Industrial Companies' Demand for Energy Based on a Micro Panel Database – Effects of CO_2 Taxation and Agreements on Energy Savings

Thomas Bue Bjørner and Mikael Togeby
AKF, Institute of Local Government Studies – Denmark

ABSTRACT

An econometric panel data analysis of industrial demand for electricity and energy is presented. In the panel energy consumption, production and value added are observed at company level. We estimate price and production elasticities for electricity and total energy (i.e. measuring the X per cent change in demand of say electricity of a one per cent increase in the price of electricity). The estimated price and production elasticities are allowed to vary according to company characteristics such as industrial sub-sector, company size, energy intensity and type of ownership.

Most previous econometric studies on industrial energy demand use aggregate data, while a couple of micro level studies mainly employ cross-section analysis. To our knowledge this is only the second econometric study on industrial energy demand based on a large micro panel database. More than 2,700 Danish industrial companies during the period 1983 to 1995 are included in the model (covering the majority of all Danish industrial energy consumption).

One advantage of micro data is that these data can be used to estimate the effect of an instrument like voluntary energy agreements. By entering a »voluntary« energy agreement a Danish company avoids paying the usual CO_2 tax. Preliminary analyses suggest that there is a large positive gross reduction of electricity and total energy consumption of companies with energy agreements. However, we also find that companies would have had about the same reduction in electricity consumption if they had not entered into an agreement, but instead paid the full CO_2 tax. Thus, our analysis suggests that the »net effect« on electricity use of the voluntary energy agreements is very low (perhaps even negative).

1. Introduction

In this paper we present an econometric study based on an extensive panel data set containing information about energy and electricity consumption, production and value added at company level for almost all Danish industrial companies.[1] A large number of econometric analyses of industrial energy demand have been carried out since the middle of the seventies based on aggregate data like time series or cross-sections of states in order to investigate the effects of changes in prices (including energy taxation) and in order to forecast future energy use. With aggregated data considerable information related to the behaviour of individual companies is inevitably lost. We use the micro data to look at two dimensions of energy use that in general are difficult to analyse with aggregate data. Firstly, we analyse whether characteristics of the industrial companies like size and energy intensity influence the demand for energy. Secondly,

[1] This paper builds on Bjørner, Togeby and Christensen (1998), which contains more detailed discussion/description of the developed database, econometric analysis, specification tests, interpretation of results etc.

with data at company level we can analyse the effect of policy instruments that only affects a fraction of the industrial companies. Examples are subsidies to investments in energy efficiency, energy audits and »voluntary« agreements on energy savings between the company and government. Here we look at the effect of voluntary agreements (including a mandatory energy audit).[2]

Previous studies on industrial energy demand are discussed in the Section 2. In Section 3 we shortly present the model to be estimated. In Section 4 the data are described. In Section 5 we compare simple (pooled) cross-section estimates with estimates that do take into account the panel structure of the data. The effect of different company characteristics are summarised in Section 6. The effect of voluntary energy agreements are discussed in Section 7. A summary and discussion is contained in Section 8.

2. Previous Studies on Industrial Energy Demand

A methodological survey of (aggregate) energy demand models is offered by Griffin (1993). Most of the previous studies belong to the following two categories. One category focusses on the demand for various types of energy, which yields information about substitution possibilities between say electricity and coal. Early examples are Griffin (1977), Halvorsen (1977) and Pindyck (1979). The other category focusses on substitution between energy (as an aggregate) and other factors like labour, capital and materials. For this category early examples include Griffin and Gregory (1976) and Berndt and Wood (1975). Both categories of models are typically estimated by a system of factor demand equations derived from cost minimisation behaviour of firms (or of an average firm) using a so-called flexible functional form that can be regarded as a second order approximation to an unknown cost function. The translog form appears to be the most favoured one among the family of flexible functional forms.

