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Abstract:

The main aim of this paper is to discuss distributional effects across households of increased electricity taxation. We focus on four progressive tax schemes and one proportional. We find that the most progressive alternatives have the best distributional properties when assuming that households cannot change their consumption. When allowing household electricity consumption to change as a response to the tax increase, the positive distributional effects of the progressive alternatives are weakened. The ranking of the tax schemes is not affected by the choice of equivalence scale.

Keywords: Household energy consumption, electricity taxation, distributional effects, micro-econometric analysis.

JEL classification: D12, H24, D39, C31.

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1. Introduction

Various kinds of commodity taxes are used in most countries. The motivation for commodity taxes may for instance be environmental concerns, but fiscal reasons are most common. Regardless of motivation, such commodity taxation has distributional effects, which are the focus of this analysis. The distributional effects of increased commodity taxation on household consumption possibilities, and thus welfare, depend on the relationship between the households' expenditures on the particular commodity and the income distribution. If the expenditures increase unambiguously with income, a tax increase may reduce the dispersion of consumption possibilities between households. However, if the flexibility of demand with respect to a price change increases with income, it will reduce potential positive distributional effects of a tax increase. This may occur if the household's possibilities to substitute the consumption with alternative goods increase with income.

Distributional effects of changes in commodity taxation have been of current interest in the Norwegian political debate. Several proposals to increase the electricity tax for households have been discussed. In the national budget for 1999 the government expressed concern that the annual domestic consumption of electricity exceeded mean production. They proposed an increase in the electricity tax to reduce the consumption and strengthen the electric power balance. In the debate that followed, e.g. in a white paper on energy and the national budget for 2000, concerns were expressed about the distributional effects of an increased electricity tax.

Most of the current literature discussing distributional effects of tax increases focuses on income inequality and changes in *income* taxation. Analyses of distributional effects of commodity taxation are not as common, 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, that is the income compensation needed to obtain the same utility as before the tax change, applying the estimates from a Linear Expenditure System (LES). Speck (1999) discusses the distributional impacts between countries of energy and carbon taxes in a Kyoto Protocol context. Another tradition of distributional analyses uses micro simulation models to quantify effects of tax reforms. One example of this tradition discussing the consumer response to a commodity tax reform is Symons and Warren (1996). In a Norwegian analysis, Aasness (1998), distributional effects of increased electricity taxation are discussed in terms of the properties of the Engel function for electricity, assuming that the households do not change their demand for electricity when the electricity price increases.

The current literature does not give all the answers needed in the Norwegian political debate on the distributional effects of increased electricity taxation. To shed further light on the topic, we make a comparative study of the distributional effects of different progressive and proportional schemes of increased electricity taxation. Our approach is a micro econometric analysis applying household data to estimate the properties of the electricity demand in Norwegian households. Thus, we can not apply microsimulation models as described in Harding (1996) or the method suggested by Speck (1999). We wanted to analyze changes in household electricity consumption due to the tax increase, to open for the possibility of reducing welfare loss due to substitution in the consumption. Since both welfare and consumption are allowed to change in our study, we do not apply the compensated income measures suggested by Cornwell and Creedy (1996, 1997) or the approach suggested by Aasness (1998).

In this paper, we define positive distributional effects as a reduction in dispersion of welfare between households. Since a household's welfare is not observable, we need to find a proxy variable highly correlated with household welfare. In order to determine the distributional effects of a tax increase, we study the effect on dispersion of households' consumption possibilities defined as *household income after taxes net of electricity* expenditures. The dispersion is measured by the coefficient of variation (CV). It is likely that there exist some economies of scale in the household production of services. Since the consumption possibilities of a household depend on the economies of scale, the chosen equivalence scale may affect the results. In the literature, a number of different equivalence scales have been suggested (see e.g. Atkinson et al., 1995, Aaberge and Melby, 1998). In this paper, we look at the two extremes: No economies of scale (the electricity consumption *per household member* is independent of the number of household members) and perfect economies of scale (the household electricity consumption is independent of the number of household members).

We discuss whether an assumption of unchanged household electricity consumption and choice of equivalence scale affects the results from the analysis. We also discuss whether differences in the price flexibility between income groups influence the distributional effects of the tax increase. Changes in the households' electricity consumption are predicted using the results from a simultaneous Maximum Likelihood estimation of a partial LES on energy.

The paper is organized as follows: In section 2 we present the five electricity tax schemes and illustrate the dispersion of income and electricity expenditures across households. In section 3, we describe a model for household expenditures on energy. The results are presented in section 4, and in section 5 some concluding remarks are made. Mean values for key variables in the data and some estimation results are given in the appendix.

