Factors determining the growth in residential electricity consumption

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In Norway, political signals have indicated that the growth in energy consumption should be reduced and that it may be necessary to increase the energy taxes. A discussion of energy taxes levels is also actualized by the Kyoto agreement. This raises the question of what effect such tax changes will have on energy consumption. Based on the data for a sample of households in the period 1976-1993, this article looks at the factors that are of importance to residential electricity demand. Household electricity consumption has increased by an average of about 3 per cent annually in the twenty-year period we have studied. Nearly half of this increase is due to an increase in the number of households, while the remainder reflects an increase in average consumption per household. The results show that several factors point to higher average electricity consumption per household in this period. Among other things, an increasing number of households have started to use electric household appliances such as dryers and dishwashers, household income measured at constant prices has increased and the floor space of dwellings has risen. The results also show that a higher electricity tax will lead to a fairly substantial change in residential electricity demand.

Introduction

Residential electricity consumption has increased over time, partly due to income growth and a composition of household consumption that requires higher energy consumption. For example, the size of dwellings and the percentage of households that have electric household appliances, such as dishwashers and dryers, have increased considerably the last twenty years. Political signals have indicated that the growth in energy consumption should be reduced, and that it may be necessary to increase taxes on energy consumption.[1] The extent to which electricity demand will be influenced by an increase in the electricity tax will in part depend on the composition of electricity consumption for various purposes. Taxes can also have unfavorable distributional effects.

Data from such sources as Statistics Norway's annual Survey of Consumer Expenditure for the period from 1976 to 1993 have been used in order to elicit how such measures will influence residential electricity demand. Based on these data, we study the factors which have influenced developments in Norwegian residential electricity consumption. The data set contains information about a household's consumption of energy goods and other goods, prices for these goods, as well as income and other household characteristics. This entails that we can make thorough empirical analyses of residential energy consumption. However, there will always be some uncertainty associated with such empirical analyses, and our results must therefore be interpreted with caution. The uncertainty may reflect, among other things, unrepresentative data, the choice of our analytical method and the specification of the econometric model. For example, our data set consists of a sample of households, although the sample is so large that the main features of the analysis are assumed to be relatively robust.

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This article focuses on studying the flexibility of household demand for electricity, i.e. the possibilities for adjusting electricity consumption when prices, income or other factors that are of importance to energy demand change. The article is based on Halvorsen, Larsen and Nesbakken (1999) and Halvorsen and Larsen (1999). In studies of flexibility, it is important to take several factors into account. First, households are not a uniform group, and the demand for electricity may vary depending on the type of household. For example, it is reasonable to assume that a family with small children living in a block of flats will have a consumption pattern that differs from a minimum pensioner living in a detached dwelling. Basing these studies exclusively on analyses of aggregated data therefore entails the risk of losing important information on variations in behaviour between different types of households. By analysing the data for each household (micro data), it is possible to provide estimates for the importance of differences in energy consumption. Energy is a means to obtain such services as heat, refrigeration, freezing and lighting. Changes in the household's stock of energy-consuming equipment therefore have a considerable influence on changes in energy consumption. In addition to household characteristics, changes in the stock of equipment (increase or replacement) will depend on prices for the equip-

1 See, for example, section 4.4.1 in the National Budget 1999, which describes the main features of taxes on the use of energy.

ment and energy types as well as expectations concerning future prices. A third factor that should be taken into account in analyses of residential electricity demand is that households so far have been billed for all uses combined (heating, lighting, etc.) based on last year's consumption profile, adjusted for actual consumption once a year. Actual prices and the cost of electricity consumption are therefore unknown to the household. It must be assumed that such factors have an influence on electricity consumption, and it is therefore necessary to test which prices that influence household energy use.

We begin by providing an overview of developments in electricity consumption. We then present the results of an econometric analysis of those factors which influence residential electricity consumption. The article concludes with a summary and concluding remarks as well as a review of data sources used in the analysis.