We are aware of only three econometric studies of industrial companies' energy demand that use information at the micro level. Woodland (1993) uses repeated cross-section data for about 10,000 companies in the years 1977-85 from the Australian state of New South Wales. He uses a translog system with coal, gas, electricity, oil, labour and capital included as production factors. Woodland observes that only a minor share of the companies have an energy »pattern«, where they use all four types of energy. He finds that there are nine different energy patterns represented in his data set (the most typical pattern is where companies only use electricity). Woodland estimates separate translog functions for each of the nine energy patterns assuming that the energy patterns are exogenous due to technological constraints.

Kleijweg et al. (1989) look at a panel of Dutch firms from 1978-86 (they only include firms that are present in all years). They also look at energy demand of firms using a translog form, but they only estimate the energy cost share equation and they do not include the cost of other inputs (they argue that the changes in cost of the other inputs will be controlled for by industrial sub-sector time dummies). A partial adjustment process is included in the energy cost share equation as lags of the energy price. They find support of a dynamic adjustment process since an increase in the energy price results in an increase of the energy cost share in the same year, but followed by a decrease in the subsequent years. Kleijweg et al. subsequently analyse the data based on subsets according to firm size, energy intensity and investment level. They find that the own price elasticity of energy increases with firm size, and – to a lesser extent – that the price elasticity decreases with energy intensity and increases with the level of investments. However,

[2] We expect to include the effect of investment subsidies at a later stage.

these findings are derived from separate estimations and therefore do not take into account correlation between firm size, level of investment and energy intensity.

Finally, Doms and Dunne (1993) estimate demand for energy and electricity using cross-section data. They find a negative cross-price elasticity between energy consumption and the wage rate implying that energy and labour are complementary inputs (opposite to Woodland's observation). Doms and Dunne do not estimate own price elasticities of energy, but they argue that the effect of energy prices is controlled for by regional dummy variables. Doms and Dunne also find that plants that use advanced technologies are less energy intensive and that they rely relatively more on secondary forms of energy like electricity, while old plants are more energy intensive and rely more on primary energy forms like fossil fuels.

In this paper we estimate the demand for electricity and energy (as a whole). We investigate how characteristics of the industrial companies like size and energy intensity influence the demand for electricity and the demand for energy respectively. Furthermore, we analyse the effect of the Danish energy agreements.

3. Model

Electricity (and total energy) can be regarded as input in production in the same way as labour, capital etc. Assuming that all companies treat the price of electricity and other factors as exogenous and that each company minimises the production cost, the demand for electricity can be expressed as a function of factor price and level of production. We choose the following functional form to estimate firms' demand for electricity (and total energy).

$$LEL_{it} = \alpha_i + \beta_1 LFVA_{it} + \beta_2 LPEL_{it} + \beta_3 DCO2AG_{it} + \lambda_t + v_{it}$$
$$v_{it} \sim \text{i.i.d } N(0, \sigma_v^2 I) \qquad (1)$$

where $LFVA_{it} = Log(VA_{it} / PVA_{Bt})$
$LPEL_{it} = Log(PEL_{it} / PVA_{Bt})$

Electricity consumption (in logarithm) measured in Joule (LEL) is given as a function of value added in fixed prices (LFVA), which is calculated as value added in yearly prices (VA) and a price deflator for value added (PVA), and the relative prices of input which are measured as price of electricity (PEL) and the price deflator for value added. Subscript *it* denotes company *i* at time *t*. Company specific deflators for PVA do not exit, so we have to rely on more aggregate deflators. Subscript *B* denotes one of 80 different industrial branches, that were the most disaggregated levels for which we could obtain deflators. DCO2AG is a dummy variable denoting if the company has signed an energy agreement (described later).

In (1) it is assumed that all parameters are equal between firms except for the individual intercept (α_i). The individual intercept will capture all unobserved company variables that have an influence on electricity demand. E.g. like management ability (or attention devoted) to minimise the electricity cost. It could also be the level of electricity consumption that is embedded in the capital (production equipment). Thus, the inclusion of the individual constant term controls for (time invariant) unobserved heterogeneity of the companies. λ_t denotes time dummies that are included to capture the influence of say exogenous technological change and the effect of any other unobserved change over time that influence the companies equally.

