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Highlights

- Energy audits influence positively the decision of SMEs to proceed with energy-efficiency investments
- Energy audits help to overcome the information barriers to energy efficiency investments, especially in small firms
- The benefits of energy audits cease to exist when firms are finance constrained
- Information campaign is an efficient tool for promoting energy audits among SMEs

Abstract

This paper assesses the role of energy audits in promoting energy-efficiency measures in SMEs. It benefits from the data collected within the European Investment Bank Surveys in 2017 and 2018, involving information about energy audits and energy-efficiency investments of some 12,500 signatures from EU28 Member States per year. Our findings suggest that energy audit is a useful tool in overcoming the information barriers and facilitating investments in energy-efficiency measures. In fact, their information is more crucial for small firms and for investments in support processes such as lighting, wall insulation etc. than in production processes such as replacement of machinery and equipment. However, we found that the beneficial impact of energy audits cease to exist when firms are finance constrained. Finally, our results indicate that information campaigns are one of the most efficient available instruments among other instruments (regulatory, financial and voluntary agreements) for promoting energy audits in SMEs.

Keywords

Energy audit, propensity score matching, energy efficiency, European investment bank survey.

JEL-Classification: P28, Q41, Q48

1 INTRODUCTION

The European Union (EU) has consistently been at the forefront of global action against climate change. It has developed various ambitious energy and climate policies (EC, 2016b) both to mitigate climate change (CCM) and to limit the global increase in temperature to less than 2oC, in line with the recent Paris Agreement. Despite the considerable progress made recently towards realising the 2020 objectives (EEA, 2018) by both the EU as a whole and individual Member States, efforts should be stepped up in order to meet the 2030 objectives, especially in the area of energy efficiency.

In particular, the magnitude of the financing gap in Europe for reaching the EU 2030 targets is considerably higher in energy-efficiency measures than any other type of CCM investment. According to the European's Commission impact assessment analysis that accompanied the 'Clean Energy for All Europeans' policy package, the relative investment gap in households stands out, but substantial investment is also needed in the tertiary sector and industry. These two sectors combined, are the primary contributors to the EU final energy consumption and to energy-related carbon dioxide emissions, accounting for 40% and 30%, respectively. To this end, significant benefits will arise from their energy efficiency improvements: the untapped potential for improved energy efficiency is estimated close to 26% and 12-17%, respectively (European Commission, 2016). Several other studies (Eurochambres, 2010, Thollander et al., 2013) have estimated this energy efficiency potential of industrial SMEs in the EU at more than 20%-25%.

In this context, we assess the impact of energy audits on the energy-efficiency measures of SMEs firms based on the European Investment Bank Survey 2017 and 2018. The Energy Service Directive (ESD) and later the Energy Efficiency Directive (EED) have advocated energy audits as an essential tool to overcome the information barriers to energy efficiency and facilitate implementation of energy efficiency measures in SMEs and large firms (EC, 2016a). Findings from the literature indicate that energy audits proved to be one of the most effective measures that are widely used to diagnose, analyze and improve energy use in the industrial and building sectors (Basurko et al., 2013; Petek et al., 2016; Moya et al., 2016). Others go a step further suggesting governments to subsidize energy audit programs for companies, as a common policy in attempting to overcome the energy efficiency gap (Bertoldi, 2001) and to mitigate CO2 emissions, even though there might be some free-riding issues (Thollander et al. (2007), Fleeter et al. 2012).

The paper is organised as follows. Section 2 provides a brief literature review of the impact of energy audits on energy-efficiency measures. Section 3 and 4 discuss the methodology and the data used to assess the role of energy audits on firms' decisions to proceed with energy-efficiency projects. Section 5 and 6 present the results of the econometric analysis and provide policy recommendations.

2 LITERATURE REVIEW

Many studies have investigated the determinants of adopting energy-efficiency measures in households (Sardianou,2007; Nair et al., 2010; Mills and Schleich, 2012, 2014; and Astmarsson et al., 2013), but industry and the tertiary sectors are less explored areas due to lack of data. Furthermore, most of the existing studies (Schleich, 2009; Schleich and Gruber, 2008; Sorrell, 2004; Thollander et al., 2007; Thollander and Ottosson, 2008; Trianni and Cagno 2013) have focused on why companies fail to adopt cost-efficient energy-efficiency measures (known as the "energy-efficiency gap" (Jaffe and Stavins, 1994a)). The most commonly cited barrier to energy efficiency relates to market failures, caused by high information costs and other transaction costs, hidden costs, financial and technological risks, capital market restrictions, split-incentives, as well organisational and behavioural constraints (Brown, 2001; Eyre, 1997; Howarth and Andersson, 1993; Jaffe and Stavins, 1994a,b; Sorrel et al., 2004; Stern, 1986).

Few studies have assessed the impact of energy audits as a means to overcome these information barriers. Five are the most well-known and cited, evaluating the energy audit programmes in different regions and countries: Australia, Germany, Sweden and the United States. Harris et al. (2000) assessed the impact of the Australian Energy Efficiency Action Plan (EEAP), which offered energy audits at 50% discount. Their findings suggest that firms decide to take almost all (80%) measures identified as cost effective by the audit, which addresses the complexity of energy-efficient investment decisions. Similarly, Anderson and Newell (2004) found that adoption rates of suggested measures by energy audits were close to 50% based on the data offered by the US Department of Energy's Industrial Assessment Center. This was also in line with the findings of Tonn and Martin (2000) for the same programme. The energy audit programmes in Germany (Schleich, 2004; Fleiter et al., 2012a; Schleich and Fleiter, 2017) offered to SMEs and non-energy intensive industries, and in Sweden (Thollander 2007, 2010) were also considered successful, with estimated implementation rates at 77% and 40%, respectively.

