Barriers to energy efficiency – an econometric analysis of determinants

Edelgard Gruber
Fraunhofer Institute for Systems and Innovation Research
Breslauer Str. 48
D-76139 Karlsruhe
e.gruber@isi.fraunhofer.de

Joachim Schleich
Fraunhofer Institute for Systems and Innovation Research
Breslauer Str. 48
D-76139 Karlsruhe
j.schleich@isi.fraunhofer.de

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Abstract

A vast body of literature suggests that there are various obstacles to energy efficiency in private and public organisations or individual households. Barriers such as market failures, transaction costs, or imperfect information may even prevent cost-effective technologies and practices from being realised. In this paper, we use econometric techniques to assess the determinants of barriers to energy efficiency for the German commerce and services sectors, which predominantly consist of small and some medium sized private and public organisations. The barriers analysed include lack of time, lack of information about energy consumption patterns, lack of information about energy efficient measures, organisational priority setting, uncertainty about energy costs, and the landlord/tenant problem. For each barrier, a separate regression is run on a set of "explanatory" variables, which includes energy consumption, organisation size, whether an energy audit was conducted, and sector-specific dummies. The findings complement case study results, but policy recommendations are based on a much broader statistical basis.

Introduction

According to the IPCC Third Assessment Report (IPCC 2001) about half the technological potential for greenhouse gas emission reductions world-wide is also profitable, that is the monetary benefits of energy saved exceeds additional capital, operating and maintenance costs (Synthesis report, chapter 3, Executive Summary, p. 174). In terms of greenhouse gas emissions, the IPCC (2001) estimates this so-called no-regret potential to range between 10 and 20% of global emissions in the year 2020. According to the latest UNDP/WEC/DESA World Energy Assessment (2000) the no-regret potential for all sectors is even higher, at about 20 - 30%. For the commercial sector in particular, the profitable savings potential in buildings is estimated at 10-20% for the year 2010 and at 30% for 2020. However, various types of barriers, may prevent even profitable organisational or technological measures from being realised, in particular in organisations with low energy costs. There is a substantial body of literature, which analyses the nature of these barriers based on (partly overlapping) concepts such as market failures, information and other transaction costs, hidden costs, financial or technological risks, capital market restrictions, split-incentives (landlord/tenant dilemma), as well as organisational and behavioural constraints (Brown 2001, Eyre 1997; Howarth and Andersson 1995, Jaffee and Stavins, 1994a,b, Ostertag 2002, Stern 1986). Empirical analyses of the relevance of the various types of barriers and of the determinants often rely on theory-based case studies (DeCanio 1994, de Almeida 1998, InterSEE 1998, Ramesohl 1998, Schleich et al. 2001, Sorrell et al. 2000, Sorrell 2003). Such case studies are well suited to gain insights into complex decision-making processes and structures within organisations. But the empirical basis for generalising their findings in a statistical sense, including policy recommendations, is weak.

Empirical analyses based on large samples are limited. For the commercial sector, Gruber and Brand (1991), and Jo-

Table 1: Overview of sub-sectors.

Sector	Number of observations	Average number of employees	Average annual energy consumption [MWh]
Metal industry	116	9	125
Car repair industry	78	8	339
Wood working and processing	94	8	209
Bakeries	88	9	378
Butchers	76	8	151
Laundries and dry cleaners	67	19	1 978
Building/interior construction trade	98	15	89
Retail trade	295	29	459
Wholesale trade	168	37	837
Banks, insurance companies	129	162	1 622
Hotel industry	129	17	589
Gastronomy	103	10	216
Services**	78	10	48
Non-commercial organisations	127	29	508
Public administrations	96	69	934
Hospitals	79	300	8 834

**split for lawyers, architects, small private health services, private agencies, etc.

chem and Gruber (1990) explore decision making in companies with regard to energy efficiency measures in a univariate analysis. For other sectors, few multivariate econometric analyses have been carried out. Brechling and Smith (1994) explore the take-up of wall insulation, loft insulation, and double glazing in the UK household sector. For Irish households, Scott (1998) carries out a similar study looking at attic insulation, hot water cylinder insulation, and low energy light bulbs. For the industry sector, DeCanio (1998) analyses companies' investment behaviour based on data from the United States Environmental Protection Agency's Green Lights program. DeGroot et al. (2001) analyse to which extend barriers for the implementation of energy-saving technologies in Dutch companies vary across sectors and across firms' characteristics, running separate regressions for each potential barrier.

