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The Effect of Energy Audits in Danish Industry – Evaluation of a DSM Programme

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ABSTRACT

This paper presents an evaluation of the impact on electricity consumption of the free-of-charge energy audit provided to all Danish enterprises by the 60 electricity network operators. The scheme has existed since the early 1990's. Approximately 0.045 EUR-Cent per kWh consumption is being spent annually on this activity. The evaluation is based on an econometric analysis of a large panel dataset. The econometric analysis is complemented with ten case studies that allow us to get a deeper understanding of the causal processes. Overall, we find that the scheme has had limited impact on the electricity consumption among the enterprises that have been audited.

KEYWORDS
Evaluation, industry energy audits, econometric analysis, case study

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INTRODUCTION

Worldwide resources are allocated to activities that promote energy savings through so-called Demand-Side Management (DSM) activities. Energy companies are often required by the government to undertake DSM activities to promote energy savings. In many countries (see e.g. IEA, 2005), the DSM activities include consultancy schemes where a consultant informs a consumer about potential energy savings initiatives. As for energy efficiency, the European Union adopted in December 2005 a 'Directive of the European Parliament and of the Council on energy end-use efficiency and energy services'.[1] A directive of course very much related to the ambitious targets of the union in relation to the reduction of greenhouse gas emissions.[2]

The underlying idea is that consumers are not sufficiently informed about the existing potential for energy savings. In Denmark, one such scheme provided by the electricity network companies and targeted at the commercial sector is the free-of-charge energy audit provided to all enterprises with a level of electricity consumption above 20 MWh/year. The scheme offers industries a free-of-charge energy audit that will inform them about the potential for implementing cost-effective initiatives. It was (based on pilot projects, see Larsen et al., 1993 and Larsen, 1994) implemented in 1992 and is still in force. The annual budget of the programme is at present about 10 million EUR (i.e. about 75 million DKK) corresponding to 0.045 EUR-Cent per kWh consumption in the target group. This figure does not include the cost, which the customers (enterprises) themselves incur due to time spent in relation to the audit and investments made in energy-efficiency improvements.

The purpose of this paper is to evaluate the average net effect of the scheme on electricity consumption of Danish industries. The evaluation is based on a large-scale analysis of a large sample of the entire population of industries for the period 1992 to 2002. The analysis is based on meter data handed over to us directly from the electricity network operator.

As for general evaluations of DSM activities, there is a comprehensive literature. Recently, DSM is surveyed for the US in Loughran and Kulick (2004). On the websites of respectively ACEEE and ECEEE[3] (American/European Council for an Energy-Efficient Economy) there are many references to DSM policies and DSM evaluation. But to our knowledge, there are surprisingly few micro-econometric evaluations of the effect of the schemes worldwide. This paper contributes by presenting the results from

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[1] http://www.euractiv.com/en/energy/energy-use-efficiency-energy-services/article-133534

[2] According to the Kyoto-agreement the EU has a commitment for reduction of 8 % in 2008-2012 compared to 1990. The Danish commitment is 21 %.

[3] www.aceee.org and www.ecee.org

evaluating the net energy savings effect of a particular DSM scheme. In section 2, the scheme is presented. In section 3, the evaluation design and the results are presented. Section 4 summarises and discusses policy implications.

1. DESCRIPTION OF THE ENERGY AUDITING SCHEME

The Danish electricity law (departmental order nr 286 of 2005/20/04) and annual task letters from the Danish Energy Authority (DEA) to the network operators (and their umbrella organisation, ELFOR) define the framework for the audit activity. It is the network companies that have the obligation to operate the DSM audit scheme. The progress and impact are monitored through the bi-annual DSM planning and DSM documentation reports. The responsibility for the audit programme rests with the individual electricity network company. Being part of DSM activities, the audit scheme is financed by the network companies that are obliged by law to promote energy savings. ELFOR coordinates certain elements such as the reporting to the Danish Energy Authority.

The free-of-charge energy audit is, as previously mentioned, provided to all enterprises with a level of electricity consumption above 20 MWh/year. An energy audit is carried out by a trained energy auditor. The energy auditor is addressed by the enterprises wishing to get advice on how to save energy. An energy audit can provide enterprises with the required information about cost-effectiveness and 'how to'. There are about 200 energy auditors employed in the network companies. They are equipped with various tools (models, guidebooks) that help make the offer relatively uniform across the country. The audits are free of charge to the enterprises that use them, except for the time cost they may themselves put into it. The firms can choose between two types of audit: a complete audit or a partial audit of the enterprise. The partial audit focuses on specific installations or systems that the enterprise has expressed an interest in whereas the general audit encompasses the whole enterprise. Should a firm decide to implement some of the identified energy savings measures, a more detailed audit can be carried out, however, not free-of-charge.