The comparison of the existing studies is complex due to differences in their analysis. These differences include methodological issues, location, studying period, barriers considered, sectors and technologies concerned. However, there are some common findings among the studies (Fleiter et al., 2012b). For example, from a methodological perspective, none except Schleich and Fleiter (2017) used a control group to identify the impact of the energy audit, due to data limitation. The latter study supports the notion that most of the empirical findings were based on subjective assessments of the data collected by the respective surveys. Nonetheless, all studies found a positive impact of energy audits on the adoption of energy-efficiency measures.

3 RESEARCH METHODOLOGY

3.1 Methodology

The econometric framework that we use for investigating the role of energy audits in promoting energy-efficiency measures builds on the work developed by Roy (1951) and Rubin (1974). Roy and Rubin proposed the propensity score matching (PSM) methodology in evaluation problems such as the effect of participating in a programme (treatment) as a method to reduce bias in the estimation of treatment effects with observational datasets. This requires an inference about the outcome that would have been observed for the treated ("treatment group"), in this case firms that have conducted an energy audit, if they had not been treated ("control group").

Matching is an appealing way to alleviate any potential functional-form misspecifications when estimating treatment effects. The idea is simple: matching firms that had an energy audit (binary variable Di equals 1) to firms with the same set of covariates (Xi) but without an energy audit (Di = 0) eliminates differences in covariates between the treatment and control samples. In this setting, the observations between treated and control groups across multiple dimensions are matched based on the probability of treatment conditional on Xi, where Xi is a vector of variables affecting both the audit programme participation and set of outcome variables (energy efficiency standards) according to the existing literature.

The standard problem of treatment evaluation involves the inference of a causal connection between the treatment and the intended outcome (Chirwa, 2010). To ensure that the conditioning covariate does not differ across the treatment and control groups, we conducted a balancing property test, and the results showed that this property is satisfied.

We estimate the propensity score based on the following logit choice model:

Prediction Model (first stage):

$$\mathrm{Logit}\ (\mathrm{P_i}(\mathrm{D_i} = 1) = \mathrm{a_0} + \mathrm{a_1}\mathrm{X_i} + \mathrm{e_i} \qquad (1)$$

The existing empirical literature has identified certain variables that can determine the propensity to conduct an energy audit. Structural variables including size, economic sector and location seem to be important (Aramyan et al., 2007; Schleich 2009; Trianni et al., 2013), as well as firms' characteristics, such as energy intensity and energy prices (Schleich, 2004; Cooremans 2011; Velthuijsen 1993; Nagesha and Balachandra, 2006). Studies have also identified relevant information such as the effort and orientation of firms in innovation (Rennings and Rammer, 2009; Horback et al., 2012), management strategy and the degree of internationalisation of the firm (Costa-Campi et al., 2015). Finally, studies based on multivariate models have considered, in addition to structural variables, aspects such as the characteristics of the market and the difficulties involved in obtaining financing for investment (Thollander et al., 2007; Fleiter et al., 2012; Trianni and Cagno 2012).

Equation (1) estimates the propensity score of the energy audit treatment. Observations are matched based on the propensity score, after imposing nearest-neighbour matching, where i represents each firm participated in EIBIS 2017; Xi is a set of three groups of relevant variables based on the existing literature: firm's characteristics (size, age, ownership, sector, location, etc.), market-related variables (policy instruments) and classic productive factors (energy intensity, energy prices, productivity, capital intensity, innovation).

Outcome Model (second stage):

$$\mathrm{Y_i} = \mathrm{b_0} + \mathrm{b_1 D_i} + \mathrm{b_2 F_i} + \mathrm{u_i} \qquad (2)$$

Next, we estimate the average treatment effect on the treated (ATT) on the matched sample using Equation (2), where Fi is a dummy that represents the finance-constrained firms; Yi denotes three relative questions about energy efficiency measures in the EIBIS 2018. The first question concerned the share of firms' investments in energy efficiency measures (Question 49 in EIBIS). Based on this information a dummy variable was constructed: this was set equal to 1 when the share of firms' investments in energy efficiency measures was above zero and equal to 0 otherwise. The second question related to the firms' support processes and asked respondents to specify the proportion of their commercial building stock that satisfies high or highest energy efficiency standards (Question 41 in EIBIS). The third question concerned the firms' production processes and asked respondents to specify the proportion of their machinery and equipment, including ICT, perceived to be state-of-the-art (Question 39 in EIBIS). For this study, higher quality of buildings and machinery indicates greater adoption of energy-efficiency measures, in case where the ATT of energy audits is positively correlated with the decision to invest in energy efficiency measures.

3.2 Data

To estimate the impact of energy audits on the adoption of energy efficiency measures of SMEs in Europe, we used the dataset of EIBIS in 2017 and 2018. This is an EU-wide survey of some 12 300 firms and includes information on investment activities for both SMEs (with between five and 250 employees) and larger firms (with more than 250 employees) with respect to their financing requirements and their obstacles to investment. In addition, the survey contains firm-specific information (such as size, firm autonomy, firm age, ownership, firm's main activity, innovation activity) and provides information about the firms that have conducted an energy audit.

Roughly one-tenth of these 12 300 firms in the original dataset had to be eliminated due to incomplete or missing data. To evaluate the impact of the energy audits, the analysis therefore focuses on those firms that provided information on the selected variables of interest i.e. energy audits, investment in energy efficiency and perceptions about the quality of buildings and machinery and equipment. This dataset was complemented by the Bureau van Dijk ORBIS and the ECFIN's datasets. The former offers information about the company's financial accounts, and the latter on real unit energy costs[1] across EU countries and economic sectors and the variables constructed based on the Commission's report with respect to energy intensity.

3.3 State-of-play of energy audits based on EIBIS

Data from the annual EIB Investment Survey (EIBIS) for 2017 and 2018 show that there are large differences in the energy audit participation rate across EU countries.[2] In both surveys, Croatia[3] had the highest participation rate in SMEs, a large difference from most EU countries. Its level accounted for 53%, almost five times higher than the implementation share in Estonia (11%), which had the lowest participation rate in Europe probably due to its belated transposition of Art. 8 of the EED into the national legislation. Most countries were evenly distributed around the average EU participation rate of 30%. Western European countries ranked above the EU average, while southern European countries and countries from the Baltics are placed below it.