2. Data and tax schemes

Our main data source is Statistics Norway's annual Survey of Consumer Expenditure (SCE) for the years 1993 and 1994 (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. 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.

The current electricity tax for Norwegian households is proportional to the electricity consumption. In 1993 and 1994 the electricity tax was 4.85 øre per kWh on average (100 øre is approximately US$ 0.11). The tax amounted to about 11.5 percent of the electricity price for households. When the different tax schemes were first proposed in 1998, the electricity tax was 5.75 øre/kWh.

The distributional effects of an electricity tax increase depend on how different tax schemes affect households in different parts of the income distribution. In this paper we consider five different tax schemes for the households, presented in table 1. The tax schemes 1 - 4 are progressive tax increases, whereas scheme 5 is a proportional tax increase.[1]

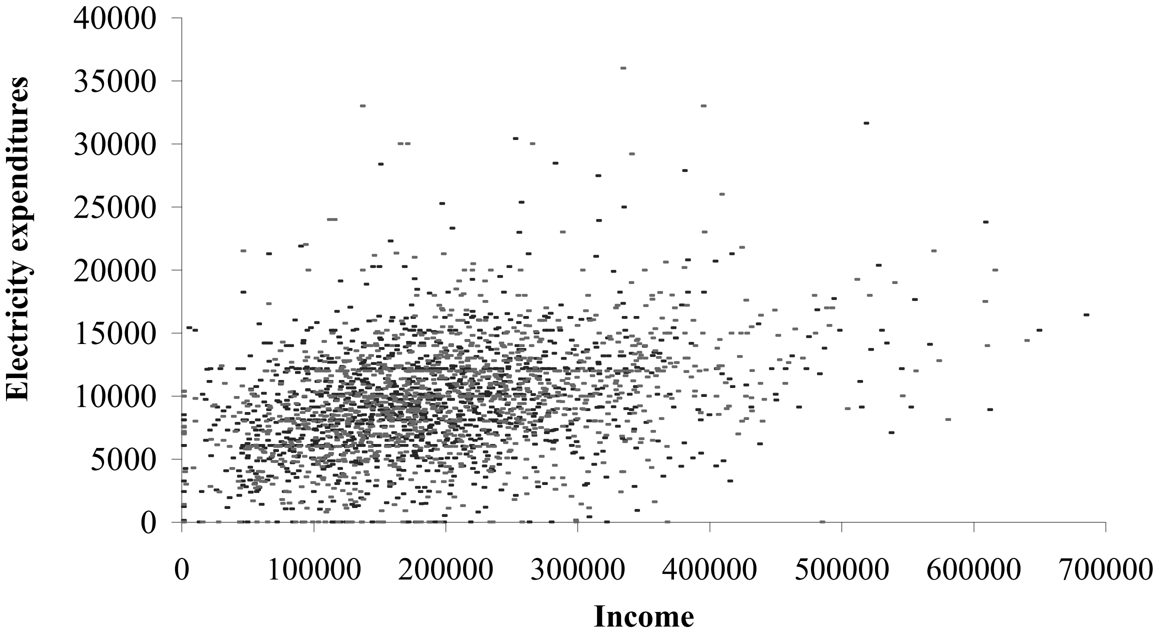
Table 1. Alternative schemes for increasing the electricity tax

Tax scheme	*Electricity tax increase (øre/kWh)*	*Limit (kWh per year)*	*Unit*
1	5.75	10 000	Household
2	5.75	5 000	Household member
3	11.5	25 000	Household
4	11.5	11 000	Household member
5	2.5	0	Household

[1] The Ministry of Petroleum and Energy considered these tax schemes subsequent to the report from the panel on energy.

In tax scheme 1, the tax on all electricity consumption exceeding 10 000 kWh per household is doubled as compared to the level in 1998. For all consumption below the limit, the electricity tax is unchanged. In tax scheme 2, the limit of exemption is set at an electricity consumption of 5 000 kWh per household member. For all electricity consumption exceeding this limit the tax is doubled. For all consumption below, the electricity tax is unchanged. In tax scheme 3, the limit of exemption is 25 000 kWh per household, and the tax is tripled for all consumption exceeding this limit. In tax scheme 4 the tax is tripled for all consumption exceeding the limit of 11 000 kWh per household member.