Development in household electricity consumption

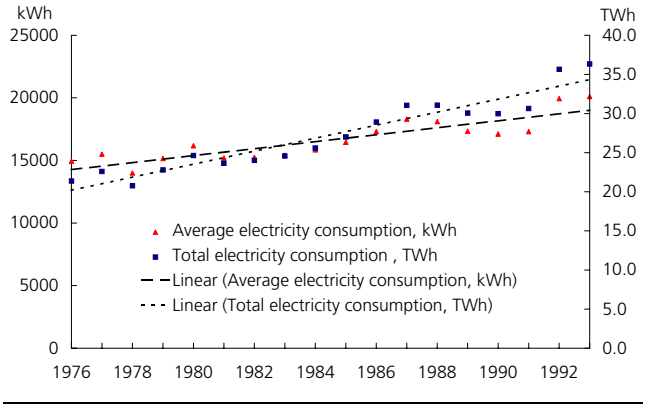
Figure 1 shows changes in total electricity consumption for all Norwegian households (measured in TWh along the right-hand axis) and average electricity consumption per household (measured in kWh along the left-hand axis) in the period 1976 to 1993, as well as a linear trend line for both series.

Total electricity consumption is calculated by multiplying average consumption per household in the sample by the number of households in Norway.[2] The estimated trend growth in average electricity consumption per household was 1.7 per cent a year in the period 1976-1993. Estimated total electricity consumption of Norwegian households increased by an average 3.1 per cent annually in the period, measured along the trend line.[3] The reason that total electricity consumption increased by a greater margin than average consumption per household is that the number of households in Norway rose by an annual average of 1.4 per cent in this period as a result of population growth and a reduction in the number of persons in the household. This means that about 45 per cent of the growth in total residential electricity consumption is due to an increase in the number of households, while the remaining 55 per cent is ascribable to changes in factors that influence the various households' electricity consumption. In the next section we take a closer look at the factors which influence household behavior.

What determines household electricity consumption?

Econometric analyses based on the data set described at the end of the article were carried out in order to explain the factors determining residential electricity consumption.

Figure 1. Estimated average electricity consumption per household (kWh) and total electricity consumption in the household sector (TWh), 1976-1993



Source: Statistics Norway.

This section starts with a brief description of how household behaviour is modelled in the analysis, followed by a presentation of the results from the estimations. The model is estimated for each year in the period 1976-1993, but to facilitate the presentation we show the results of an analysis based on a pooling of all the data. The estimated coefficients can thus be interpreted as the average importance of each variable for electricity consumption over the entire period. Finally, we look more closely at how these explanatory variables have changed in the period 1976-1993 in order to provide an indication of their influence on developments in electricity consumption over time. For example, if a higher electricity price results in reduced electricity consumption, the electricity price will contribute to increasing consumption when the price falls over time, and reducing consumption when the price increases over time.

The model for household electricity demand

The consumption of energy does not give the household utility *per se*, but is used along with equipment to obtain goods and services, such as hot meals, clean clothing, hot water and a comfortable indoor temperature. In the model, we assume that the household's utility depends on both goods and services produced by the household and a number of other goods consumed directly by the household. The household's production of a given service is a function of the use of electricity in the production of the service and the equipment used to produce the service. The household's appliance stock depends on the stock in the previous period as well as investments in new equipment.

In the model, the household is assumed to minimize the present value of the production cost of a service with respect to electricity consumption and the desired stock of appliances. The production cost from this minimization

2 The number of households in Norway is obtained from Statistics Norway's population and housing censuses.
3 The percentage annual trend growth in electricity consumption over the period is close to the figures in Statistics Norway's energy accounts.

problem will depend on the price of electricity and appliances, and leads to household demand for electricity and investments in new appliances for different levels of production. To determine the desired level of household production and consumption of goods that are not included in the production of services, we assume that the household maximizes its utility subject to budget constraints. A household's budget constraint depends on the household's income, the price of goods that are consumed directly and on the unit cost of producing the service from the cost minimization problem. The unit cost is defined as the cost per unit produced for producing the desired level of the service.

The stock of appliances is given in the short run, but in this model the electricity price may influence the stock in the long run through investments in new household appliances. A change in the electricity price will therefore have two different effects on electricity consumption: a direct (short run) effect and an indirect (long run) effect through investments in new electric household appliances.

Halvorsen and Larsen (1999) provide a further description of household behavior and the econometric specification of the problem.