In addition to the required reporting procedure, ELFOR has taken the initiative to develop a common database for the audit activity, namely UNITOOL, containing case-specific information from the auditor. For this, the auditors collect information about the costs and benefits associated with each audit. Specifically, the auditor registers the suggestions for energy savings. Three months after the audit, the auditor contacts the firm by telephone asking what has been implemented. This information is stored in the UNITOOL database. This data is used for an analysis of penetration, cost-

effectiveness and avoided CO_2 emissions, and enter as such in the overall DSM planning regime[4].

2. THE EVALUATION APPROACH

The evaluation centres on two types of analysis. The core is a micro-econometric analysis of a large sample from the entire population of industries for the period 1992 to 2002. The analysis is based on meter data handed over to us directly from the electricity net operators. This data has the important quality in that it has been collected independently from the auditing scheme. The micro-econometric analysis is supplemented with ten case studies of enterprises that are expected to have the largest potential for energy savings. The approach is inspired by Christoffersen et.al. (forthcoming), Dyhr-Mikkelsen (2004), Energistyrelsen (2003), Rieper (2004), Togeby (2000) and U.S. Department of Energy (2003).

2.1 The Econometric Analysis

The effect of the programme is estimated on a large panel dataset where individual enterprises are followed for up to 11 years. On average, each enterprise is observed 7 times. The data set includes enterprises that are customers at one of the 11 largest network companies in Denmark during the period 1992 to 2002. The network companies have provided us with consumption data. This data had the important quality of being able to follow individual companies across time. This is a unique feature of this dataset. The enterprises in the data set that have been audited are identified from the information in the UNITOOL database. To this data set of enterprises, additional information has been merged. First, information about the number of employees and industry sector of the enterprise has been obtained from the official business register administered by Statistics Denmark. We have used the number of employees as the best possible proxy for production activity. On the very detailed production site level, we needed to analyse the number of employees which was the only possible variable. From the Danish Energy Agency, we obtained information about companies that had received subsidies from the agency and/or made a so-called voluntary agreement with DEA (Johannsen and Larsen, 2000). Finally, we have merged onto the data

[4] In the evaluation project carried out for DEA the results from these two analyses (the econometric and the case-studies) are compared with the energy savings information collected by the auditors and stored in the UNITOOL database. As the quality of UNITOOL in relation to this information turned out to be questionable we have omitted this comparison in this article.

set information about electricity prices. The final data set includes 7,515 enterprises of which 1,419 have been audited[5].

The purpose of the econometric analysis is to estimate the average net impact of the programme on the consumption of electricity for the companies who have been audited. This parameter is known as the treatment effect on the treated in the literature on evaluation of labour market programmes; cf. Heckman et al. (1999).

The effect we are interested in is given by

$$E\left[y_{it}^{d=1}-y_{it}^{d=0}\middle|d_{it}=1,X_{it},\beta_{0i}\right]=E\left[y_{it}^{d=1}\middle|d_{it}=1,X_{it},\beta_{0i}\right]-E\left[y_{it}^{d=0}\middle|d_{it}=1,X_{it},\beta_{0i}\right] \quad (1)$$

where $y_{it}^{d=1}$ is log of electricity consumption for company i, $i=1,\ldots,N$ at time t, $t=1992,\ldots,2002$, given that the company has been audited. $d_{it}=1$ indicates that the company has been audited, X_{it} is a vector of observed time varying characteristics, and β_{0i} is an unobserved company specific effect (a fixed effect). $y_{it}^{d=0}$ is the level of consumption for a company that has not been audited. $E\left[y_{it}^{d=0}\middle|d=1,X_{it},\beta_{0i}\right]$ is the expected level of consumption for an audited company with characteristics X_{it},β_{0i} had it not been audited. This is not observed because an audited enterprise is never observed in the un-audited state at the same time, so we replace it with $E\left[y_{it}^{d=0}\middle|d=0,X_{it},\beta_{0i}\right]$ which is the level of consumption of non-audited companies for companies with characteristics X_{it},β_{0i} that have not been audited. For estimation purposes, we specify the equation to be estimated as a linear panel data model.

$$y_{it}=\beta_{0i}+\beta_1 d_{it}+\beta_2 X_{it}+u_{it} \quad (2)$$

where β_1 is the average effect of an audit among the group of companies that has been audited. β_{0i} is a firm-specific effect that is constant across the observation period. This includes unobserved and observed characteristics that are constant across time such as sector and geographical location. X_{it} is a vector of observed variables, including number of employees and prices. We have also included year dummies to control for business cycle effects. u_{it} is an error term. The parameters in (2) are estimated by within-transforming

[5] Statistics about the representativeness of our sample can be found in Hansen et al. (2004).

equation (2)[6], so that β_{0i} vanishes, see for example Baltagi (1995), and running ordinary least squares, i.e. a regression on the transformed variables. This allows firm-specific components to be correlated with d_{it}. This could be the case if companies have unobserved characteristics that make it more advantageous for them to enrol in auditing than the enterprises observed without auditing..[7] A similar approach has been applied by Leth-Petersen and Togeby (2001) in an evaluation of the effect on consumption of energy of a consultancy scheme targeted at apartment blocks.