The analyses presented in this paper are closest to DeGroot et al. (2001). For various barriers to energy efficiency in the German commercial and services sectors[1], that is, lack of time, lack of information about energy consumption patterns, lack of information about energy efficient measures, organisational priority setting, uncertainty about energy costs, and the landlord/tenant problem, we econometrically estimate a separate regression equation. Based on the estimation results we are able to assess the statistical significance of various "explanatory" variables such as energy consumption, size of the company, or whether there are differences across sub-sectors. Simultaneously, we test whether there is empirical support for the claim that energy audits are an effective means to overcome barriers to energy efficiency in SMEs as has often been suggested (Enquête Commission 1989).

For the analyses we use almost 2 000 observations from a recent survey on energy consumption (Geiger et al. 1999). As shown in Table 1, our sample consists of small industrial enterprises and all public and private services. The sector commerce and services accounts for about 16% of final energy consumption (Federal Ministry of Economics and Labour 2002) and 20% of CO_2-emissions in Germany (Federal Environmental Agency 2002.). Thus, appropriate policies to address the barriers to energy efficiency in this sector may not only help to improve organisations' profitability but contribute to achieving national and international greenhouse gas reduction targets, and reduce reliance on fossil fuel imports.

The remainder of the paper is organised as follows. The next section contains a brief description of the survey together with some descriptive statistics. Then, the model variables, which reflect the barriers considered and the determinants, are presented. Estimation results are then presented. The paper concludes with policy implications.

The data

The data used for the analyses in this paper are taken from a recent representative survey in the commercial and services sector in Germany (Geiger et al. 1999). This study continued the data collection of energy consumption and use of two former surveys done in 1978 and 1982. But this time, the survey not only included questions on economic and technical factors, which affect energy use. In addition, questions about energy management, measures taken, and obstacles for energy efficiency were included. Because of its heterogeneity, the sector was broken down into several more or less homogeneous splits which reflect the sub-sectoral structure in official statistics and if necessary, in some cases even in sub-splits[2]. Based on literature research, discussions with specialists, in-depth interviews and plant inspections, a structured questionnaire was elaborated and 2 848 managers of enterprises and public institutions were interviewed personally by a well-trained staff. The sample was based on a quota method: a

1. In the German energy balances, final energy consumption is partitioned into four end-use sectors: industry, private households, transportation and the combined sector commerce and services.
2. For lack of sufficient data and data compatibility, not all splits could be included in the econometric analysis.

minimum number of respondents in each split in three different groups of companies' size was required.

As far as energy-efficiency measures were concerned the respondents received a list of sector-specific measures and were asked which of those measures were implemented in their organisations. These lists differed across sub-sectors and referred to the specific production equipment in the industrial sectors and to the building and the heating system in the remaining branches being characterised by offices. In the sub-sectors dominated by room heating, those lists included technical issues such as insulation of walls and windows, control systems for heating and lighting, heat recovery, as well as organisational measures such as energy analysis, and establishment of an energy management. In the industrial splits, additional production-oriented measures were included, such as leakage removal in compressed-air systems or investments in energy-efficient cooling. In addition, the survey also asked interviewees to judge the relevance of potential barriers to energy efficiency within their organisation.

Variables description

In this section, we describe the variables that are used in the econometric analyses as "dependent" and "independent" (explanatory) variables, respectively. The dependent variables reflect barriers to energy efficiency, and the independent variables consist of determinants.

DEPENDENT VARIABLES: BARRIERS

All variables, which stand for a barrier to energy efficiency, are dummy variables. That is, these variables take on the value of 1, if the statement or observation associated with that barrier is true. Otherwise the value of the dummy is 0. In total, we use six dependent variables, which are assumed to reflect various kinds of barriers. Next, the barriers considered are briefly described together with the associated dependent variables.