Estimation results for the period 1976-1993

Estimations were carried out in two stages. In the first stage, purchases of electric appliances are determined as a function of, among other things, prices for household appliances and electricity. In the second stage, electricity consumption is then determined as a function of the estimated values from the first stage, the electricity price as well as variables that take account of household characteristics. This allows us to identify both the short run and long run effect of a change in the electricity price on household electricity consumption. Various model approaches and explanatory variables were tested before we ended up with what we consider to be the best model for explaining electricity consumption.

The results of the econometric analysis based on a pooling of the data for the entire period 1975-1994 are shown in table 1. The variables determining electricity consumption are shown in the first column, the estimated effect of the different variables on electricity consumption (coefficient values) in the second, and the t-ratios (standardized estimated values) in the third column of table 1. The table shows how different variables influence electricity consumption, measured as an average over the period 1976-1993.

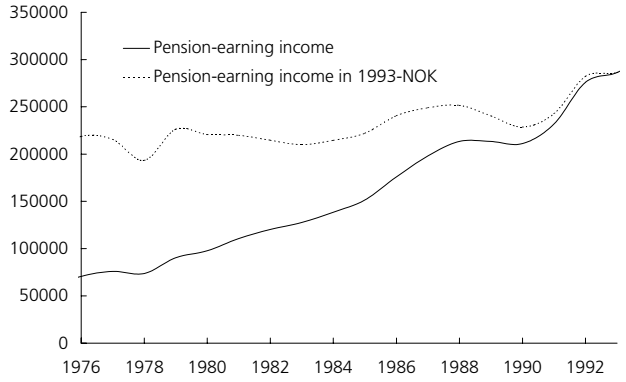
We see that electricity consumption rises with household income, with the number of household members and with floor space, while it declines with the electricity price and the age of the dwelling. The latter may be due to a higher wiring capacity in newly built houses and the greater use of equipment serving as an alternative to electric heating in older dwellings. Other factors that are of importance to electricity consumption are whether the dwelling has central heating, whether it has a bathroom and whether the household lives in a block of flats. For example, estimated electricity consumption is reduced by about 2 800 kWh a year for a household living in a block of flats compared with other households, *ceteris paribus*. We also see that electricity consumption rises with the *stock* of electric appliances and that this stock of appliances has a relatively large impact on electricity consumption. The estimation results primarily show significant effects with the exception of the stock of freezers and purchases of freezers, refrigerators, dishwashers and kitchen stoves. Moreover, *purchases* of kitchen stoves and freezers result in a reduction in electricity consumption, while purchases of other

Table 1. Estimated household electricity consumption, 1976-1993. kWh[1]

Variable	Coefficient	t-value
Intercept	-31 212	-8.56
Price of electricity, 2-year mean (1994-øre/kWh)	-200	-16.91
Price of kerosene (1994-øre/liter)	10	1.76
Price of heating oil (1994-øre/liter)	-13	-2.22
Household's annual pension-earning income (10,000 1994-NOK)	79	16.85
Newly established household pension-earning income (10,000 1994-NOK)[2]	-48	-6.89
Low-income household pension-earning income (10,000 1994-NOK)[3]	3 744	12.81
Predicted purchase of household appliances:		
Freezer	-519	-0.87
Refrigerator	459	0.48
Washing machine	1 174	2.09
Dishwashing machine	418	0.76
Kitchen stove	-2 103	-1.56
Current stock of household appliances:		
Freezer	102	0.79
Refrigerator	571	3.58
Washing machine	1 213	5.77
Dishwashing machine	2 706	17.69
Kitchen stove	885	2.65
Central heating	-4 500	-25.36
Block of flats	-2 839	-10.07
Dwelling's year of construction	19	10.19
Bathroom	2 574	9.39
Net floorage (m^2)	50	34.87
One-person household	-462	-2.20
Number of household members	714	12.45
Moved to present residence the current year	-1 775	-4.80
Free electricity	-3 347	-4.58
Dummy for additional sample	-1 345	-3.15
Temperature (heating degree-days*100)	9	1.00
Trend	345	9.60
R^2	0.3544	
Adjusted R^2	0.3533	