Figure 1. Household electricity expenditures by income for all households in the survey. 1993 - 1994. (1994-NOK)



Source: Statistics Norway

Figure 1 illustrates how household electricity expenditures vary with income. The figure indicates that the expenditures on electricity increase with income. We also see that several households with low income have high electricity consumption. These low-income households will thus be effected by most progressive tax schemes. Correspondingly, some high-income households have low electricity expenditures, and thus consumption, and will be exempted even in the less progressive tax schemes 1 and 2. In tax scheme 5, all households are affected regardless of electricity consumption.

3. The model

In this paper, we study the effects of increased electricity tax on household consumption possibilities, both when electricity consumption is assumed to be unaffected and when it is assumed to change due to the tax increase. To be able to quantify the households' change in electricity consumption, we need to model how households respond to price changes. We start this section by describing the household's decision problem determining the demand for electricity. Then, we discuss how to use this model to estimate the change in electricity demand and calculate the distributional effects of a tax increase.

3.1. Theoretical model

The consumption of energy does not give the household utility *per se*, but is used along with equipment to produce goods and services. To determine the desired level of household production and consumption, we assume that the household maximizes its utility subject to a budget constraint. In this model, we only look at the effects on the consumption of energy goods, assuming that the households do not change their labor supply or the consumption of other goods due to the tax increase on electricity. This implicitly assumes separability in the consumption of energy and other goods. This optimization problem gives the household demand function for energy source *f*:

$$F_f = F_f\left(p_F, E, A, \beta\right) \tag{1}$$

where p_F is a vector of all energy prices, E is the total energy expenses, A is a vector of the household's appliance stock and β is a vector of household characteristics influencing the demand for energy, e.g. the number of household members, net floorage of the residence, etc. We focus on three energy sources: electricity (*f=1*), kerosene and heating oil (*f=2*) and firewood (*f=3*).

Assuming that the utility function is concave and continuous, several properties of the demand functions follow from the consumer theory. First, the demand function is homogeneous of degree zero in all prices and the budget. Second, if the budget constraint is assumed to be binding, the expenditure system is uniquely defined by all expenditure functions minus one, that is two expenditure functions in our model. Finally, homogeneity imposes Slutsky symmetry. If we assume household expenditure on energy to be given by a linear approximation, imposing these restrictions gives a Stone-Geary expenditure system. For more details on consumer theory, see e.g. Deaton and Muellbauer (1980) or Varian (1992).

3.2. Econometric model

Economic theory imposes restrictions on consumption *within* each household. If the "true" expenditures are identical Stone-Geary functions for all households, we will not experience any aggregation problems and all properties of the individual expenditure functions may be imposed on the estimated function. It is however, not certain that all restrictions may be imposed on the estimated expenditure system since we average the expenditures over different households. Since the expenditures may vary by the number of household members, heating portfolio, stock of electric household appliances, dwelling size, etc., we approximate differences in expenditures by an additive linear function of household characteristics. The expenditure for the mean household is thus approximated by:

$$E_f = \gamma_f p_f + b_f\left(E - \sum_{j=1}^{3}\gamma_j p_j\right) + \sum_{k=1}^{K} d_{fk} D_k + v_f\ , \tag{2}$$

where E_f is the household expenditure on energy source *f*, E is the household energy budget, p_f is the price of energy source *f*, D_k is a vector of various household- and dwelling characteristics and v_f is a stochastic error term. We assume the error terms to be identical and independently distributed with zero mean and constant variance. γ_f, b_f and d_{fk} are parameters to be estimated. γ_f may be interpreted as the minimum consumption of energy type *f*. If the homogeneity restriction holds, all d_{fk}s equal zero. If the estimated d_{fk}s differ significantly from zero, the homogeneity property does not hold for the estimated expenditure function. Furthermore, if the budget constraint holds, the sum of the b_fs equals one.

The energy budget is endogenous to the household, defined as the household's total expenditures on all energy sources. To avoid the simultaneity problems which follows from including an endogenous variable as an explanatory variable, we estimate an instrument for the total energy budget, given by:

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

where we assume that the instrument for the energy budget is a linear function of household income (Y), other household characteristics (K_c) and a stochastic error term (ε). Furthermore, we assume the error term ε 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 (2), which is estimated by simultaneous Maximum Likelihood estimation.

3.3. Calculating new electricity expenditures after a tax increase

In this analysis we discuss whether the distributional effects of a tax increase depend on whether the households are allowed to change their electricity consumption or not. We apply the estimates from the expenditure system in (2) to calculate the individual households' change in electricity consumption due to the tax increase. Then, we use the estimated change in electricity consumption to calculate the household's new expenditure on electricity. These expenditures are used to calculate the change in the dispersion of household consumption possibilities, that is income net of electricity expenditures, due to the different tax schemes.