Figure 1 Share of energy audits per size of firm

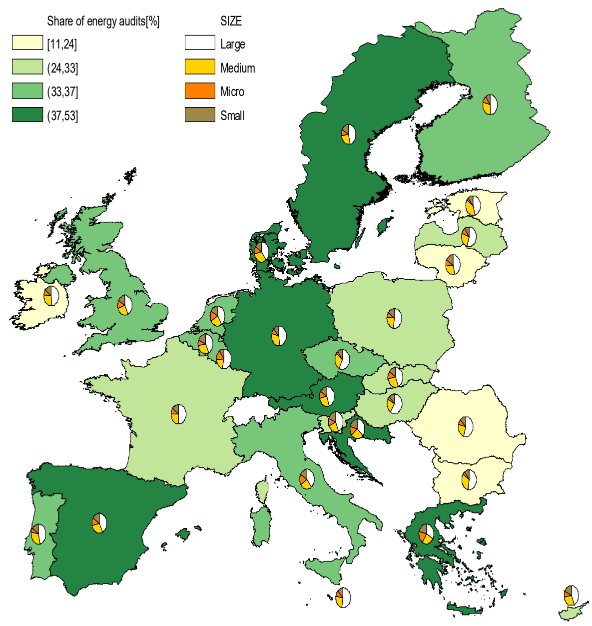
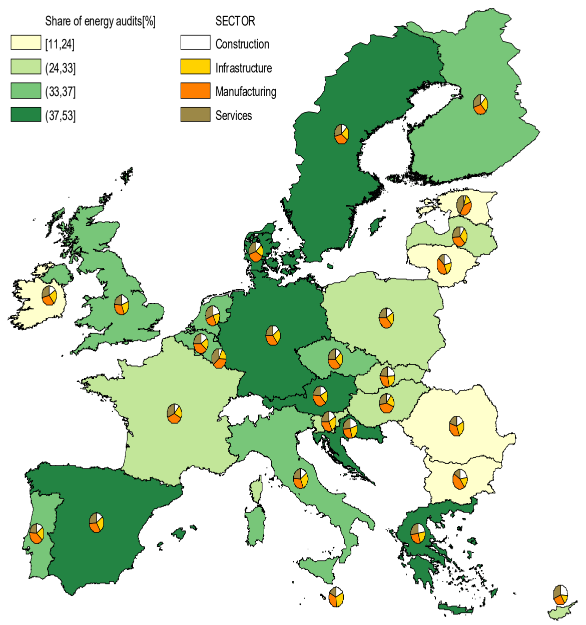


Figure 2 Share of energy audits per sector



Source: EIBIS 18.
Note: The participation rate per group of firms according to sector and size was normalised in order for the sum to equal to 100%.

There are even greater differences in the energy audit participation rate versus firm size. As expected, larger SMEs present higher average participation rates (40%) than smaller SMES (15%; micro firms).

[1]The energy intensity variable is winsorised at the 1st and 99th percentiles by NACE (Nomenclature des Activités économiques dans la Communauté Européenne) code two-digit classifications.

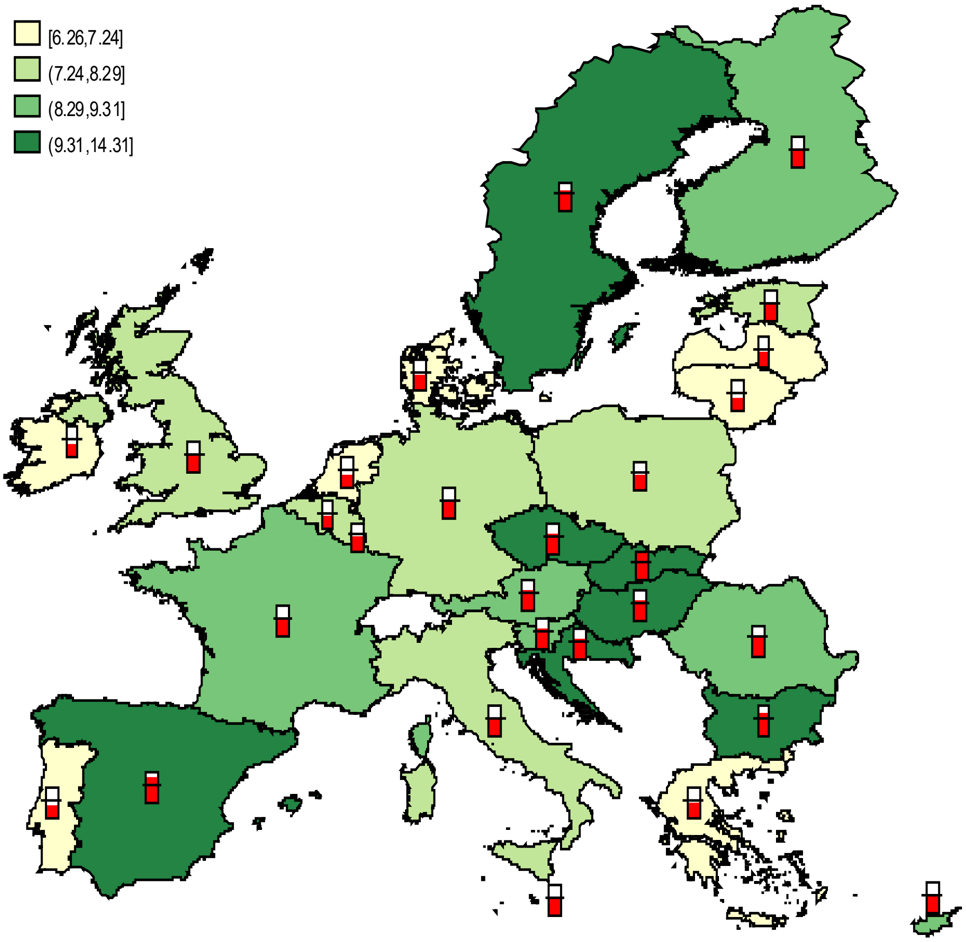
[2] More information about EIBIS can be found in the following link: http://www.eib.org/en/about/economic-research/surveys-data/investment-survey.htm

[3] Croatia promotes energy audits in SMEs by offering them financial support for energy-efficiency improvements and providing them with educational support. The financial support is granted by the program Investments and Environment Protection and Energy Efficiency Fund (EPEEF).