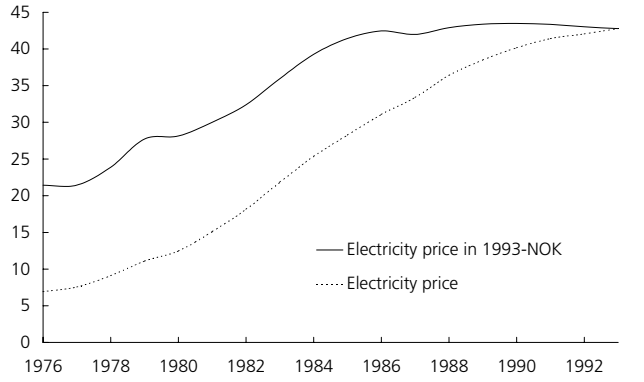
[1] An estimator is significant at the 10 per cent level if the t-value exceeds the value of 1.645, i.e. we are 90 per cent confident that the variable influences consumption. The estimator is significant at the 5 per cent level if the t-value exceeds the value of 1.96.
[2] Newly established households are households that have moved to the present residence during the last three years and where the main income contributor is under the age of 35.
[3] Households where annual electricity expenses exceed 40 per cent of annual household gross income.

Figure 2. Changes in average pension-earning income for households, 1976-1993. NOK



Source: Association of Norwegian Power Stations and Norwegian Water Resources and Energy Directorate.

Figure 3. Changes in average electricity price (2-year mean), 1976-1993. Øre/kWh



Source: Statistics Norway.

electric household appliances result in an increase. The reason for the negative coefficients is that electric appliances can be purchased either to replace old appliances or to increase the stock. For many types of appliances, technological advances have occurred over time, which make the appliance more energy efficient. The purchase of new appliances therefore influences electricity consumption both through a change in the stock of appliances and through more energy efficient appliances. In this estimation, we do not have sufficient information to separate these effects. We will, however, come back to how the estimation results for each year can be used to illustrate changes in electricity consumption for different household appliances over time.

Some aspects of developments in electricity consumption (shown in figure 1) are due to the use of a sample of households for our estimates and incomplete information concerning some key variables. In the estimations, we have attempted to correct for such effects. First, we lack information about the stock of heating equipment. In order to correct electricity consumption for the use of electricity for heating, we have included various housing characteristics, such as whether the household has a central heating system. The long run effects of a change in electricity prices therefore only contain effects through the stock of electric household appliances and not effects through changes in the stock of heating equipment. Second, we have corrected for the estimated income effect for newly established households, i.e. households that have moved to the present residence during the last three years and where the main income contributor is under the age of 35. We also correct the income effect for households with a very high budget share for electricity. The reason for these high budget shares is that in the estimations annual household gross income is defined as pension-earning income, which does not include old-age pensions, child support payments, disability pensions, etc. We have also corrected the estimations for households that have moved during the past year, as information about electricity expenses is incomplete for these households. Finally, we have corrected for special supplementary samples of households drawn in the Survey of Consumer Expenditure in some years.

Change in explanatory variables over time

The estimates in table 1 show the average effect of a variable on electricity consumption through the entire period. In order to gain an impression of the variables that have influenced the increase in average consumption per household over time, we must also look at changes in these variables.[4] Figures 2 to 6 show changes in some of the most important explanatory variables.

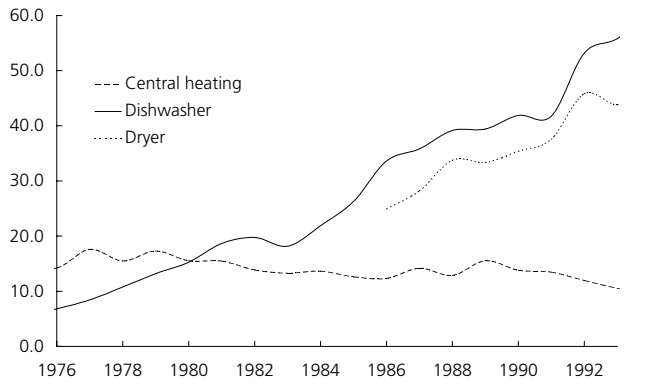
Figure 2 shows changes in average pension-earning income for households in the Survey of Consumer Expenditure from 1976 to 1993, measured both in current and real prices. The figure illustrates that household income has risen in the period. Income measured at constant prices rose by an average 1.6 per cent a year measured along a linear trend. Table 1 shows that income has a significant and positive effect on electricity consumption. All in all, this would therefore point to an increase in electricity consumption per household in the period being studied.