For any expenditure function, the effect on expenditures due to a price increase may be decomposed into two effects, the price and quantity effects, illustrated by equation (4). The equation is derived by taking the partial derivative of the electricity expenditure (E_1) with respect to the electricity price (p_1):

$$\frac{\partial E_1}{\partial p_1} = \frac{\partial (p_1 F_1)}{\partial p_1} = F_1 + \frac{p_1 \partial F_1}{\partial p_1} \ . \tag{4}$$

The *price effect,* given by the term F_1 in equation (4) multiplied by the price change, is the increase in expenditures due to the price increase, assuming consumption to be constant. The *quantity effect,* given by the term $p_1 \partial F_1 / \partial p_1$ multiplied by the price change, is the effect on expenditures of households changing their consumption due to the price change.[2]

In our model (equation 2), the partial derivative of the electricity *expenditure* with respect to the electricity price is:

$$\frac{\partial E_1}{\partial p_1} = (1 - b_1)\gamma_1 \tag{5}$$

The expression for the marginal change in electricity expenditures in (5) may be interpreted as the *average* marginal change as it is assumed to be constant for all levels of consumption. By combining equation (4) and (5), we find that the marginal effect on the electricity *consumption* of a price change is given by:

[2] The quantity effect can be decomposed into *substitution* and *income effects*. The household may either substitute electricity for other energy sources, or reduce energy consumption due to the loss of income, or both (see e.g. Varian, 1992).

$$\frac{\partial F_1}{\partial p_1} = \frac{(1-b_1)\gamma_1 - F_1}{p_1} \tag{6}$$

To calculate the marginal quantity effect, we insert the estimates of b_1 and γ_1 and the initial observed electricity consumption into (6). We use the initial observed consumption and not the predicted consumption in order to preserve the original variation in consumption between households. The predicted electricity consumption after the tax increase ($\hat{F}_1^{new}$) is given by the sum of the initial consumption (F_1) and the predicted change in the consumption ($\Delta\hat{F}_1$):

$$\hat{F}_1^{new} = F_1 + \Delta\hat{F}_1 = F_1 + \frac{(1-\hat{b}_1)\hat{\gamma}_1 - F_1}{\hat{p}_1}\Delta\overline{p}_1 \ , \tag{7}$$

The predicted change in consumption (that is the last term in equation 7) is calculated as the estimated marginal quantity effect in (6) multiplied by the mean electricity price change ($\Delta\overline{p}_1$). For the proportional tax scheme, the mean price change equals the marginal price change. This is, however, not true for the progressive 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. Ignoring the quantity effect implicates a totally inelastic electricity demand, represented by $\hat{F}_1^{new} = F_1$ in equation (7).

The new estimated electricity expenditures after the tax increase ($\hat{E}_1^{new}$), when allowing the households to change their electricity consumption, is given by:

$$\hat{E}_1^{new} = \vec{F}_1 p_1 + \left(\hat{F}_1^{new} - \vec{F}_1\right)\left(p_1 + \Delta p_1\right) \ , \tag{8}$$

where the limit ($\vec{F}_1$) equals zero in the proportional tax scheme. Thus, in the proportional tax scheme, the tax increase leads to an increase in the electricity price of Δp_1 for all electricity consumption. In the progressive tax schemes the electricity tax is increased for all consumption exceeding the limit.[3]

3.4. Heterogeneity between income groups

One objective of this paper is to illustrate how ignoring the quantity effect affects the distributional properties of various tax schemes. The distributional effects of ignoring the quantity effects depend on the price sensitivity of the demand function, which may vary by income groups. Thus, we want to estimate the expenditure system for different income groups separately, to investigate if such differences influence our results. In our estimations, we divide the households into three groups depending on annual household income after taxes, where the lower limit is 140 000 1994-NOK and the upper limit is 240 000 1994-NOK[4]. In our data the high-income group consists of 28 percent of the households, and the low-income group amounts to 32 percent of the households.

Looking at equation (4), we see that the increase in expenditures due to the *price effect* increases with electricity consumption. Thus, if the electricity consumption increases with income, (that is, electricity is a normal good) high-income households will experience a larger increase in electricity expenditures

[3] We have no observations of progressive electricity prices in the data. Thus, we assume that we can apply the marginal quantity effect given in (6) to estimate changes in household electricity consumption, both for proportional and progressive tax schemes.