Lack of time

In companies from energy-intensive industries like the power or the iron and steel industries, energy performance affects the core production process and the energy cost share is rather high. So for these companies, economic incentives to find and realise efficiency potentials are strong. By contrast, in the sector commerce and services, the energy cost share is usually low, and investments in energy efficiency do not affect the core production processes. In addition, since companies in this sector are usually rather small, the indirect or hidden costs associated with investments in energy efficiency, such as overhead costs for energy management, or costs for training personnel are more likely to be prohibitive. The same may hold for, transaction costs, which generally include costs of gathering, assessing and applying information on energy savings potentials and measures, as well as costs to find and negotiate the contracts with potential suppliers, consultants or installers, or the costs of reaching, monitoring and enforcing contracts (Coase 1991). Thus, lack of time to analyse potentials for energy efficiency, is likely to constitute a barrier to energy efficiency in the commercial and services sectors. The dependent variable TIME takes on the value of 1, if survey respondents considered lack of time to analyse potentials for energy efficiency to be a relevant barrier in their organisation.

Lack of information about energy consumption patterns

Measuring and controlling energy consumption at a desegregate level is costly to organisations. Labour costs for metering and data management, and investment costs for the metering devices may prevent organisations from installing the appropriate equipment. However, if energy consumption, and hence, energy costs, are not known in detail, the profitability of energy saving measures cannot be properly assessed. The dependent variable ENDSPLIT takes on the value of 1, if the split of final energy consumption in thermal energy and electricity consumption is not known.

Lack of information about measures

Organisations' lack of information about energy efficiency measures may arise for several reasons. First, as explained above, organisations with low energy cost share have little incentive to overcome transaction costs and spend resources to find out about new energy savings technologies. Second, information about the performance of energy efficiency measures is a typical public good. Thus, if the production of this public good is left to the private market, "too little" information about energy efficient technologies will be produced. The dependent variable INFO takes on the value of 1, if survey respondents considered lack of information about energy efficient measures to be a relevant barrier in their organisation.

Investment priorities

A crucial criteria for investments in energy efficiency is, as for other investments, profitability, or the pay-back period. Both depend on the costs of capital for the organisation. Restricted access to capital markets is often considered to be an important barrier to investing in energy efficiency. That is, investments may not be profitable because companies face a high price for capital. As a result, only investments yielding an expected return that exceeds that (high) rate will be realised. Since the price for capital also reflects the risk associated with the borrower, small and medium sized companies often have to pay higher-than-average interest rates. Possible explanations include smaller companies' limited ability to offer collateral or potential lenders having to bear higher costs to assess the credit-worthiness of small and medium sized companies. When access to capital market is constrained, the allocation of funds within an organisation becomes even more important. Internal decision making and priority setting will not only depend on hard investment criteria such as rate of return or pay-back time of an investment project, but also on soft factors such as the status of energy efficiency, reputation, or the power of those responsible for energy management within the organisation (Morgan 1985, DeCanio 1994). The dependent variable PRIORITIES takes on the value of 1, if investment priorities are considered to be a barrier to energy efficiency in the organisation.

Uncertainty about future energy costs

Investing in a more energy efficient technology may turn out to be unprofitable if energy prices fall after the new technol-

Table 2: Logit estimation results on barriers to energy efficiency.