Figure 3 shows changes in the price of electricity in the period 1976-1993. Both the current and real price has risen in the period. Measured at constant prices, the electricity price has a strong, negatively significant effect on electricity consumption (see table 1), which means that the change in the electricity price points to reduced electricity consumption.

Figure 4 shows the percentage of households in the sample with a central heating system, dishwasher and dryer, respectively. The percentage of households that own kitchen stoves, refrigerators, freezers or washing machines has shown very little change in this period, and will therefore have less influence on changes in electricity consumption. We have therefore decided to exclude them here (see

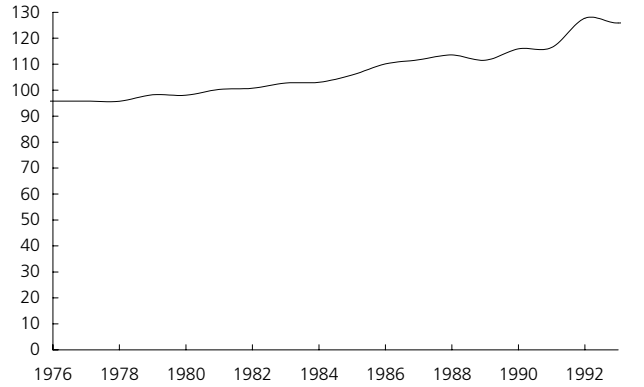
4 In the next section we look more closely at the importance of the different variables for electricity consumption over time.

Figure 4. Share of households that own a dryer, dishwasher or central heating system, 1976-1993. Per cent



Source: Statistics Norway.

Figure 5. Changes in average net floor space of dwellings, 1976-1993. m^2



Source: Statistics Norway.

Halvorsen et al. 1999 for developments in other electric household appliances). We see in figure 4 that the percentage of households with dishwashers or dryers has increased throughout the period (on average 16.7 per cent a year since 1976 for dishwashers and 9 per cent a year since 1986 for dryers), while the share with central heating was reduced (on average –1.9 per cent a year). Since the coefficients for the stock of household appliances is positive and the coefficient for the share of households with central heating is negative, this contributes to an increase in average electricity consumption per household.

Housing characteristics also influence changes in household electricity consumption. Figure 5 shows average net floor space for households in the Survey of Consumer Expenditure for the period 1976-1993. As illustrated in the figure, floor space has increased in the period. Since electricity consumption increases with floor space, this has also led to higher electricity consumption over time.

Vintage effects

The results of the estimation shown in table 1 presuppose that the effect of a given explanatory variable on household electricity consumption is constant throughout the period, with the exception of a common time trend. It is likely, however, that this assumption will not be satisfied for all variables. If, for example, income and prices have an effect on households' investments in electric household appliances, and prices and income change over time, the stock of appliances will, *ceteris paribus*, vary. As a result, electricity consumption for various purposes will vary over time because most electric household appliances are perceived as durable consumer goods and households will not adjust the stock of this equipment continuously. We have called the change in the coefficients over time as a result of such factors *vintage effects*.

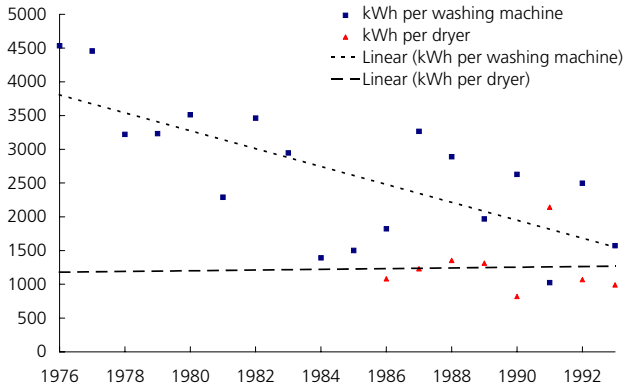
Our data set consists of annual cross sections of Norwegian households for the period 1975 to 1994. In order to provide a better description of changes in electricity consumption, and to test whether the coefficients are constant, we have estimated a corresponding model as in table 1 for each year in the period. In the next two sections we shall describe these vintage effects. We focus on the effects through the stock of dishwashers and dryers as well as price and income elasticities.