The same functional form as given in equation (1) is used to estimate companies' demand for energy (as a whole).[3]

In order to take into account that various types of companies may respond differently to changes in electricity (or overall energy) prices or changes in production we introduce a vector of company characteristics (C) that partitions the companies according to industrial sub-sector (S), size, type of ownership, energy intensity etc. (see Bjørner, Togeby og Christensen (1998), p. 47-55, for details). With characteristic effects the model becomes:

$$LEL_{it} = \alpha_i + C_1 \times \beta_1 LFVA_{it} + C_2 \times \beta_2 LPEL_{it} + \beta_3 DCO2AG_{it} + S \times \lambda_t + v_{it}$$
$$v_{it} \sim \text{i.i.d } N(0, \sigma_v^2 I) \qquad (2)$$

Note that most of the characteristics included in C are time invariant. Therefore, it is not possible to identify the level of electricity use of companies with certain characteristics by including the characteristic vectors as simple dummies (e.g. whether large companies are more energy intensive etc.), because these effects are controlled for by α_i.

With respect to the motivation of introducing company characteristics aggregate studies based on time series for different industrial sub-sectors often find that say price elasticities vary according to sector. However, it could be the case that the difference in these price elasticities derives from differences in company size, ownership and energy intensity, which are often unobserved (or difficult to control for) in aggregate time series data.

Another argument for introducing characteristics like company size and energy/ electricity intensity is that in an estimation of equation (1) each observation will be given the same »weight« in the determination of the parameters. However, energy and electricity consumption in industry has a very unequal distribution, in the sense that the majority of companies has a small share of overall electricity/energy consumption, while a relatively small number of large and/or energy-intensive companies accounts for most of the electricity/energy consumption.[4] If there is a large difference in say the price elasticity of the many (small) consumers and the (few) large consumers, then the elasticity obtained from equation (1) (which is largely determined by the many small consumers) may give very misleading information about the way that aggregate demand (which is influenced by the relatively few large consumers) responds to price changes. Controlling for company size and energy intensity will reduce this problem.

4. Data

The starting point of the data is the last seven industrial *energy surveys* carried out by Statistics Denmark for the years 1983, 1985, 1988, 1990, 1993, 1995 and 1996. All industrial companies with 20 or more employees are included in these surveys except in 1995, where only 50% of the companies with 20-50 employees were included in the surveys. The surveys contain information about use of energy divided among 19 different types of energy. The energy surveys

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[3] This implies that the models for electricity and overall energy use should be seen as two separate models and not as nested models. It is acknowledged that the implicit simplifying assumptions behind the factor demand specifications for electricity and overall energy are not coherent, e.g. they are not derived from the same underlying production function.

[4] As an example, three quarters of all the companies with the smallest electricity consumption only account for 10% of the total electricity consumption, while the 10% largest consumers account for more than 70% of all electricity.

have been matched with data from *accounting statistics* to obtain information about value added (as well as production, the value of capital and investments surplus of the firm etc.). The Danish Energy Agency (DEA) has provided information about the energy agreements between individual companies and DEA and subsidies for investments in energy efficiency.[5] General energy prices, energy taxes, deflators for value added and production were collected from various sources.

Information related to companies exists at three different levels: At company level (covering all production sites of the same company), the individual production site, and an intermediary one: all production sites within the same industrial sub-sector for each company. The energy data exist for each production site, while information concerning activity, e.g. value added, exists at the intermediary level. Our level of analysis is the intermediary one. In general we denote this unit as a »*company*« (disregarding that the real company may cover several such units).

The energy survey includes information about expenditures and the consumption in physical units for electricity and district heating. Therefore, it is possible to calculate average prices for each company for these two energy sources. The price of electricity varies between different companies, because the price of electricity is individual to each of the 100 electricity utilities in Denmark. Unlike many other countries the Danish utilities do not generally use a declining block schedule, where the marginal price is a decreasing function of demand. Some large electricity consumers may have the possibility to negotiate lower prices (which may cause a bias in the estimated price elasticity), but this is believed to be a rare phenomenon, which may be relevant only to very large users. Thus, the average electricity price will (generally) correspond to the marginal one.[6] For the other energy sources (e.g. fuel oil, coal and natural gas) general prices are used (compared to the price of electricity it is also more plausible to use a general price for these types of energy).