Significant dispersion close to 40% is also observed within the various size of firms (micro, small, medium) between the country with the lowest and the highest participation rate.

Differences in the participation rate still exist when one considers the sectorial dimension. According to the EIBIS 2017 and 2018, audit participation rates are higher in the manufacturing sector (42%), which is more energy intensive than any other economic sector. The services and infrastructure sectors follow, with 31% and 28%, whereas the construction sector is substantially far behind, with 20%. These average shares might also be driven by the energy profile and the size of the firms included in each sector. For instance, the construction sector sample includes the smallest share of large firms and the largest share of small firms and appears to be less energy-intensive activity.

Figure 3 Proportion of total investments for measures to improve energy efficiency (%)



Source: EIBIS 18.
Note: The box shows each country's mean level (red) in relation to the EU mean (horizontal line).

EIBIS 2018 data show that energy-efficiency investments are a small fraction of the firms' total investments. In 2018, the EU average proportion of total investments for measures to improve energy efficiency was around 8.6% (Figure 3). Firms in Slovakia represent the highest proportion in the EU with 14.3%, which is more than twice as large as the lowest proportion documented in Lithuania, with 6.3%. However, for most countries (24 out of 28) this proportion ranges from 7% to 11% and increases with firm size.

4 RESULTS

4.1 Determinants for conducting an energy audit

Figure 4 confirms that decisions to conclude an energy audit are driven by firm characteristics, market conditions and national policies for both large firms and SMEs.[4] Firm size, which has been the most commonly researched parameter (Aramyan et al., 2007; Schleich 2009; Trianni et al., 2013) is the most important factor in this process based on the dominance[5] analysis (Figure 5). In particular, the coefficient of size indicates that, as size increases, the propensity to conclude an energy audit increases (size effect). The relative importance of the energy cost in the production function could be among the main drivers of these decisions.

Sectoral differences are highly significant in determining whether a firm conducts an energy audit. Firms operating in the manufacturing and services sectors are more likely to conduct an energy audit than those in infrastructure and construction sectors, based on their estimated coefficients (the benchmark is the manufacturing sector). This result confirms previous empirical findings for many countries (Busom, 2003; Arvanitis et al., 2002; Almus and Czarnitzki, 2003; Czarnitzki et al., 2002), which indicate that certain sectors, most prominently energy-intensive ones, are willing to identify energy efficiency opportunities.[6]

Figure 4 Estimated coefficients of audit's participation[a]

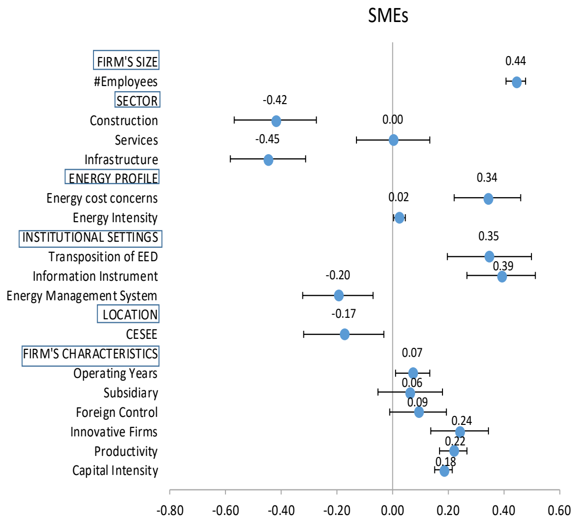
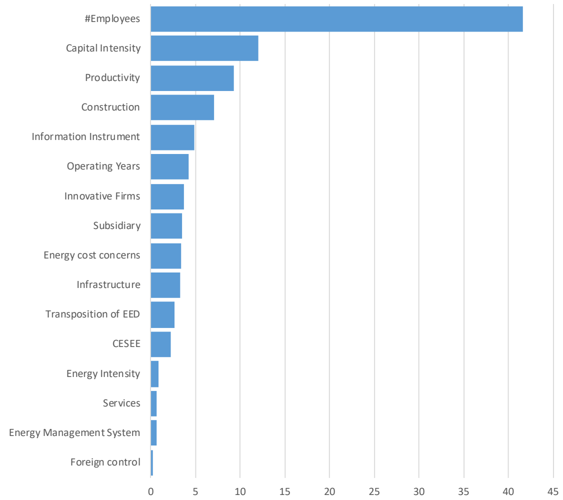


Figure 5 Dominance[b] analysis of estimated coefficients (%)



Source: Authors calculations.

Note: [a]Presentation of statistically significant coefficients; the intersection of the horizontal line with the vertical line indicates that the coefficient is not statistically significant at the 99% confidence interval.

[b]Ranking of estimated coefficients based on standardised weights, which are the general dominance weight from McFadden R^2[33] normed or standardised to be out of 100%.

[4]Several variables that influence energy audit decisions according to the existing literature, such as the internationalisation, financial constraints, regulations, etc., were excluded from the econometric analysis because they were statistically insignificant.

[5] Results are presented in the Appendix.

[6] Energy efficiency opportunities are defined as investments that are financially sustainable and require limited capital spending compared to other core-business investments.