Changes in electricity consumption for dishwashers and dryers

The estimated coefficients for the stock of household appliances can be interpreted as the difference in electricity consumption (measured in kWh) between households that have such appliances and those that do not. In the period being studied there have been no substantial changes with regard to the percentage of households that own kitchen stoves, refrigerators, freezers and washing machines. As early as the beginning of the 1970s such household appliances were common in Norwegian households, and 80-90 per cent of the households owned this type of equipment (see figures in Halvorsen et al. 1999 for details). It is difficult for this reason to isolate electricity consumption for such appliances in the annual estimations due to little variation between households with regard to the stock of appliances and high covariation between different types of appliances, a factor that has resulted in unstable and insignificant estimates. For the share of households that own dishwashers and dryers, on the other hand, the variation between households is sufficient for identification. In 1974, about 7 per cent of the households owned a dishwasher, while this share had risen to about 70 per cent in 1995. For dryers, we have data back to 1986, and the share that owned a dryer was then about 25 per cent, rising to 50 per cent in 1995. The estimates for these two appliances are therefore far more stable and significant. For this reason, we shall in this section *only* look at changes in electricity consumption for dishwashers and dryers.

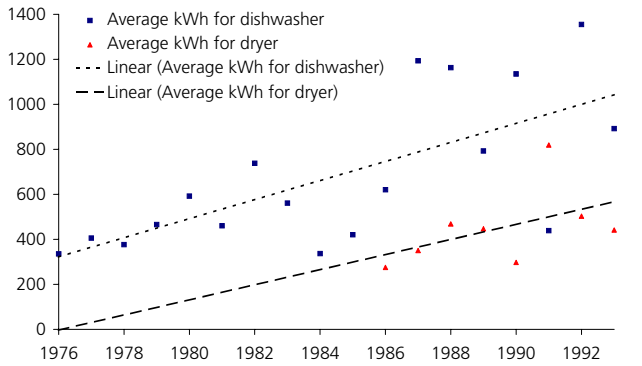
Figure 6 shows changes in estimated electricity consumption per dishwasher and dryer for households in the Survey of Consumer Expenditure. The figures have been obtained from the annual estimations, and show changes in the estimated coefficients for each of the appliances with accom-

Figure 6. Estimated electricity consumption per household appliance per year, 1976-1993. kWh



Source: Statistics Norway.

Figure 7. Estimated changes in electricity consumption for dishwashers and dryers, 1976-1993. kWh



Source: Statistics Norway.

panying linear trend lines. The figure illustrates that the coefficients for the stock of dishwashers are relatively high and show a clear downward trend. The coefficients indicate that a dishwasher used on average about 3 800 kWh in 1976 and 1 700 kWh in 1993. The coefficients for a dryer are lower and more constant over time.

The consumption of electricity for household appliances depends on the appliance's power consumption (kW) and utilization time (hours per year). There may be several reasons for the sharp fall in electricity consumption for dishwashers. First, it may be due to increased energy efficiency, since the power consumption of a dishwasher has fallen in the period (see Ministry of Petroleum and Energy, 1998), partly as a result of reduced water consumption. Moreover, the utilization time per dishwasher may have fallen during the period for two reasons. First, dishwashers were relatively expensive in the 1970s, and it is likely that households that bought such machines were fairly large households with substantial dishwashing needs.[5] As the price of dishwashers gradually fell and average income increased (adjusted for inflation), the frequency of use has probably also been reduced as smaller and more marginal households have purchased dishwashers. Second, dishwashing time has been steadily reduced in new machines.

The stock of appliances in households consists of both old and new technology because the appliances may have a relatively long service life. An average dishwasher in households will therefore have a higher power requirement and longer utilization time than a new machine. This may be the reason that our estimates for electricity use for dishwashers is higher than other estimates, where the estimates are based on new technology.[6] It should again be noted that there is considerable uncertainty associated with the estimated coefficients in figure 6, and that the estimates may be slightly high due to a possible correlation between the stock of dishwashers and excluded electric household appliances, such as microwave ovens. There were no major changes in electricity consumption for old dryers in households from 1986 to 1993. The reason that we do not see any declining trend in electricity consumption for dryers may be that they are used more (for more hours) than earlier, and that new and more energy-intensive dryers (e.g. condense dryers) offset the effect of a reduced price and more efficient technology.