Our measure of »total« energy use is an aggregate (according to energy content) of eight major types of energy. They are electricity, district heating, coal, LPG, fuel oil, heating oil, natural gas and city gas. Some other types of fuels (e.g. coke, waste and wood) are not included mainly because it has not been possible to obtain reliable indicators of prices, but the omitted fuel types only account for a small part (1%) of the overall energy consumption in industry.[7] Also transport fuels (gasoline and diesel) have been left out, but this is due to the different nature of use. A few companies with extreme changes over time in energy intensity are also excluded from the calculations. Let E8 denote an aggregate of the eight major types of energy (log(E8) is denoted LE8). The cost of energy is calculated as the energy expenditures divided by the total energy content. Thus, this average price is also related to energy content.[8]

The panel is unbalanced. In the estimations presented we include only companies that are present for at least three years.

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[5] However, information about subsidies to investments in energy efficiency is not yet incorporated fully in the database.

[6] Note that the average cost depends on the daily distribution of electricity since industrial consumers pay according to a three period time-of-day tariff. Thus, the average electricity price will only be exogenous, if the daily distribution is exogenous.

[7] For some subsectors the omitted fuel types account for a larger share of energy use (e.g. Wood and Furniture).

[8] Energy content is a simple and intuitively natural way to aggregate different types of energy often denoted as a Btu-aggregator (British Thermal Units). However, it can be argued that other aggregators are superior, see e.g. Nguyen (1987).

5. Results of Simple Model without Characteristic Effects

Estimation results for equation 1 are presented in Table 1. The first regressions (for electricity and energy demand respectively) show results, when a common intercept is estimated, i.e. when the panel structure of the data has not been taken into account. Company specific fixed effects are introduced in the second regression. It appears that the fixed effects have a large influence on the estimated parameters. As an example the parameter to value added is about one (constant return to scale) in the common intercept model, while there is decreasing return to scale in the fixed effect models. Looking at the estimated elasticities for electricity price and total energy price the differences between the pooled and the fixed effect models are even larger. It also appears from the different goodness of fit statistics that the fixed effects account for a large part of the variation in the endogenous variable. Parameters in the model with common intercept are therefore likely to be biased due to omitted variable (the fixed effects). Thus, the panel information has a profound influence on the estimated parameters in our case. This suggests that previous micro econometric studies on industry's energy demand, which are based on (repeated) cross-section (Woodland (1993) and Doms and Dunne (1993)), could also be biased due to misspecification. In the following we will therefore focus only on the fixed effects model.

In the fixed effects model the elasticities with respect to value added are about +0.6 for electricity and slightly lower for aggregate energy demand (+0.5). The elasticities with respect to electricity and energy price are about -0.5 and -0.6 respectively. Taken together electricity consumption and aggregate energy consumption seem to respond in a fairly similar way to changes in price and industrial activity.

The reported elasticities all appear to be highly significant. It should, however, be noted that the errors of the estimated models appear to be strongly auto-correlated and also to some extent non-normal and heteroscedastic,[9] which implies that significance levels and other inference probably are biased and therefore should be interpreted with care. However, these deviations from the standard assumptions should not lead to biasses in the estimated elasticities.[10]

The estimated parameters should be interpreted as the micro level response of the companies in our database. As an example we will shortly discuss two cases where the interpretation is important. Firstly, it is reasonable to assume that there is decreasing return to scale at company level (as we found), but this does not necessarily imply that there is also decreasing return to scale at a macro level. When total production or energy price (and other costs) changes, the structure of industry may also be changed as some companies close and others emerge. In this type of study the focus is on the behaviour of (continuously) existing companies. At a macro level the effect of entry/exit of companies should also be included.[11] Secondly, note that each observation is weighted equally in our estimations. In a macro study the weight will correspond to the

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[9] See Bjørner, Togeby and Christensen (1998) for details. Here we also compare random effects and fixed effects models. A random effects model results in very different estimates compared to the fixed effects model, which suggests that the fixed effects models should be chosen (this is also the result of the Hausman specification test).