	TIME	ENDSPLIT	INFO	PRIORITIES	UNCERT	RENTED
ENERGY	-0,100*	-0,088	-0,004	-0,070	-0,014	-0,226**
	(0,056)	(0,056)	0,060)	(0,056)	(0,056)	(0,068)
	[0,077]	[0,116]	[0,942]	[0,213]	[0,798]	[0,001]
SIZE	-0,002**	-0,001*	-0,001*	0,000	-0,001*	-0,013**
	(0,001)	(0,001)	(0,001)	(0,000)	(0,000)	(0,003)
	[0,010]	[0,036]	[0,085]	[0,385]	[0,059]	[0,000]
AUDIT	-0,793**	-0,643**	-0,599**	-0,313*	-0,230*	-0,755**
	(0,129)	(0,127)	(0,144)	(0,124)	(0,122)	(0,178)
	[0,000]	[0,000]	[0,000]	[0,012]	[0,059]	[0,000]
Metal	1,084*	0,675	-0,385	0,993*	0,655	1,614*
	(0,552)	(0,548)	(0,583)	(0,549)	(0,545)	(0,659)
	[0,050]	[0,218]	[0,510]	[0,071]	[0,230]	[0,014]
Car	1,339*	0,570	-0,451	1,240*	0,433	1,204*
	(0,586)	(0,581)	(0,618)	(0,583)	(0,576)	(0,701)
	[0,022]	[0,326]	[0,465]	[0,034]	[0,452]	[0,086]
Wood	1,255*	1,029*	-0,942	1,333*	0,261	0,738
	(0,577)	(0,572)	(0,617)	(0,577)	(0,567)	(0,702)
	[0,030]	[0,072]	[0,127]	[0,021]	[0,645]	[0,293]
Bakeries	1,660**	0,798	-0,062	1,339*	0,612	1,234*
	(0,617)	(0,609)	(0,647)	(0,613)	(0,606)	(0,741)
	[0,007]	[0,190]	[0,923]	[0,029]	[0,312]	[0,096]
Butchers	1,836**	0,730	-0,324	1,044*	1,049*	1,395*
	(0,604)	(0,595)	(0,631)	(0,594)	(0,597)	(0,718)
	[0,002]	[0,219]	[0,607]	[0,079]	[0,079]	[0,052]
Laundries	1,204*	0,999	-0,424	0,975	0,879	1,383*
	(0,637)	(0,634)	(0,674)	(0,632)	(0,632)	(0,770)
	[0,059]	[0,115]	[0,530]	[0,123]	[0,164]	[0,072]

ogy has been implemented. Hence, there is an option value associated with postponing investments (McDonald and Siegel 1986; Dixit and Pindyck 1994). Thus, postponing irreversible investments in energy efficiency may be optimal if future energy prices are uncertain, even though the expected value remains unchanged (Hasset and Metcalf 1993, van Soest and Bulte 2001). In addition, since the interviews were conducted in 1997, thus prior to the liberalisation of energy markets in Germany (1998 for electricity, and 2000 for gas), organisations may have (correctly) expected energy prices to fall in the wake of the liberalised energy markets, rendering investments in energy efficiency less profitable. The dependent variable UNCERT takes on the value of 1, if uncertainty about future energy costs is considered to be a barrier to energy efficiency in the organisation.

Landlord/tenant dilemma

If a company is renting buildings or office space, neither the landlord, nor the company (tenant) may have an incentive to invest in energy efficiency, because the investor cannot appropriate the energy cost savings. On the one hand, the landlord will not invest in energy efficiency if the investment costs cannot be passed on to the tenant, who will benefit from the investment through lower energy costs. On the other hand, the tenant will not invest if she is likely to move out before fully benefiting from the energy cost savings. In the regression equation, the dependent variable RENTED takes on the value of 1, if rented space is considered to be a barrier to energy efficiency in the organisation.

INDEPENDENT VARIABLES: DETERMINANTS

A set of "independent" or "explanatory" variables is included as regressors in the equations.

Energy consumption

As explained earlier, organisations' incentives to spend resources to overcome barriers to energy efficiency depend on expected energy cost savings. Total annual specific energy consumption, ENERGY, is included to reflect the importance of energy consumption and energy costs to the organisation. To control for size effects, not the actual levels of fuel consumption, but rather specific measures are used. To create ENERGY, total annual fuel and electricity consumption were added up and divided by the number of employees.[3] Since ENERGY is expected to have a negative impact on barriers to energy efficiency, the expected sign for the parameter estimate associated with ENERGY is negative.

Size

Larger organisations are more apt than smaller organisations to deal with barriers such as information and other transaction costs, credit constraints, or uncertainty. Thus, the variable SIZE, which stands for the number of employees in the organisation, is expected to have a negative effect on barriers.

