mean affected* household, we find that there is a conflict of interests independent of the motivation of the tax increase. The reason for this is that it is ambiguous which tax scheme is best when considering the objective of reduced electricity consumption and the objective of positive distributional effects. Tax scheme 3 is preferable regarding the objective of reduced consumption, while the other non-linear tax scheme (tax scheme 2) and tax scheme 1 seem to be best when considering distributional effects.

The ranking of tax schemes with regard to the distributional effects are more ambiguous for the *mean affected* household than for the *mean* household. The distinction between the *mean* household and the *mean affected* household is thus important when considering the effects of different tax schemes. Among the ten percent of households with lowest income, 17 percent have electricity consumption higher than 25000 kWh and are affected by tax scheme 3. The question is whether only affected households or all households in each income group should be considered when choosing tax scheme.

8. Concluding remarks

From the analyses presented in this paper, we find that whether there is a conflict of interests in the electricity taxation between the objectives of reduced electricity consumption, positive distributional effects and efficiency effects depends on what is the motivation of the tax increase and whether we focus on the *mean* household or *mean affected* household.

The proportional tax scheme alternates with the most extreme non-linear tax scheme being the preferable tax scheme when focusing on different objectives and groups of households. We find that the most extreme non-linear tax scheme, with a high tax increase and high level of exemption, results in the largest total reduction in household electricity consumption even though few households are affected by this tax scheme. Additionally, this tax scheme has the best distributional effects if mean results for all sample households are considered. However, it is important to notice that this tax scheme also affects several households in the lowest income decile. The utility loss, as measured by the compensating variation and increase in tax burden, is relatively high for the *affected* households in the most extreme non-linear tax scheme compared to other tax schemes. When considering the CV relative to household net income, the utility loss is even higher for affected low-income households than for affected high-income households.

When considering the loss of efficiency, as measured by the predicted excess tax burden, the proportional tax scheme is preferable in all cases. Thus, if the motivation for the tax increase were purely fiscal, the loss of efficiency would be least in this tax scheme. However, if the motivation for introducing the tax increase in order to reduce electricity consumption were to correct for an external effect, the ranking of tax schemes with respect to efficiency consideration is ambiguous. This is because the non-linear alternative reducing the consumption most also increases excess tax burden the most. Thus, in this case we need to measure the benefits from the correction of the externalities in order to calculate the net benefit/cost in all tax schemes in order to rank them. This is a topic of interest for our future research on household energy consumption.

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Appendix: Tables

Table A1. Mean values of variables included in the estimations for the whole sample (2 410 households) and for households in different income deciles. 1993 and 1994

Decile	*Electricity expenditure (NOK)*	*Oil expenditure (NOK)*	*Fuel wood expenditure (NOK)*	*Electricity consumption (kWh)*	*Income (NOK)*
1	7 293	492	221	17 278	49 901
2	8 007	483	298	18 901	99 418
3	8 577	434	285	20 564	127 086
4	9 550	576	214	22 831	151 466
5	9 595	514	263	22 897	174 223
6	9 943	514	337	23 502	196 281
7	10 271	661	367	24 471	222 302
8	10 726	427	209	25 581	254 065
9	10 786	868	239	26 190	300 810
10	12 768	732	217	30 829	434 787
Total	9 752	570	265	23 304	201 034

1 US$ is approximately 8.5 NOK.

Table A1 cont.

Decile	*Flat (0,1)*	*Floor space (m^2)*	*House-hold members (#)*	*Tumble dryer (0,1)*	*Dish-washer (0,1)*	*Electric floor heating (# rooms)*	*Electric heaters (#)*	*Stoves for oil (#)*	*Stoves for wood (#)*	*Individual central heating: Oil (0,1)*	*Individual central heating: Electricity (0,1)*	*Common central heating (0,1)*
1	0.20	104	2.4	0.30	0.26	0.83	4.04	0.24	0.95	0.025	0.025	0.050
2	0.15	107	2.5	0.30	0.36	1.08	4.60	0.28	1.14	0.004	0.012	0.037
3	0.12	111	2.9	0.41	0.47	1.00	4.57	0.25	1.14	0.033	0.046	0.066
4	0.10	124	3.3	0.45	0.57	1.45	5.00	0.27	1.31	0.041	0.046	0.029
5	0.09	132	3.3	0.44	0.64	1.57	5.07	0.29	1.22	0.021	0.029	0.029
6	0.09	130	3.4	0.53	0.63	1.63	5.35	0.27	1.29	0.037	0.033	0.029
7	0.07	133	3.5	0.47	0.68	1.50	5.48	0.27	1.39	0.033	0.054	0.033
8	0.06	136	3.6	0.52	0.77	1.70	5.90	0.25	1.36	0.041	0.029	0.037
9	0.06	145	3.6	0.54	0.80	1.81	5.99	0.33	1.33	0.071	0.054	0.041
10	0.05	169	3.9	0.68	0.90	2.36	6.26	0.37	1.47	0.066	0.054	0.021
Total	0.100	129	3.2	0.46	0.61	1.50	5.23	0.28	1.26	0.037	0.038	0.037

Table A2. Results from the OLS estimation of the instrument for the energy budget [a)]

Variable	*All households*
Constant	12.493 **
Household income (1994-NOK)	0.076 **
No energy expenditures	-9.019 **
Electricity expenditures covered by others	-1.875 **
Living in a city (Oslo, Bergen or Trondheim)	-2.355 **
Electricity rental charge	0.001 **
Age of main income contributor	0.072 **
Number of children under 16 years	0.820 **
Number of income contributors	0.855 **
Change of residence	-1.376 **

a) Coefficients marked * or ** are significant at a 10 and 5 percent level, respectively.

Table A3. Household and dwelling characteristics represented by D_k in Equation (2)

Number of rooms with electric floor heating
Number of electric heaters
Number of heaters based on fuel oil and kerosene
Number of heaters based on fuel wood
Individual central heating system based on oil (dummy)
Common central heating system (dummy)
Individual central heating system based on electricity (dummy)
Number of drying tumblers
Number of dishwashing machines
Living in a block of flats (dummy)
Net floor space
Number of persons in the household
Number of children under age 16
Fixed electricity fee, regular household tariff
Electricity bill paid by employer or others (dummy)

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