[10] Note also that the (unbiased) estimated elasticities with respect to value added and electricity/energy costs are »significant« even at a 0.1% level. This indicates that the standard errors of the elasticities should be even very seriously biased for these elasticities not to pass at usual significance levels (like 1 or 5%).

[11] The aspects of entry/exit can also be described from our database. Initial descriptive analyses show that companies leaving the database are twice as energy intensive as companies entering (while companies that have existed in the whole period have an energy intensity in between).

energy consumption of each company. If small and large consumers of energy respond in different ways, the estimated parameters will also be different. However, we will look more into this issue in the following section, where we allow parameters to vary according to characteristics of the company.

Table 1. Estimation results for electricity and total energy (pooled and fixed effects models without company characteristics)

Exogenous	---- Electricity ----		---- Total Energy (E8) [a] ----	
Modelling of constant	$\alpha_i = \alpha$ (pooled)	α_i (fixed effects)	$\alpha_i = \alpha$ (pooled)	α_i (fixed effects)
Modelling of time	$\lambda \neq 0$	$\lambda_t \neq 0$	$\lambda \neq 0$	$\lambda_t \neq 0$
Production	1.095 (0.008)	0.611 (0.009)	1.054 (0.008)	0.545 (0.010)
Price	-1.376 (0.035)	-0.473 (0.018)	-1.506 (0.024)	-0.576 (0.016)
DC02AG	1.282 (0.096)	-0.104 (0.042)	1.383 (0.117)	-0.136 (0.053)
λ_{83}	0.352 (0.039)	-0.366 (0.017)	0.848 (0.036)	-0.024 (0.018)
λ_{85}	-0.018 (0.033)	-0.406 (0.013)	0.609 (0.034)	-0.027 (0.015)
λ_{88}	-0.149 (0.030)	-0.321 (0.011)	0.015 (0.030)	-0.214 (0.012)
λ_{90}	0.096 (0.031)	-0.152 (0.012)	0.198 (0.031)	-0.105 (0.012)
λ_{93}	-0.011 (0.031)	-0.086 (0.012)	0.058 (0.032)	-0.061 (0.012)
λ_{95}	0	0	0	0
σ_v^2	0.8056	0.1079	0.7532	0.1032
R^2	0.6699	0.9654	0.6826	0.9664
R^2 within	-	0.49	-	0.38
RSS	10220.3	1070.5	8415.3	891.2
Number of parameters in model	9	2778	9	2550
Observations	12695	12695	11182	11182
DF	12686	9917	11173	8632

Note: Std. error of estimates in brackets. The level of the estimated λ_t in regression no. 5 is not uniquely identified (but the differences between λ_t and λ_s can be interpreted). R^2 *within* is a measure of goodness of fit after the fixed effects have been controlled for.

a. By *total energy* we mean electricity, district heating, coal, LPG, fuel, heating oil, natural gas, and city gas. Other fuels like wood and waste are not included since we do not have prices for these. We only include companies where total-8 energy demand accounts for 99% of all energy consumption (this account for the difference between the number of observations used in the estimation of electricity and energy).

6. Results of Model with Company Characteristics

For the model with a characteristic effect we only present results estimated with individual company fixed effects. A priori a large number of characteristics were included (see Bjørner, Togeby og Christensen (1998), p. 47-55), but we concentrate on the results of the reduced models. To get the reduced models, we have performed an F-test for the omission of a characteristic in C_1 and C_2. We have used a 1% significance level. Recall, however, that the test statistics may be biased, because of auto-correlation and other factors, so the validity of the model reduction could be questioned. Most of the qualitative results of the reduced models can, however, also be subtracted from the general models (but the general models contain several more parameters and is therefore more difficult to comprehend).