3. In the specification for the econometric estimations, the natural log of specific energy consumption is used.

Table 2. …continued

	TIME	ENDSPLIT	INFO	PRIORITIES	UNCERT	RENTED
Construction	1,020*	0,482	-0,921*	0,706	0,566	0,265
	(0,521)	(0,517)	(0,558)	(0,517)	(0,514)	(0,651)
	[0,050]	[0,351]	[0,099]	[0,172]	[0,271]	[0,684]
Retail trade	1,112*	0,838	-0,541	0,557	0,424	2,014
	(0,545)	(0,540)	(0,578)	(0,540)	(0,536)	(0,659)
	[0,041]	[0,121]	[0,349]	[0,303]	[0,428]	[0,002]
Wholesale	1,202*	0,740	-0,257	0,773	0,293	1,649*
	(0,551)	(0,545)	(0,581)	(0,545)	(0,541)	(0,662)
	[0,029]	[0,175]	[0,659]	[0,157]	[0,588]	[0,013]
Banks & Insurances	1,027*	1,354*	-0,110	-0,498	0,359	1,604*
	(0,544)	(0,541)	(0,574)	(0,549)	(0,534)	(0,662)
	[0,059]	[0,012]	[0,848]	[0,364]	[0,502]	[0,015]
Hotel	1,019*	0,722	-0,871	1,075*	0,844	0,698
	(0,611)	(0,607)	(0,652)	(0,607)	(0,603)	(0,757)
	[0,096]	[0,234]	[0,182]	[0,076]	[0,162]	[0,357]
Gastronomy	1,079*	0,692	-0,385	0,571	0,644	2,104**
	(0,590)	(0,586)	(0,624)	(0,586)	(0,583)	(0,706)
	[0,068]	[0,238]	[0,538]	[0,329]	[0,269]	[0,003]
Services	0,999*	0,750	-0,654	0,323	0,409	2,037**
	(0,538)	(0,535)	(0,571)	(0,534)	(0,530)	(0,636)
	[0,063]	[0,161]	[0,252]	[0,546]	[0,441]	[0,001]
Non-Commercial Services	0,596	1,275*	-1,050*	0,717	0,110	0,705
	(0,572)	(0,566)	(0,613)	(0,565)	(0,560)	(0,707)
	[0,297]	[0,024]	[0,087]	[0,204]	[0,845]	[0,319]
Public Administrations	0,322	1,238*	-1,174*	0,814	0,108	1,046
	(0,558)	(0,549)	(0,601)	(0,546)	(0,541)	(0,686)
	[0,564]	[0,024]	[0,051]	[0,136]	[0,841]	[0,127]
Hospitals	1,332*	0,912	-1,226*	1,732**	0,646	1,552
	(0,651)	(0,631)	(0,720)	(0,629)	(0,618)	(1,013)
	[0,041]	[0,148]	[0,088]	[0,006]	[0,295]	[0,125]
N	1821	1813	1821	1821	1821	1821
Pseudo-R^2	0,08	0,06	0,22	0,07	0,05	0,41
Share of correct predictions	0,60	0,57	0,68	0,58	0,59	0,74

Standard Errors are given in parenthesis ( ), P-Values are given in brackets [ ].
* individually statistically significant at least at 10 % level
** individually statistically significant at least at 1 % level
'Pseudo' R^2 is the Nagelkerke coefficient of determination provided by SPSS

Energy audit

In the survey companies were also asked whether they recently had an energy audit, which means that an external consultant came to the company, carried out an energy efficiency check and made suggestions for improvement. To test the efficacy of energy audits to overcome barriers to energy efficiency, the dummy variable AUDIT was included, which takes on the value of 1 if an audit was carried out. Thus, the expected sign of the parameter estimate associated with AUDIT is negative.

Sub-sector dummies

As pointed out before, the commercial and services sectors are quite heterogeneous. To allow for sub-sectoral differences, a dummy variable was included for each sub-sector.[4]

Results

To empirically assess the relevance of the various determinants on the barriers to energy efficiency, a separate Logit model was estimated for each barrier. The estimation results for the six equations appear in Table 2.

The percentage of variation in the dichotomous dependent variables which can be explained by the estimated regression equations ranges – as indicated by the coefficient of determination (Pseudo R^2) – from 5% for UNCERT to 41% for RENTED. In general, estimation results are consistent with the hypotheses developed in the section "Dependent variables: barriers". In particular, all nonzero parameter estimates for ENERGY, SIZE, and AUDIT exhibit the expected negative sign, even when they are not statistically significant.[5] More specifically, SIZE is found to be statisti-

4. To prevent singularity of the regressor matrix, a constant was not included in the regressions.
5. "Statistically significant" as used in this paper means significant at least at the 10% level, i.e. the P-values associated with the parameter estimates are no greater than 0.1.