At the descriptive level, there is no difference in the average level of consumption between enterprises that have been audited and those that have not. We therefore turn to the econometric analysis where we introduce a number of control variables to see if that reveals any effect of the auditing scheme. The results from estimating equation (2) are presented summarily. For descriptive statistics and details and complete estimation results we refer to Larsen et al. (2004). (2) has been estimated under different specifications of d_{it}: (A) The audit has only an effect the year of the audit. (B) The audit has the same effect from the year it is carried out and all the following years. (C) The audit has full effect the year of the audit and then the effect diminishes linearly depending on the number of years that have passed since the audit. (D) The audit has full effect in the year of the audit plus the year after. Estimates of β_1 are presented in Table 1.

Table 1. Parameter estimates

	(A)		(B)		(C)		(D)	
Variable	Coef.	Pr > |t|	Coef.	Pr > |t|	Coef.	Pr > |t|	Coef.	Pr > |t|
Audit ($\hat{\beta}_1$)	0.0445	0.022	0.0379	0.000	0.0526	0.000	0.0303	0.001

Note: Parameter estimates on number of employees, year dummies, subsidies, electricity price and constant are not reported. We refer to Larsen et al. (2004) and for even further details to Hansen et al. (2004).

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[6] The within transformation subtracts from a variable, X_{it} the mean across the sample period for the group, $\overline{X}_i = \frac{1}{T}\sum_{t=1}^{T} X_{it}$, so that a within transformed variable, $\tilde{X}_{it}$ is given by $\tilde{X}_{it} = X_{it} - \overline{X}_i$

[7] Comparing pooled estimates with the fixed effects estimates, the fixed effects estimates are different indicating correlated heterogeneity, see Hansen et al. (2004) for the pooled estimates.

Table 1 shows that elasticity of consumption with respect to auditing, i.e. (A) indicate that consumption is 4.45 percent higher for audited enterprises than for enterprises that have not been audited. In all cases, the treatment effect is estimated to be positive, i.e. that audit according to the estimates should have led to an increasing level of consumption. This is an indication that the audit does not lower the level of consumption. Positive parameter estimates suggest that the model may be mis-specified. We have therefore carried out additional estimations where the data set is split according to the level of consumption in order to check if the estimated effect is sensitive to size effects. Moreover, we have re-estimated the model on subsamples so as to investigate if the effect varies according to:

- size of suggested savings,
- the energy intensity of the production,
- the sector (industry, trade/service, and administration).

In some cases, the estimate of β_1 becomes insignificant, but in no case do we observe a negative estimate. While the model we have estimated may not be precisely specified, the econometric analysis indicates that an effect of the audit is indeed very small and difficult to detect.

2.2 The Case Studies

The econometric analysis pointed towards the auditing programme having no average effect in terms of reducing the consumption of electricity in the population of enterprises. The average effects estimated in the econometric study may swamp actual effects that are present only for a subset of the population. To address this issue and to get more detailed information about the driving forces behind the result, ten case studies have been carried out. While the case studies have obvious limitations (e.g. as for detection of an overall net impact on efficiency) due to the number of units interviewed, the timing of the interview relative to the timing of the audit do complement the statistical analyses very well in that the case studies are able to capture the satisfaction and opinions of the enterprises as well as provide information on economic aspects that was not available in the data used for the econometric analysis. For the ten cases, we report interview results and calculate energy savings and costs associated with investments.

The ten enterprises were picked from the group of companies that were expected to have the biggest potential for generating reductions in electricity consumption from an audit, so-called positive extreme cases. The firms were suggested by ELFOR. The cases were picked because an assessment of this

particular group will provide us with an upper bound for the impact that can be expected from the auditing scheme. At the same time, case studies allow to get insights into the mechanisms in the enterprises causing the result.

Among the enterprises that were identified as having a large potential for energy savings according to the audit, the ten cases were picked from different sectors and across levels of consumption. The distribution is shown in Table 2.

Table 2. Sample distribution for the case studies

	Agriculture	Industry	Trade & Service	Public
20-100 MWh/year			1	
100-500 MWh/year	1	2	1	1
>500 MWh/year		2	1	1

Source: Rieper et al. (2004).

The case study was based on face-to-face standardised, open interviews lasting 1-2 hours. Face-to-face interviews are more costly than telephone interviews, but allow capture of vague opinions and unexpected issues to be registered. A guideline for each interview was developed based on the existing audit report and the information registered in UNITOOL. In each case, both the case enterprise and the associated auditor were invited to comment on the case interview report.