[4] 1 NOK is approximately US$ 0.11. The households are divided into income groups to secure identification of the parameters when estimating separately for each income group.

due to the price effect, *ceteris paribus*, than low-income households. The possibility and willingness to change electricity consumption due to a change in the electricity price (that is, the quantity effect) may also vary across income groups. Looking at the *quantity effect*, there are two components on the estimated change in electricity consumption that may differ between high-income and low-income households. First, the marginal change in the electricity consumption decreases with the consumption level (see equation 6). Second, the direct own price derivative on electricity expenditures (see equation 5 and 6) may differ between high- and low-income households due to differences in heating portfolio and the possibility to substitute electricity by other energy types. If electricity is a necessity good, i.e. $1-b_1>0$, the partial effect on electricity expenditure of a price change ($(1-b_1)\gamma_1$) is positive. The quantity effect may thus be positive or negative depending on which of the two components is the largest.

Figure 1 indicates that there is a positive correlation between electricity consumption and household net income (see also table A1 of the appendix). We thus expect the *price effect* of the progressive tax schemes to reduce the dispersion of consumption possibilities between households, as high-income households on average will be more affected by the tax increase than low-income households. We also expect the distributional effects to be more uncertain when we correct the results for *quantity effects*. This is because our data indicate that high-income households have a higher possibility than low-income households do to avoid loss in consumption possibility from the tax increase by substituting their energy consumption towards alternative energy sources. In appendix table A1 we see that the share of households having oil heating or firewood equipment increases as income increases. High-income households also often live in large houses and may more easily reduce their total energy consumption by reducing the heated area of the house or turn off energy intensive electric appliances like electric ground heating, spas, swimming-pools etc.

4. Empirical results

In this section, we present the results from the estimations of the expenditure system in (2) and the estimated effect of the tax schemes on the dispersion of household consumption possibilities. We use the results both from the estimation for all households and for different income groups, to estimate the changes in electricity consumption and consumption possibilities after the tax increase. When discussing the distributional effects of the five tax schemes, we both consider the separate price effect and the total effect (that is, both price and quantity effects). We also compare the results when using two alternative equivalence scales.

4.1. Estimation results

In table 2 we present the results from a simultaneous estimation of the energy expenditure system for all households. (Results from the estimation of the instrument for the energy budget in (3) are presented in table A3 in the appendix.) In the first column of table 2, 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 probability of falsely rejecting the hypothesis of no effect. In the first section of table 2 (A) we present the common parameters of the expenditure functions for electricity and for heating oil and kerosene. The next section (B) presents parameters specific to the electricity expenditures, and the third section (C) presents parameters specific to the expenditures for heating oil and kerosene. Finally, we present the estimated standard deviation of expenditures on electricity, heating oil and kerosene.

Looking at the results in table 2, we see that the estimates of b_1 and $(1-b_1)\gamma_1$ are positive, which means that the electricity expenditure increases with the total energy budget and the electricity price. The estimated minimum electricity consumption (γ_1) is 3 792 kWh. We also see that electricity expenditures increase significantly with the number of rooms with electric floor heating, the number of electric heaters, tumble dryers, dishwashers, household members and dwelling size. The electricity expenditures are reduced if the residence is located in a block of flats, if it is a single person household or if the household has common central heating.

Table 2. Results from a simultaneous Maximum Likelihood estimation of the energy expenditure system. 1993-94

Variable	*Coefficient (1994-NOK)*	*T-value*	*P-value*
A) Common parameters for the electricity and kerosene/heating oil expenditures:			
γ_1 (electricity)	3 792	2.809	0.0050
γ_2 (heating oil)	3	0.057	0.9543
γ_3 (firewood)	4	0.473	0.6360
b_1 (electricity)	0.439	15.753	0.0000
b_2 (heating oil)	0.036	2.903	0.0037
B) Electricity expenditures:			
Number of rooms with electric floor heating	412	11.146	0.0000
Number of electric heaters	228	12.646	0.0000
Number of units of oil based equipment	-117	-0.875	0.3817
Number of units based on firewood	64	1.029	0.3033
Common central heating	-459	-3.026	0.0025
Number of tumble dryers	475	3.111	0.0019
Number of dishwashers	648	3.668	0.0002
Living in a block of flats	-1 061	-3.078	0.0021
Dwelling size (m^2)	12	9.813	0.0000
Single person household	-666	-1.960	0.0500
Number of household members	157	2.395	0.0166
C) Kerosene and heating oil expenditures:			
Number of rooms with electric floor heating	-66	-3.486	0.0005
Number of electric heaters	-59	-6.815	0.0000
Number of units of oil based equipment	1 172	20.392	0.0000
Number of units based on firewood	-100	-4.024	0.0001
Own oil based central heating	4 597	53.957	0.0000
Living in a block of flats (m^2)	-112	-0.591	0.5543
Dwelling size	2	4.892	0.0000
D) Standard deviation of energy expenditures:			
Standard deviation, electricity	3 425	120.347	0.0000
Standard deviation, oil	1 276	146.309	0.0000