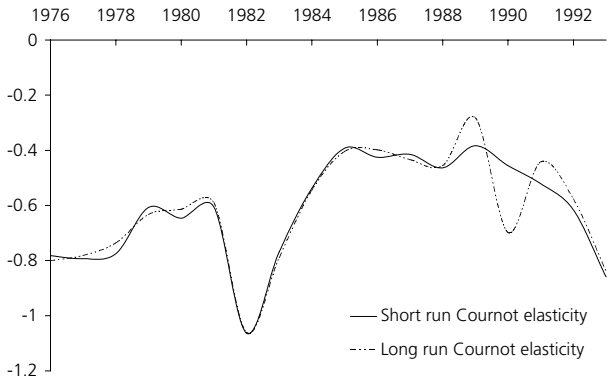
As illustrated in figure 4, the percentage of households that own a dryer and/or dishwasher has increased sharply during this period. This means that even if electricity consumption per appliance has fallen or been stable, the average consumption for such appliances will increase. We have corrected for this in figure 7, where we have plotted average electricity consumption per household for dishwashers and dryers with accompanying trend lines. The average electricity consumption per household appliance is obtained by multiplying electricity consumption per household appliance by the average number of appliances in the household.

Average electricity consumption for dryers has risen by about 7.6 per cent a year measured along the trend line, while average electricity consumption for dishwashers has increased by 7.8 per cent a year. The share of electricity consumption in an average household that is due to the use of a dishwasher, i.e. the figures in figure 7 divided by average electricity consumption each year, has risen from 2.4 per cent in 1976 to 5.6 per cent in 1993, measured along a linear trend. For dryers, this share has increased from 1.9 per cent in 1986 to 3.0 per cent in 1993.

Estimated electricity consumption for dishwashers and dryers for all Norwegian households increased from about 1.7 TWh in 1986 to 2.8 TWh in 1993. Measured as a share of total household electricity consumption, electricity consumption for dishwashers and dryers rose from 7.6 per cent in 1986 to 10 per cent in 1993. Total electricity con-

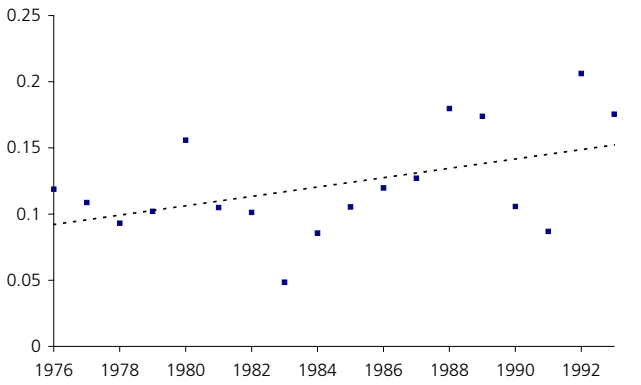
5 See figure 5.26 and C6 in Halvorsen et al. (1999) for an overview of changes in prices for white goods in this period.
6 See, for example, figure 7.14 in the Ministry of Petroleum and Energy (1998).

Figure 8. Short run and long run Cournot elasticities for Norwegian households' electricity consumption, 1976 - 1993.



Source: Statistics Norway.

Figure 9. Income elasticities (Engel elasticities) for the Norwegian households electricity consumption, 1976-1993



Source: Statistics Norway.

sumption for dishwashers and dryers increased by about 9.1 per cent annually in the period 1986 to 1993. The estimated growth in the use of electricity for dryers and dishwashers was therefore almost three times the growth in total estimated electricity consumption in figure 1.

Changes in price and income elasticities over time

In the same way as for the estimated effects of the stock of household appliances, price and income coefficients will also be subject to vintage effects through the period. The reason is that changes in the appliance stock may influence the price and income sensitivity of household electricity demand, even in the short run. Moreover, price and income sensitivity may depend on factors that are not captured in these estimations, such as government energy efficiency campaigns.