The interview questions related to: (1) the preconditions for and experience with energy efficiency improvements, (2) the contact between enterprise and auditor, (3) implementation of the recommended energy saving measures, (4) investment costs and savings, (5) strong and weak points in the audit and audit process and suggestions for improvement of the service.

The audited enterprises have on average received 5-6 pieces of advice. Most of them concern lighting and ventilation. Of the 56 advices, 36 have been implemented. For 7 out of the 10 cases it was possible to calculate the electricity savings. The calculations were based on reports during the interviews with the responsible manager for energy savings in the enterprises. These reports were specifically related to each advice given in the audits and implemented by the enterprises. In the first year, the saving was between 7 and 20 percent; not bad, but we have to recall that it was positive extreme cases. The main reasons for not implementing an advice were lack of economic resources and the advice no longer being relevant. The reasons given for implementing advices are economic, but also positive spin-offs and general environmental concern. Typically, the contact is initiated by the electricity network companies and not the customers.

As expected, the implemented measures have a shorter pay-back period than the ones left unimplemented. The average size of the investment, however, does not vary between those implemented and those not implemented.

Overall, the enterprises were satisfied with the audit service as could be expected due to the choice of sample. Weak elements listed include lack of communication skills of the auditors – written as well as oral. Strong points included that the on-site inspection of the auditors was very thorough.

Only three of the ten enterprises used commercial audit services; two of these are energy intensive and use commercial services at regular intervals. For the other enterprises, it was important that the audit was free of charge and they are unlikely to seek commercial services.

Half of the enterprises had received a subsidy, and three of those had obtained the subsidy in relation to the audit. Still, only one enterprise attributes the implementation of advice to the availability of a subsidy. The main economic results are shown in Table 3. The results show that there appears to be an effect for these ten cases, but also that the effect is often relatively small taken into regard, that the case enterprises were selected as positive extreme cases.

Table 3. Cost savings associated with energy audits at case enterprises

Case enterprises by branch and size (MWh/year)	Change in electricity bill NPV in 1000 EUR	Investment minus subsidy NPV in 1000 EUR	Net savings NPV in 1000 EUR
Agriculture 100-500	-5	2	3
Industry >500	not available	not available	not available
Industry >500	-68	0	68
Industry 100-500	-16	10	6
Industry 100-500	-38	6	32
Trade and service >500	-20	11	10
Trade and service 100-500	not available	not available	not available
Trade and service 20-100	-5	1	4
Public >500	-173	8	132
Public 100-500	-12	4	8
Public 100-500 incl. heating (the same public organisation as above)	-21	4	17

Source: Rieper et al. (2004).

Note: For calculations of net present values (NPV) we have assumed a 6% interest rate, 15 years lifetime with full effect the first 5 years and then linearly diminishing the following 10 years.

CONCLUSION AND DISCUSSION

The energy audit provided free-of-charge to all Danish enterprises was introduced in the beginning of the 1990's and constitutes by far the biggest part of the Danish electricity companies' efforts directed towards end-users to save energy. The annual expenses for the audits are approximately 10 million EUR. That corresponds to about 0.045 EUR-Cent per kWh consumption in the target group. The audit is directed towards all types of firms with a level of energy consumption above 20 MWh. Thus, the auditing is directed towards all (even small) firms, but at the same time the auditing is supposed to be optimised economically for the aim of realising as many energy savings as possible.

We have analysed the effect of the audit measured in energy savings in two different analyses. First, we have made econometric analyses of the effect at approximately 1,400 audited firms compared with approximately 6,000 firms without an audit. Second, we have made in-depth analyses of the effect at 10 firms. The firms were selected in such a way that we could expect a big effect.

Based on the evidence from the econometric analysis, there is no indication that the auditing scheme has led to a reduction in the consumption of electricity. Most detailed information about the effect is obviously found in the 10 case studies. The first year's savings was between 7 and 20% and in total, 56 pieces of advice was given for energy savings in the 10 companies. Out of these, 36 have been realised. Barriers for implementation are economic, and the fact that advice became irrelevant for the firms. Support for the savings is economic, but also positive side effects and company culture.

However, the crucial point is that the effect is so limited in terms of the number of enterprises affected and in the size of the effect among those affected that it has not been possible to trace it in a large-scale econometric study.

The cost of electricity consumption in most enterprises is only a modest component of its total costs and enterprises are implementing energy-saving measures anyway. Thus it might not be that surprising that the overall net effect of an energy audit is hard to trace.

The future of the audit has to be considered in connection with other policy instruments in the field. The situation today is that the environmental taxes on the firms' electricity consumption for many reasons – e.g. employment and competitiveness – do not cover the external costs. When this happens, it ought to be reconsidered if there is still a need for publicly organised electricity audits that appear to have a limited effect.

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