The elasticities according to characteristics are presented in Table 2 (detailed estimation results are presented in Bjørner, Togeby and Christensen (1998), p. 54-55). At the top of Table 2 we have calculated the simple average of elasticities across all characteristics (in bold), except with respect to type of ownership, where we have used limited ownership, which is the dominant type of ownership. Note that these means are about the same size as the elasticities from the simple models in Table 1.

The rest of Table 2 should be read in the following way. Starting out from the average elasticity one can obtain the elasticity of a certain type of company by adjusting with the deviation from the average of the relevant industrial sector, and subsequently adjusting with the other characteristics of the company. As an example, the total energy price elasticity of a limited company from the meat product sector that belongs to the category of the largest and most energy intensive companies is equal to -0.669 (average) +0.042 (sector) -0.055 (size) +0.095 (energy intensity) = -0.587.

Focussing on the *price elasticity of total energy* it appears that this elasticity decreases with the size of the company, while it increases with energy intensity (This confirms results from Kleijweg et al. (1989)).[12]

With respect to the *price elasticity of electricity* we did not find any effect of company size, but the electricity intensity (measured with respect to value added) and electricity share (relative to total energy consumption) has large effects on the elasticity. The price elasticity increases (numerically) with electricity intensity. The group of companies with the highest electricity intensity and the highest electricity share has a price elasticity that is 0.4 higher than the group with the lowest electricity intensity and the lowest electricity share. For total energy we obtained the opposite result. The variation of the price elasticity of electricity between sectors is relatively small compared to total energy.

The mentioned price and value added elasticities are calculated with the same weight to all companies. If we instead calculate averages weighted by consumption of electricity and energy we obtain electricity elasticities of value added and electricity price of 0.618 and -0.474 respectively, while the weighted energy elasticities of value added and energy price are 0.579 and -0.660 respectively. These elasticities correspond to the response of the aggregate electricity and energy demand.

Compared to the few other studies on industrial energy demand based on micro data we obtain very similar elasticities for total energy use like Kleijweg et al. (1989), both with respect to return to scale and with respect to total energy price. Kleijweg et al. (1989) also used a panel of companies. Woodland (1993) estimated separate own-price elasticities of the different types of energy. His study finds the electricity price elasticity to be about twice as high as the one we have obtained in the fixed effects model. As previously discussed it is possible that this discrepancy simply reflects that he only had pooled cross-section data available. In the pooled estimation in Table 1 we have obtained an electricity price elasticity that was just as high as reported in Woodland. Woodland has not calculated a price elasticity with respect to total energy, but most of his own-price elasticities for energy were higher than one, i.e. about the same as the high price elasticity for total energy we obtained in a pooled regression.

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[12] Note that Kleijweg et al. (1989) found much more pronounced differences between the price elasticity with respect to energy intensity and specially company size. However, these differences were obtained in separate models were they looked at one type of characteristic separately. I.e they do not take account for correlation between the industrial sub-sectors and the characteristics, which may bias their estimates.