cally significant for all barriers, except for PRIORITIES, ENERGY for half the barriers considered. The findings for AUDIT suggest, that carrying out an energy audit will help reduce all barriers analysed. As for individual barriers, lack of time appears to be a problem in all sub-sectors, except for the quasi-public non-commercial organisations and public administrations. By contrast, public non-commercial organisations and public administrations, together with wood processing and banking and insurance, suffer from lack of information about energy consumption patterns relative to the other sub-sectors included. Lack of information about energy savings measures does not appear to be a problem for any sub-sector in particular. However, the negative parameter estimates for the non-commercial organisations, public administrations, and hospitals, which tend to be public or quasi-public, indicate that these organisations appear to be significantly better informed about energy savings measures than the other sectors, at least in a statistical sense. The results for PRIORITIES suggest, that organisational priority setting is biased against energy efficiency in small industrial and commercial enterprises, hotels and hospitals, relative to the other sub-sectors. The only sector, where UNCERTAINTY about future energy prices appears to be significantly more relevant than in other sub-sectors are butchers with their relatively energy-intensive production. By contrast, results for RENTED indicate that the landlord/tenant dilemma is a problem for half the sectors included in this study.

It should be noted though that, since sub-sectoral differences are assumed to be captured by a dummy only, the conclusions for individual sub-sectors are somewhat coarse and should be viewed as a fist indicator, only. To gain additional sector-specific insights, estimations would have to be conducted at the level of sub-sectors, which also take into account the heterogeneity within the sub-sectors.

Policy implications

To address the variety of barriers analysed, a mix of various policy measures will be required. As previous research pointed out (Gruber and Brand 1991, InterSEE 1998, Sorrell et al. 2000) the objective to improve energy efficiency should not only be pursued by overall international, national or regional energy policy, but at all levels such as trade associations, utilities, training organisations, research institutions and other groups which have a multiplier function.

The results of this paper, in particular, suggest, that energy audits could be useful, especially for SMEs or branches with low energy intensity where companies usually do not have recourse to their own energy experts and where managers do not have time to take care of energy issues. Initial audits could be free of charge for the companies or highly subsidised and measures should be undertaken to convince the managers that audits are useful, combined with a quality control of consultants. Branch-specific associations are the most important actors in this communication process. Results from former studies showed only a limited success of an energy consultation programme in Germany, which included small grants for energy audits in SMEs (Gruber and Venitz 1994). Many small companies did not know the programme at all. Likewise, smaller companies were less likely to use the programme (Gruber and Brand 1991). Others judged the grant too low because they do not know in advance whether the benefits of an audit will outweigh the costs. Most of them preferred a short but cost-free initial audit and wanted to pay the follow-up detailed audit on their own as soon as a reliable estimate about the saving potential existed. In order to achieve a multiplier effect of such a programme, information campaigns should disseminate successful examples of both free, short audits as well as subsequent in-depths audits, so that other managers will recognise that audits are worthwhile. In any case, in particular for SMEs public programs should not be too complicated and require companies to fill out tons of forms, for which they don't have the time (Gruber and Venitz 1994, Gruber and Brand 1991).

Other financial incentives such as energy or CO_2-taxes or tradable emission allowances programs will raise the cost of energy use and increase the profitability of energy savings measures. Such policies would have to be implemented on a European Union or national level, but - as our results also indicate - financial incentives alone are unlikely to suffice. Other analyses, based on case study results, also suggest that financial support has been only one supporting factor among others and often not the most important one (InterSEE 1998). promising instruments are pilot and demonstration projects and best-practice examples, benchmarking for companies for comparable branches or processes, energy workshops with company managers for exchange of experiences, internal target setting and monitoring of energy efficiency measures.

Policies to address this dilemma should aim at reducing the transaction costs for investors to appropriate the benefits. Such policies may include rent control legislation to facilitate passing on the investment costs for measures improving energy efficiency to tenants. Simultaneously, legislation should improve the quality of information about the energy consumption and energy costs of rented buildings and office space. That is, a certificate of the energy consumption for commercial premises should be required, similar to residential buildings.

Finally, energy service including planning, implementation, financing and operating of energy-saving equipment can help overcome multiple barriers to the rational use of energy such as lack of time and staff for energy management, costs for gathering information on energy savings technologies, or lack of capital (Chesshire 2000, Schleich et al. 2001).

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