4.2. Household behavior across income groups

The estimated electricity expenditure after a tax increase depends on the estimated change in electricity consumption. As discussed in section 3.3, the estimated change in electricity consumption depends on the level of electricity consumption initially and the estimated partial derivative of electricity expenditures with respect to the electricity price. We see from figure 1 that consumption is positively correlated with income, but we do not know how the partial derivative of the expenditure varies with income. We have estimated thus the expenditure system in (2) for each of the three income groups separately to see how the parameters differ between high- and low-income households. The results from these estimations are presented in appendix table A2. The results show that the estimated minimum consumption (γ_1) is 581, 4 505 and 3 152 kWh for low-income, middle-income and high-income households, respectively. The estimated marginal budget share (b_1) is 0.52 for low-income households, 0.46 for middle-income households and 0.43 for high-income households. Thus, γ_1 does not vary systematically with income, whereas b_1 decreases with income.

To illustrate how the estimated changes in electricity consumption vary with income, we have calculated the marginal effect on electricity expenditures and consumption with regards to the electricity price (from equations 5 and 6) for different income groups, presented in table 3.

Table 3. Marginal effect on electricity expenditures (NOK) and electricity consumption (kWh) due to an increase in the electricity price for all households and by income groups

	All households	*High-income households*	*Middle-income households*	*Low-income households*
Marginal effect on electricity expenditures (NOK) [a)]	21	18	24	3
Marginal effect on electricity consumption (kWh) [a)]	-551	-662	-553	-446

a) This marginal effect is due to a one-øre increase in the electricity price (2.4 percent). 100 øre, that is 1 NOK, is approximately US$ 0.11.

We see that the estimated marginal effect on electricity expenditures due to a price change ($(1-b_1)\gamma_1$) is higher for high-income and middle-income households than for low-income households. The estimated marginal increase in the electricity expenditures is 18 NOK for high-income households and 3 NOK for low-income households for a one-øre increase in the electricity price. We also see that the estimated electricity consumption is reduced when the electricity price increases, and that the reduction increases with income. The household may take the welfare loss as reduced electricity consumption or increased electricity expenditure, or both. The results imply that high-income households take a larger portion of the welfare loss as reduced consumption and a smaller part as increased expenditures than low-income households do.

4.3. Distributional effects

Our main aim is to discuss how the different tax schemes affect the dispersion of consumption possibilities across households. The after tax electricity expenditures in different tax schemes for each household is calculated applying equation (8). We calculate the new electricity expenditures using the estimates for the different income groups (from appendix table A2) in order to test whether the assumption of identical households affects the distributional effects of the tax schemes. We use the Coefficient of Variation (CV) to measure the dispersion in household consumption possibilities. The CV is defined as the sample standard deviation divided by the sample mean (see e.g. Champernowne and Cowell, 1998). If all households have equal consumption possibilities, the sample standard deviation and thus also the CV equals zero. If the standard deviation is larger than the mean, the CV may take a value larger than one.

To illustrate the effect on the dispersion of household consumption possibilities we have calculated the CV before and after the tax increase, presented in table 4. We report the CV measure in percent, that is the share multiplied with 100. In part *A)* we present the CV before the tax increase. In section *B),* we present the change in the CV after introducing the tax increase (in percentage points) for all tax schemes given in table 1. The first column represents the price effect only, assuming that the households do not change their electricity consumption. In the next two columns, we present the CV when both price and quantity effects are included in the new electricity expenditure. In the first of these columns, we present the CV when the new expenditure is calculated applying the estimation results from table 2, assuming that all households have identical expenditure functions. In the last column, we present the CV when we allow the expenditure function to vary between income groups, where the new expenditure is calculated applying the estimation results presented in table A2.