Higher energy costs, productivity and capital intensity appear to be additional determining factors in energy audit participation. The analysis includes two variables to capture the energy cost effect: expectations about higher energy prices and energy intensity present positive coefficients. Similarly, positive coefficients document the degree of firm's productivity and capital intensity. Energy audits attract more attention in an organisation when high-energy prices force it to consider every possible means of cutting energy costs to stay competitive. Regardless of the magnitude of the energy costs relative to the value added (VA), increased energy costs negatively affect results and competitiveness within an industry, leading to lower production and, in some cases, a decision to relocate abroad. On the other hand, increased energy efficiency positively and directly affects a company's overall costs, often leading to greater productivity that in turn increases profits (Worrell et al., 2000).

Innovative[7] firms are also more likely to conclude an energy audit. This decision might be driven not only by financial and operational objectives, but also by strong environmental concerns. Most of them include in their production function elements of energy efficiency as a means of bridging the "energy-efficiency gap". For innovative firms, the information provided by the energy audit plays a crucial role in overcoming the existing numerous market failures and economic, organisational and behavioural obstacles (Backlund et al., 2012), especially when the energy audit identifies measures that offer great savings, require limited capital and are financially profitable.

The type of instruments Members States have established to promote energy audits affect the inclination to conduct an energy audit. Results indicate that the countries that transposed the Energy Efficiency Directive (EED) requirements into their national legislation the fastest have positively influenced firms' decisions to conduct an energy audit. Contrary to the literature, our results show that only the information[8] instruments have a positive and statistically significant impact on energy audit decisions. Investment-based incentives, such as tax breaks, subsidies and loans and regulations have the expected sign (positive), but they are not statistically significant. As expected, the introduction of an energy management system (negative coefficient) in some countries acts as a substitute for energy audits.

The likelihood of energy auditing are also linked to the quality of the firm's stock, location or ownership structure. The decision of firms is positively associated with the age of the capital stock. To proceed with an accurate refurbishment or replacement of any type of asset, it is crucial to conduct an energy audit in order to identify the energy savings potential of feasible interventions and their related costs. The probability of an energy audit is also higher for subsidiaries of multinational firms, likely driven by the parent company's effort to reduce costs. Finally, the results show that on average firms operating in the central, eastern and south-eastern European countries are less keen to conclude an energy audit, with the exception of Croatia.

4.2 The estimated effects of energy audits on energy-efficiency measures

Figure 6 confims that energy audits play a crucial role in the decision of firms to proceed with energy-efficiency improvements. In almost all cases (across sectors and size of firms), the point estimates of the average treatment effect on the treated (ATT) generated by the matching algorithm are positive

[7] Innovative firms are firms that have substantial R&D (R&D to sales ratio equal to or higher than 0.1%) and have introduced or developed products, processes or services that are new to the country or to the global market.

[8] Information instruments provide information on the energy use of firms and their opportunity to cut their energy consumption. An example of this type of instrument is the energy efficiency networks applied in Germany and in Sweden where firms exchange their experiences on energy efficiency.

and statistically significant. Based on the overall sample, the odds of investing in energy-efficiency measures are 1.5 times greater for firms with an energy audit (estimated coefficient is 0.38) than the odds for those without one and for innovative firms is even higher. This suggests that the energy audit is an effective tool for overcoming the information barriers to energy efficiency and facilitating the implementation of energy-efficiency measures in SMEs.

Figure 6 Estimated effects of energy audits on the probability of investing in energy-efficiency improvements (%)

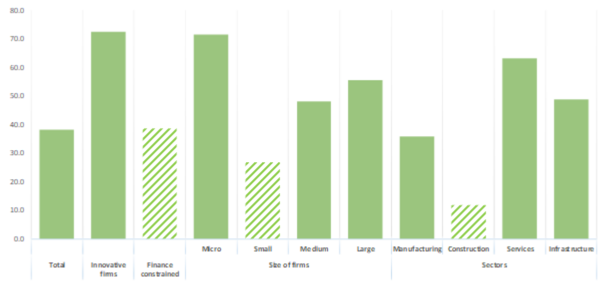


Figure 7 Estimated effects of energy audits on the quality of support processes (p.p.)

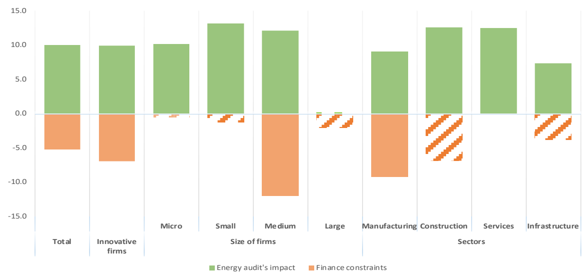
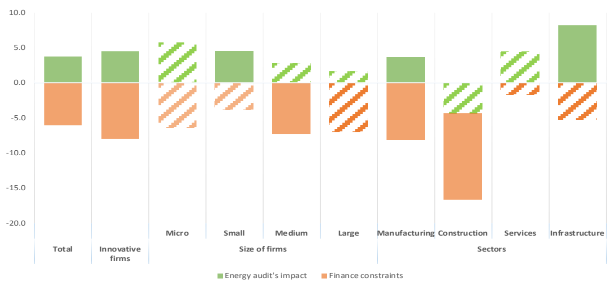


Figure 8 Estimated effects of energy audits on the quality of production processes (p.p.)



Source: Authors estimations.

Note: Pattern indicates that the coefficient is not statistically significant at p<0.1; Estimation results are included in the Appendix.