Table 2. Elasticities and company characteristics

	Electricity		Total energy (E8)	
	Production	Price	Production	Price
Simple average for limited companies	**0.601**	**-0.439**	**0.52**	**-0.669**
Sector: 3: (Extraction of gravel, clay, salt, etc.)	-0.353	0.222	-0.739	-0.693
4: Meat and meat products	-0.130	0.049	0.136	0.042
5: Dairies	-0.012	0.008	0.059	0.211
6: Other food products	-0.070	0.067	-0.084	0.289
7: Bakeries	0.143	-0.122	0.060	0.181
8: Beverages	-0.011	0.107	0.174	-0.637
(9: Tobacco)	0.251	-0.417	0.356	0.344
10: Textiles *	-0.061	0.002	-0.111	0.094
(11: Leather and footwear)	-0.112	0.182	-0.213	0.025
12: Wood and furniture *	0.042	-0.095	-0.044	0.083
13: Paper	0.026	0.151	0.149	-0.121
14: Printing	-0.126	-0.102	0.029	0.026
15: Chemicals	0.040	-0.117	-0.022	0.162
(16: Pharmaceuticals)	0.162	0.040	0.178	-0.388
18: Rubber and plastic	0.115	0.113	0.100	0.055
19: Ceramics, bricks and cement	0.183	-0.017	0.181	-0.425
20: Basic metal and manufacturing *	-0.033	0.007	0.000	0.020
21: Machinery and equipment *	0.049	-0.038	-0.003	0.124
22: Electronics	0.031	-0.115	0.046	0.164
23: Transport equipment	-0.011	0.008	-0.062	0.141
24: Miscellaneous	-0.126	0.065	-0.196	0.313
Size: Small	0.003	--	-0.024	0.056
-	-0.002		-0.014	0.031
-	-0.003		0.012	-0.032
Big	0.002		0.026	-0.055
Electricity/Energy intensity: Low	--	0.107	--	-0.040
-		0.049		-0.047
-		-0.066		-0.007
High		-0.090		0.095
Share of electricity: Low	-0.030	0.124	Not included	Not included
-	-0.070	0.036		
-	0.026	-0.043		
High	0.073	-0.116		
Owner: Cooperative society	0.012	0.192	0.015	-0.040
Owned by individual	-0.001	-0.029	0.083	-0.171
Private limited companies	-0.011	-0.021	0.030	-0.078
Limited companies (reference)	0	0	0	0
Yearly dummies	5 common		5 for each sector	
Agreements (93-95)	-0.074		-0.131	

Note: Four sectors with less than 100 observations are in brackets. Four sectors with more than 1000 observations are marked with an asterisk. All groups of parameters are significant at a 1% level. Only the parameters for the agreements are included with other levels of significance: Electricity: 10%, energy: 2%. Other non-significant parameters are excluded from the models (--). The electricity share is not tested for total energy.

7. Gross and Net Effects of Energy Agreements

In 1993, a CO_2 tax was introduced in Denmark. For electricity the tax corresponds on average to 15% of the price. For coal the tax corresponds to 35% of the price. A special arrangement was set up for the most energy-intensive companies, which were given the opportunity to enter an energy agreement with the Danish Energy Agency (DEA). The companies that entered an agreement had to carry out an energy audit, realize some of the proposed energy savings and initiate energy management. In return, they did not pay the CO_2 tax.[13]

According to DEA, 141 companies have entered these energy agreements. For the period 1993-95 only 78 out of the total of 141 companies can be found in the database. Most of the differences between these numbers can be explained by different definitions of industry and because we do not have companies with less than 20 employees in the database. (The database is not complete for 1995 either. For about 200 large companies we have not yet matched information from account statistics.) The agreement runs for a three-year period. Some companies made agreements in 1993, while others entered later. For some of the companies with agreements we have two observations of energy use during the agreement period (1993 and 1995). For those that entered after 1993 only one agreement observation for 1995 is available. There are no observations for the period after the agreements have been terminated, so it is not possible to examine if the effect of agreements prevails after the end of the agreement period.

The effect of the agreements has been estimated as a simple dummy variable. In general, self-selection may yield biased estimates of »treatment« effects (like the energy audit) if companies that choose a certain type of regulation (choose a special treatment) are *different* (in an unobserved way) from companies that do not enter an agreement. However, if the unobserved differences that influence selection are time invariant (e.g. say that the attitude to energy savings of the managers does not change over time), then the fixed effect estimator will produce consistent estimates of the treatment effect, since the unobserved (time invariant) differences will be captured by the company specific fixed effects. It should, however, be noted that if companies respond differently to the energy audit, the fixed effect estimator yield the effect of the companies that have been selected for the audit (which is not necessarily the same as the effect from giving a random chosen company an energy audit).[14] See Heckman and Robb (1985a and 1985b) for a detailed discussion on treatment effects and self-selection.

If we look at electricity, the agreement effects in the simple model and in the model with characteristics were -0.104 and -0.074 respectively (Tables 1 and 2). For total energy the respective figures were -0.136 and -0.131. However, some of these estimates were only significant at a 10% level. Due to the log transformation the interpretation of these estimates is straightforward. With an agreement the level of total energy use is about 13% lower than without an agreement. For electricity consumption the effect of an agreement is a bit lower (7-10%).