Table 4. Coefficient of variation (CV) for household consumption possibilities *per household*, A) before the tax increase (percent) and B) changes after the tax increase (percentage points). 1993 and 1994

	Price effect	*Price and quantity effect*	
		All households on average	*All households by income class*
A) CV before the tax increases. Percent			
	63	63	63
B) Change in the CV after the tax increase. Percentage points:			
Tax scheme 1	0.099	-0.186	-0.195
Tax scheme 2	-0.257	-0.129	-0.138
Tax scheme 3	-1.582	-0.023	-0.025
Tax scheme 4	-1.702	-0.030	-0.032
Tax scheme 5	0.184	0.009	-0.003

Table 4, part A) shows that the mean variation of consumption possibilities is 63 percent of the mean value. In most cases the tax schemes have positive distributional effects since the tax increase reduces the dispersion of consumption possibilities. The only exception is the price effect in tax scheme 1, and tax scheme 5, which have negative distributional effects. Looking at the price effect only, we find that tax schemes 3 and 4 have considerably better distributional effects than the other tax schemes. The reason is that these tax schemes only affect households with very high electricity consumption, which mainly are households with high income (see appendix table A1).

Comparing the results when we include both price and quantity effects with the results for the price effect only, we find that the positive distributional effects of tax scheme 3 and 4 are reduced considerably. We also see that the ranking of tax schemes with respect to distributional effects has changed, as tax schemes 3 and 4 no longer have better distributional effects than the rest of the schemes. Furthermore, the conclusions are more sensitive towards the assumption of no quantity effects than the assumption of homogeneous expenditure functions between income groups. Allowing the expenditure functions to differ between income groups does not alter the ranking between tax schemes.

4.4. Choice of equivalence scale

We now want to check whether our conclusions are robust with regard to the choice of equivalence scale. In table 5 we present the CV for consumption possibilities *per household member*. Comparing tables 4 and 5, we find the similar pattern for the dispersion of household consumption possibilities *per household member* as *per household*. Looking at the *price effect* only, tax schemes 2 and 4 which account for the number of household members, have better distributional effects when looking at the CV for consumption possibilities per household member than when we look at the distribution of consumption possibilities per household. Schemes 1 and 3, which do not account for the number of household members, have better distributional effects if we look at the distribution of consumption possibilities per household than when looking at the distribution per household member. Still, the ranking of the different tax schemes with respect to the distributional effects is not altered when focusing on the price effect only. When including the *quantity effect*, the distributional effects do not differ significantly depending on whether we measure consumption possibilities by household or household member, even if the sign of the CV for some tax schemes changes. Regardless of equivalence scale, the main reason for differences in the distributional effects is looking at price effects only or including quantity effects.

Table 5. Coefficient of variation (CV) for household consumption possibilities *per household member*, A) before the tax increase (percent) and B) changes after the tax increase (percentage points). 1993 and 1994

	Price effect	*Price and quantity effect*	
		All households on average	*All households by income class*
A) CV before the tax increases. Percent			
	64	64	64
B) Change in the CV after the tax increases. Percentage points:			
Tax scheme 1	0.133	-0.172	-0.180
Tax scheme 2	-0.407	-0.044	-0.052
Tax scheme 3	-1.100	-0.033	-0.034
Tax scheme 4	-2.364	0.038	0.036
Tax scheme 5	0.157	0.005	-0.005

5. Conclusions

The results from our analysis indicate that an increase in the electricity tax does not only affect high-income households. This is due to high electricity consumption in several low-income households. Even though there is a positive correlation between the households' electricity consumption and income, this coherence varies considerably across households. The possibility of low-income households to substitute their electricity consumption towards other energy sources is also smaller than for high-income households.

Our analysis shows that in most cases the progressive alternatives have better distributional properties than the proportional. Which of the four progressive alternatives that have the best distributional properties depends on whether we study price effects only, or whether we include the quantity effects. Allowing the demand for electricity to change due to the tax increase alters the ranking of the different tax schemes according to distributional effects. This is partly because high-income households have a more flexible heating portfolio, allowing them to reduce their welfare loss from the tax increase to a larger extent than low-income households do. The equivalence scale, that is whether we measure the variation in consumption possibilities per household or per household member, does not affect the ranking of different tax schemes. Furthermore, assuming identical household expenditure functions across income groups does not affect the ranking of tax schemes, even though some signs change. When households are allowed to change their electricity consumption, differences in distributional effects between tax schemes are small.

Our approach enables us to discuss the dispersion of consumption possibilities when we allow households to adjust their electricity consumption to reduce welfare loss. The approach is, however, based on several assumptions and simplifications. For instance, we assume separability in the consumption of energy and other goods, and we look at a short time model, ignoring the possibility to invest in more heating equipment to avoid increased expenditures (which is likely to vary with income). Our choice of income variable and the choice of expenditure function may also influence our results. Furthermore, the effect on expenditures for heating oil and wood are not considered because our model does not significantly explain the substitution of electricity for other energy types. In our future work on this topic, these areas will be investigated in further detail to get a better understanding of distributional effects of increased household electricity taxation.