Given that, the energy audit positively influences firms' decisions to implement energy-efficiency measures, we investigate the impact of energy audits on the quality of buildings, and on machinery and equipment following the implementation of the energy audit.[9] The difference between the estimated effect of energy audits on the two processes ranges from 5p.p. for innovative firms to more than 10p.p. for medium-sized firms (Figure 7 and Figure 8). Generally, our results suggest that implementing an energy-efficient support process measure seems easier than implementing an energy-efficient production process measure. This is closely related to the discrepancy between operational and strategic actions and to the initial cost of investments. In capital-intensive sectors, capital expenditures that companies make for production purposes are substantially higher than those for support processes. In utilities, construction and manufacturing, for example, the replacement of machinery equipment costs several million euros, whereas the cost of changing the lighting as part of

[9] This is done by taking into account the information collected in EIBIS 2017 for energy audits, which reveals whether SMEs had an energy audit in the past three years and the information in EIBIS 2018 concerning the investment in energy efficiency and the perceptions of SMEs on the quality of their buildings and machinery equipment in 2018.

the adopted energy-efficiency strategy is much lower. In addition to this, firms may be unwilling to disrupt their production process by changing their machinery and equipment, especially when they are subject to quality control issues (e.g. automotive industry – suppliers need to have their machinery certified to be allowed to deliver products to the large car manufacturers, which is a long-lasting process). This is why companies prefer to invest more in the support processes than the production processes.

Another factor in the energy-efficiency investment type is the energy intensity of the production process. The lower the intensity, the greater the likelihood that less energy-intensive sectors, such as the construction sector, will adopt energy-efficiency measures for support processes. In non-energy intensive firms, 70% of energy is used in support processes, compared with energy-intensive firms, where this share is less than 50%. In addition, investment in support processes, such as lighting, ventilation and compressed air production, offers great potential for energy savings (European Commission, 2006), without affecting the firm's production line. This is confirmed by most energy audit programmes, which revealed that 60–90% of the measures implemented by industrial SMEs concern support processes (Thollander et al., 2007; Fleiter et al., 2012a).

Energy audits appear to be more beneficial for smaller firms. The estimated effect of energy audits on the decision to invest and subsequently on the quality of buildings' energy-efficiency standards and state-of-the-art machinery and equipment is positive and statistically significant for almost all firm sizes. This impact decreases with firm size, which indicates that energy audit information is more crucial for smaller SMEs than for larger SMEs. For larger SMEs, the information asymmetry might be lower, which is why they tend to have higher adoption rates than smaller SMEs, regardless of the existence of an energy audit. There are various reasons for this: economies of scale and availability of resources could be major drivers of investment in energy-efficiency measures; resources can be either technical or financial and affect both firms' information level and transaction costs, which have been identified as major factors in organisations' decisions to adopt energy-efficient technologies (Gruber and Brand, 1991; Schleich and Gruber, 2008; Schleich, 2009; Asensio and Delmas, 2017).

Finance constraints[10] are an important driver of a firm's decision to invest in energy-efficiency improvements and subsequently of the quality of support and production process, for some firm sizes and sectors. Findings suggest that finance-constrained firms that are micro-sized, innovative or belong to the manufacturing sector are associated with lower quality building energy-efficiency standards. Similarly, finance-constrained firms that are medium-sized, innovative or operate in the manufacturing

[10] A firm is considered to be finance constrained if one of the following four conditions is satisfied: 1) the firm sought a certain amount of financing but received (or was offered) a smaller amount (quantity constrained); 2) a firm sought external finance but did not obtain it (rejected); 3) a firm sought external finance but the cost of it was too high (price constraint); 4) a firm was discouraged from obtaining external finance due to the possibility of being rejected (discouraged).

or in the construction sector have lower state-of-the-art machinery and equipment standards. These characteristics drive the overall negative impact of financial constraints on the quality of both machinery equipment and buildings. In addition, the results show that the positive impact of energy audits on the implementation of energy-efficiency measures ceases to exist in the presence of financial constraints, especially for smaller firms and for the construction sector, which consists mainly of small firms. This indicates that not only information barriers but also financial constraints discourage firms from investing in energy-efficiency measures.

The impact of the energy audit differs across economic sectors. Results suggest that the industry and sector[11] the firm performs in has an effect on the adoption rate of the suggested energy-efficiency measures from energy audits. This impact is higher for firms in the manufacturing and services sectors, for which investing in energy-efficiency measures is almost twice as likely in the case of an energy audit. This is reflected in the higher quality standards of their buildings and to some extent in the quality of their machinery.

This heterogeneity across sectors could be driven by differences in the importance of the energy cost share in firms' turnover. There are two factors driving this cost share: energy intensity and the value of energy inputs. Energy intensity measures the energy consumption per unit of VA and differs substantially between economic activities. The higher the energy intensity, the greater the incentives for energy-intensive industries to adopt energy-efficiency measures (Schleich, 2004). For these organisations, energy efficiency is more likely to affect their competitiveness and to be of "strategic" importance (Cooremans, 2011). Similarly, higher energy prices result in higher energy costs and induce energy-intensive firms to focus more on energy efficiency, as they regard it as an important factor in their competitiveness. At the same time, higher energy prices improve the rate of return and shorten payback times for investments in energy efficiency, and thus they tend to be associated with higher adoption rates (Velthuijsen, 1993; Nagesha and Balachandra, 2006). By contrast, investing in a more energy-efficient technology may turn out to be unprofitable if energy prices fall after the new technology has been implemented. Hence, there is an option value associated with postponing investments (McDonal and Siegel, 1986; Dixit and Pindyck, 1984) and postponing irreversible investment 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).

Innovative firms are more likely to pursue improvements in energy-efficiency measures, taking advantage of energy audit information. Our findings indicate that innovative firms are twice as likely to invest in energy-efficiency improvements after an energy audit than such firms without an energy audit. This depicts why buildings and machinery and equipment are 10 p.p. and 5 p.p. higher for innovative firms with an energy audit, than without one. Rennings and Rammer (2009) give a number of reasons why innovative firms tend to introduce energy-efficiency improvements. These relate mainly to their financial and operational performance. For example, innovative firms aim for higher productivity rates, investing more in new technologies, using more sources of information and obtaining greater cost savings.