It should, however, be noted that other studies – mainly bottom up studies – suggest that the effect on electricity or energy consumption of energy audits associated with the energy agreements is considerably lower than suggested by our estimates. These studies report electricity/energy savings only up to 3%. The bottom up studies focus on the more direct investments following the energy audit. The bottom up studies may underestimate the actual effects of audits if there are large spill-over effects in energy savings. Companies that enter into an agreement also commit to energy management. The discrepancy between our results and the bottom up studies may therefore be due to a large effect from a more committed management of energy use in the industrial companies.

The effect of energy audits we have estimated could however also be biased for two

[13] This description applies to the first generation of the Danish CO_2 taxes and energy agreements running from 1993 to 1995. A second generation of energy agreements started in 1996.

[14] Note that this may also be the correct answer if the purpose of the study is either to evaluate the past effect of a policy or if the interest centres on forecasting the future effects of energy agreements, when the same selection rules characterize past and future energy agreements.

reasons. Firstly, we have not so far got all information for about 200 large companies in 1995. Some of these companies may also have an energy agreement. If these (large) companies are affected differently by an energy audit, then our present estimate cannot be compared with the estimates obtained in the other studies mentioned above. Secondly (and perhaps more important), a number of industrial companies have obtained subsidies for investment in energy saving projects. Other studies suggest that companies with an energy agreement also have been more likely to get an investment subsidy. Thus, the estimate of the energy audits may be too high, because this variable also captures the effects of investment subsidies (i.e. omitted variable bias). However, information about investment subsidies is being added to the database and we also expect that information about the 200 remaining companies in 1995 will soon be available, so these potential sources of bias can be eliminated in future work.

The estimated effect of the agreements (accepting these at face value) can be regarded as a gross effect. In some contexts it is more interesting to find out if the companies with an energy agreement would have used less electricity and energy if they had just paid the higher prices of electricity and energy. This can be labelled as the net effect of energy agreements. This effect can be calculated for the companies with agreements using the price elasticities from Table 2 (that takes into account company characteristics). Focussing on electricity consumption of companies with an agreement in 1993, it appears that the effect of the general CO_2 tax on electricity use would have been 8%. This is slightly higher than the estimated agreement effects (7%) in the model with characteristic effects. This suggests that the companies with an agreement would have had even lower electricity use, if they had not entered an agreement, but instead just had paid the CO_2 tax on electricity. Thus, the net effect on electricity use of the energy agreement appears to be negative (at least at this preliminary stage).

8. Summary and Discussion

An econometric analysis of electricity and total energy use has been carried out based on a panel data set with observations at company level over a 12-year period. At the company level, there is decreasing return to scale. For electricity and total energy we have obtained scale parameters between 0.5 and 0.6. The price elasticities of respectively electricity and total energy were -0.5 and -0.7 (weighted by the companies' share of electricity and total energy). These elasticities are obtained in fixed effects models. It appears that simple pooled estimators, that do not take into account the panel structure of the data, yield very different estimators. This suggests that cross-section estimates of industrial energy demand may be biased due to unobserved heterogeneity.

Looking at the total industrial sector the demand for electricity and total energy responds fairly similar to changes in level of activity and prices. When looking at companies in different industrial sub-sectors a more heterogenous picture emerges.

In correspondence with the only other micro panel study on industrial energy demand it is found that large companies' overall use of energy is more sensitive to changes in prices than small companies, and that energy intensive companies responds less to price changes compared to less energy intensive comparies.

We have also estimated the effect of individual energy agreements between Danish industrial companies and Danish energy authorities. However, the estimated results with respect to the effects of energy agreements may be sensitive to the inclusion of more observations and new information (subsidies to energy efficiency investments). The estimated effect of the agreements should therefore be interpreted cautiously. But it is interesting to note that even though we find a large – and perhaps too large – energy reducing effect of agreements, then the models also predict that the companies would have reduced energy use even more if they had not been offered the agreement, but just had to pay the tax instead.

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