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 classes. 1993 and 1994

	All households	*High-income households*	*Middle-income households*	*Low-income households*
Electricity consumption (kWh)	20 567	24 997	20 652	16 234
Electricity expenses (1994-NOK)	9 752	11 479	9 848	7 979
Fuel oil expenses (1994-NOK)	570	680	566	471
Firewood expenses (1994-NOK)	265	219	297	266
Household income (1994-NOK)	201 034	332 747	187 882	92 971
Electricity price (1994-NOK/kWh)	0.422	0.418	0.424	0.425
Fuel oil price (1994-NOK/liter)	3.310	3.308	3.315	3.306
Firewood price (1994-NOK/sack)	45	45	45	46
Do not have electricity expenses	0.021	0.010	0.017	0.035
Do not have oil heating equipment	0.753	0.722	0.766	0.765
Do not have firewood equipment	0.196	0.131	0.155	0.313

Table A2. Results from a simultaneous Maximum Likelihood estimation of the expenditure system on energy for all households, and for different income groups. 1993-1994[a)]

Variable	*All households*	*High-income households*	*Middle-income households*	*Low-income households*
A) Common parameters for the electricity and kerosene/heating oil expenditures:				
γ_1 (electricity)	3 792 **	3 152	4 505	581
γ_2 (heating oil)	3	-25	-66 *	30 *
γ_3 (firewood)	4	49 **	0.5 **	3 **
b_1 (electricity)	0.439 **	0.4320 *	0.4592 *	0.5207 *
b_2 (heating oil)	0.036 **	0.0327 **	0.0559 **	0.0382 **
B) Electricity expenditures:				
Number of rooms with electric floor heating	412 **	466 *	362 *	436 *
Number of electric heaters	228 **	246 **	205 **	195 **
Number of units oil based equipment	-117	-346	194	-317
Number of units based on firewood	64	443	179	-152
Number of units common central heating	-459 **	-341	-481	-501
Number of tumble dryers	475 **	528	312	764
Number of dish washers	648 **	1 200	440	506
Living in a block of flats	-1 061 **	-1 565	-1 510	-270
Dwelling size (m^2)	12 **	12 **	8 **	16 **
Single person household	-666	218	-250	-587
Number of household members	157 **	133	167 *	171
C) Kerosene and heating oil expenditures:				
Number of rooms with electric floor heating	-66 **	-112 **	-22 **	-76 **
Number of electric heaters	-59 **	-72 **	-54 **	-39 **

Variable	*All households*	*High-income households*	*Middle-income households*	*Low-income households*
Number of units oil based equipment	1 172 **	1 159	1 176 *	1 205
Number of units based on wood fuel	-100 **	-81 *	-107 **	-102 **
Own oil based central heating	4 597 **	4 526	4 938	3 835
Living in a block of flats	-112	-230	37	-173
Dwelling size (m^2)	2 **	4 **	2 **	0.3 **
D) Standard deviation:				
Standard deviation, electricity	3 425 **	3 802 *	3 270 **	2 926 **
Standard deviation, oil	1 276 **	1 467 **	1 236 **	1 097 **

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

Table A3. Results from the OLS estimation of the instrument for the energy budget [a)]

Variable	*All households*		*High-income households*		*Middle-income households*		*Low-income households*	
Constant	12.4931	**	18.2074		12.2142		14.4165	*
Household income (1994-NOK)	0.0762	**	0.0626	**	0.0587		0.0102	
No energy expenditures	-9.0185	**	-11.3609	**	-9.0925	**	-8.3045	**
Electricity expenditures covered by others	-1.8750	**	-2.8147	**	-1.0503		-1.6578	
Living in a city (Oslo, Bergen or Trondheim)	-2.3546	**	-1.8298	**	-2.6471	**	-2.6402	**
Electricity rental charge	0.0010	**	0.0006		-0.0042		0.0014	**
Age of main income contributor	0.0723	**	0.1143	**	0.0715	**	0.0575	**
Number of children under 16 years	0.8200	**	0.7373	**	0.7385	**	1.0428	**
Number of income contributors	0.8549	**	0.4924	*	0.4392	*	1.0890	**
Change of residence	-1.3755	**	-1.2072		-2.6930	**	-0.8636	

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

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