In addition to cost savings, innovative firms are more environmental friendly and attempt to reduce their carbon footprint as one of their production function objectives (Horbach et al., 2012). This effect might be more pronounced in larger companies because they tend to be more innovative, as they can

[11] To investigate the effect of the economic activity, firms were classified into four main sectors – Manufacturing, Construction, Services, and Infrastructure – based on the NACE (Nomenclature des Activités économiques dans les Communautées Européennes) classification of economic activities.

spread the risk of technology adoption across a larger portfolio and may more easily acquire external funding. EIBIS data indicate that SMEs can be considered to be more financially constrained than larger companies and that the former are twice as dissatisfied with the collateral required to secure external finance as the latter.

5 CONCLUSIONS AND POLICY IMPLICATIONS

In this study, we attempt to shed light on the role of energy audits in unleashing the energy efficiency potential in SMEs. Using a large dataset collected by the EIBIS in 2017 and 2018 for SMEs in the EU and we investigate the impact of energy audits on firm's decision to invest in energy-efficiency improvements in general and specifically in support and/or production processes. Our research methodology combines propensity scores and linear and non-linear regressions, by comparing SMEs that had an energy audit with a control group of firms with similar characteristics.

Our findings indicate that energy audits are the first step towards energy-efficiency improvements. They can help firms to assess their energy consumption, understand the potential for energy savings and suggest measures (investments or behavioural changes) to improve energy performance. Their objective is to provide tailor-made recommendations and help to overcome the information gap that is one of the main barriers to energy-efficiency investments. Specifically, our results indicate that this information is more crucial for small firms and for investments in support processes, on the condition that firms are not finance constrained.

Our empirical findings also point out that information campaigns appear to be useful instruments in incentivising energy audits, promoting investment in energy efficiency. To that end, Member States should promote programmes that raise awareness among firms about the potential benefits of energy audits. To further increase firms' motivation to conclude energy audits, Member States could subsidize their costs, especially when firms decide to proceed with energy-efficiency improvements following the results of the audit. In this process, governments should ensure that the quality of audits is maintained, by putting in place a control mechanism, such as random check or a central register (at least for subsidised audits).

However, our analysis underlines that access to CCM financing is important in promoting investments in energy-efficiency measures. Results indicate that the benefits of energy audits cease to exist when firms are finance constrained. This means that limited capital resources force firms to abandon or postpone energy-efficiency investments regardless of the benefits suggested by energy audits. Therefore, policymakers should turn their attention to small and medium-sized enterprises, enabling them to obtain easy access to CCM financing in order to make energy-efficiency investments more attractive and help unleashing the energy-efficiency untapped potential in SMEs.

6 APPENDIX

Table 1 Description of the variables and results from the Propensity Score Model (Equation 1)

Categories	Variables	Definition	Source	Model
Firm's Size	#Employees	Number of employees	EIBIS 2017	0.444*** [0.0269]
	Small	10 to 49 persons employed	EIBIS 2017	
	Medium	50 to 249 persons employed	EIBIS 2017	
	Large	250 or more persons employed	EIBIS 2017	
Sector	Construction	Dummy variable based on NACE classification, group F	EIBIS 2017	-0.422*** [0.0820]
	Services	Dummy variable based on NACE classification, groups G and I	EIBIS 2017	0.002 [0.0761]
	Infrastructure	Dummy variable based on NACE classification, groups D, E, H and J	EIBIS 2017	-0.449*** [0.0791]
Energy Profile	Energy cost concerns	Dummy variable; important factor = 1	EIBIS 2017	0.341*** [0.0672]
	Energy Intensity	Energy consumption over value added (EUR/Mbtu)	DG ECFIN	0.023** [0.0122]
Institutional Settings	Transposition of EED	Dummy variable based on transposition of EED	Commission	0.347*** [0.0879]
	Information Instrument	Dummy variable	Commission	0.390*** [0.0690]
	Energy Management System	Dummy variable	EIBIS 2017	-0.196*** [0.0713]
Location	CESEE	Dummy variable	EIBIS 2017	-0.175** [0.0818]
Firm's Characteristics	Operating Years	Number of operating years	EIBIS 2017	0.072** [0.0344]
	Subsidiary	Dummy variable; Subsidiary=1	EIBIS 2017	0.063 [0.0697]
	Foreign control	Dummy variable; foreign control above 50% = 1	EIBIS 2017	0.092* [0.0578]
	Innovative Firms	Dummy variable	EIBIS 2017	0.241*** [0.0592]
	Productivity	Log ratio sales to number of employees	EIBIS 2017, ORBIS	0.218*** [0.0287]
	Capital Intensity	Log ratio of assets to number of employees	EIBIS 2017, ORBIS	0.184*** [0.0178]
	Constant			-5.518*** [0.4222]
Observations				7,323
Pseudo R^2				9.60%
Sample				SMEs

Source: Author's calculations.
Note: Standard errors in parentheses; ***$p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2 Dominance analysis-importance of the predictors for concluding an energy audit

Categories	Variables	Model	
		Standardised weight	Rank
Firm's Size	#Employees	0.416	1
	Small		
	Medium		
	Large		
Sector	Construction	0.071	4
	Services	0.007	14
	Infrastructure	0.033	10
Energy Profile	Energy cost concerns	0.034	9
	Energy Intensity	0.009	13
Institutional Settings	Transposition of EED	0.026	11
	Information Instrument	0.048	5
	Energy Management System	0.006	15
Location	CESEE	0.022	12
Firm's Characteristics	Operating Years	0.042	6
	Mother company	0.035	8
	Foreign control	0.002	16
	Innovative Firms	0.037	7
	Productivity	0.093	3
	Capital Intensity	0.120	2
Sample		SMEs	

Source: Author's calculations.
Note: Standardised weight is the general dominance weight from McFadden R^{2}[33] normed or standardised to be out of 100%.