To what extent electricity consumption is influenced by changes in price and income is best expressed by price and income elasticities, i.e. the percentage change in electricity consumption when there is a one per cent change in the electricity price and income, respectively. Figure 8 shows changes in long run and short run price elasticities for household electricity consumption in the period 1976-1993. The long run price elasticity contains, in addition to the short run effect, the effect of the possibility of adjusting the appliance stock to changes in the electricity price.

The price elasticity for electricity varies somewhat over the period studied, but electricity consumption is relatively price elastic. The figure shows that when the electricity price increases by one per cent, electricity consumption is reduced by between 0.4 and 0.8 per cent. On average for the entire period, our results show that electricity consumption is reduced by 4 per cent when the electricity price increases by 10 per cent.

There are no significant differences between the short run and long run price elasticity, and there is no clear trend in the electricity price elasticity in the period 1976-1993. The reason that short run and long run elasticities are virtually the same is that changes in electricity prices have little influence on investments in household appliances. The short run effects will therefore dominate the long run price elasticity.[7]

Changes in income elasticity are shown in figure 9. We see that income has a quite small effect on electricity consumption.[8] When income changes by one per cent, electricity consumption changes by an average of about 0.13 per cent in the period 1976-1993. This means that the difference in electricity consumption between low-income and high-income households is fairly marginal, since increases in income are not used to any extent for increased electricity consumption. In contrast to price elasticities, the income elasticity increases over time. The reason is that the budget share for electricity declines over time, and the estimated coefficient increases when the average income level of households increases. Measured along a linear trend, the income elasticity increases from about 0.09 to about 0.15.

Conclusions

Household electricity consumption has increased by an average of about 3 per cent annually in the twenty-year period we have studied. Just under half of this increase is due to an increase in the number of households. The remainder is due to an increase in average consumption per household. There are several factors that point to an in-

7 See Halvorsen and Larsen (1999) for a theoretical explanation and further discussion of short run and long run effects of a change in electricity prices on household electricity consumption. See, for example, Rødseth (1997) for more information about interpretations of income and price elasticities.

8 This is the net effect of income on electricity consumption, i.e. after correcting for the effect of income on e.g. floor space and purchases of equipment.

crease in average electricity consumption per household. Among other things, an increasing number of households are using electric household appliances such as dryers and dishwashers, household income measured at constant prices has risen and the floor space of dwellings has increased.

Moreover, we find that electricity consumption varies relatively little between low-income and high-income households, and that changes in the electricity price have a fairly substantial influence on electricity consumption.

The data

The data set used as a basis for our analyses in this article was obtained from five different sources. The main source is Statistics Norway's annual Survey of Consumer Expenditure, which contains consumption data at the household level. These surveys are based on a sample of Norwegian households drawn according to Statistics Norway's sampling plan. The surveys have taken place continuously from 1 January 1973 to the present, with the registration of these households' purchases of all types of goods and services classified in 673 different categories. The annual net sample is between 900 and 1 400 households. All households keep accounts of their expenditures on purchases of consumer goods during a two-week period which is spread throughout the year. In addition, they complete a questionnaire concerning expenditures on such items as durable consumer goods, electricity and fuel during the last 12 months. The households are also classified according to household characteristics such as the dwelling's floor space and year of construction, type of dwelling, sex, age and status in the labor market for all household members. The Survey of Consumer Expenditure registers annual expenditures on electricity in the household and not consumption in kWh. We have therefore estimated electricity consumption (measured in kWh) by dividing the household's annual expenditures on electricity by the electricity price, where the electricity price for all households in the same municipality is assumed to be the same.

The Survey of Consumer Expenditure lacks information about some variables that are important for describing household demand for electricity, including information about prices and outdoor temperatures. This information is therefore obtained from other data sources. Information on income for all household members is linked up to the survey through Statistics Norway's tax statistics. The tax statistics are derived from the Directorate of Taxes' tax assessment registers. Moreover, we have used information on municipal electricity prices from the Norwegian Water Resources and Energy Directorate, monthly temperature data for all municipalities included in the Survey of Consumer Expenditure from the Norwegian Institute of Meteorology and files containing information on regional prices for goods and services from the data used to calculate the Consumer Price Index. Each year of the data from 1974 to 1995 is linked together and checked for any errors.

For a more detailed description of the data set used, see Halvorsen et al. (1999). For more information on Statistics Norway's Survey of Consumer Expenditure, see Statistics Norway (1996).

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