Table 3 Estimated effects of energy audits based on the Propensity Score Matching methodology (Equation 2)

	Effects on the decision to invest in energy efficiency improvements										
	Total	Innovative firms	Finance constrained	Size of firms				Sectors			
VARIABLES				Micro	Small	Medium	Large	Manufacturing	Construction	Services	Infrastructure
Energy audit's impact	0.382***	0.726***	0.386	0.716*	0.268	0.481***	0.556**	0.360**	0.119	0.633***	0.490**
	(0.0983)	(0.165)	(0.378)	(0.397)	(0.199)	(0.153)	(0.257)	(0.166)	(0.267)	(0.211)	(0.221)
Constant	-0.745*	-1.124*	0.540	-2.205*	-1.068	-0.295	2.046*	-1.437*	-1.299	0.282	-1.090
(Benchmark: AT)	(0.384)	(0.580)	(1.294)	(1.278)	(0.777)	(0.523)	(1.102)	(0.735)	(1.021)	(0.886)	(0.722)
Observations	1,904	717	176	177	535	807	350	676	310	479	417
Pseudo R^2	6%	7%	11%	11%	5%	5%	8%	6%	11%	11%	8%
Country effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sector effects	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
Size effects	YES	YES	YES	NO	NO	NO	NO	YES	YES	YES	YES

Source: Author's estimations.

Note: Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 4 Estimated effects of energy audits based on the Propensity Score Matching methodology (Equation 2)

Variables	Total	Innovative firms	Size of firms: Micro	Small	Medium	Large	Sectors: Manufacturing	Construction	Services	Infrastructure
	Effects on the quality of buildings that satisfy high energy efficiency standards									
Energy audit's impact	10.00***	9.920***	10.10**	13.16***	12.15***	0.171	9.024***	12.62***	12.53***	7.394**
	(1.468)	(2.500)	(5.070)	(2.953)	(2.334)	(3.293)	(2.381)	(3.941)	(3.015)	(3.281)
Finance constraints	-5.245**	-6.955*	-0.558	-1.184	-12.08***	-2.117	-9.184**	-6.863	-0.0901	-3.765
	(2.429)	(4.015)	(7.574)	(4.572)	(4.031)	(5.024)	(4.178)	(6.290)	(4.948)	(5.014)
Constant	46.50***	55.53***	55.92***	45.92***	48.12***	37.13***	40.91***	49.27***	50.51***	62.76***
(Benchmark: AT)	(5.513)	(8.412)	(16.84)	(12.43)	(7.981)	(8.345)	(8.837)	(16.18)	(11.25)	(12.01)
Observations	2,033	756	224	571	851	387	717	348	513	455
R-squared	13%	14%	30%	14%	15%	21%	18%	16%	15%	18%
Country effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sector effects	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
Size effects	YES	YES	NO	NO	NO	NO	YES	YES	YES	YES
	Effects on the quality of machinery and equipment									
Energy audit's impact	3.766***	4.560**	5.754	4.547*	2.817	1.696	3.637*	-4.367	4.486	8.229***
	(1.333)	(2.269)	(4.777)	(2.758)	(2.029)	(3.281)	(2.185)	(3.543)	(2.821)	(2.920)
Finance constraints	-6.050***	-7.963**	-6.337	-3.760	-7.294**	-6.948	-8.094**	-12.20**	-1.668	-5.199
	(2.192)	(3.656)	(6.790)	(4.242)	(3.500)	(5.043)	(3.812)	(5.654)	(4.646)	(4.398)
Constant	54.74***	52.88***	59.55***	62.07***	46.66***	61.06***	42.85***	65.30***	67.88***	58.17***
(Benchmark: AT)	(4.940)	(7.705)	(14.87)	(11.83)	(6.632)	(8.401)	(7.932)	(14.75)	(10.60)	(10.43)
Observations	2,092	778	233	593	868	398	740	357	521	474
R^2	16%	17%	24%	14%	20%	19%	16%	20%	20%	19%
Country effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sector effects	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
Size effects	YES	YES	NO	NO	NO	NO	YES	YES	YES	YES

Source: Author’s estimations.

Note: Standard errors in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

7 REFERENCES

Almus, M. and Czarnitzki, D. (2003). "The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany". *Journal of Business & Economic Statistics*, Volume 21(2), pp. 226–36.

Anderson, S.T. and Newell, R.G. (2004). "Information programs for technology adoption: the case of energy-efficiency audits". *Resource and Energy Economics,* Volume 26(1), pp. 27–50.

Arvanitis, S., Hollenstein, H. and Lenz, S. (2002). "The effectiveness of government promotion of advances manufacturing technologies (ATM): an economic analysis based on Swiss micro data". *Small Business Economics*, Volume 19, pp. 321–40.

Asensio, O.I. and Delmas, M.A. (2017). "The effectiveness of US energy efficiency building labels". *Nature Energy*, Volume 2, 17033.

Backlund, S., Thollander, P., Palm, J. and Ottosson, M. (2012). "Extending the energy efficiency gap". *Energy Policy*, Volume 51, pp. 392–6.

Basurko, O.C., Gabina, G., Uriondo, Z. (2013). "Energy performance of fishing vessels and potential savings". *Journal of Cleaner Production*, Volume 54, pp. 1–352.

Bertoldi, P. (2001). "Effective policies and measures in energy efficiency in end-use equipment and industrial processes". *In: Proceedings of the 2001 Workshop on Good Practices in Policies and Measurers.*

Brown, M.A. (2001). "Market failures and barriers as a basis for clean energy policies". *Energy Policy*, Volume 29, pp. 1197–207.

Busom, I. (2003). "Participation in R&D subsidy programme: who gets the money? The case of Spanish Manufacturing Firms". *WZB Economics Seminar Series*. Berlin.

Chirwa, T. G. (2010). "Program evaluation of agricultural input subsidies in Malawi using treatment effects: methods and practicability based on propensity scores". MPRA Paper No. 21236. http://mpra.ub.uni-muenchen.de/21236/.

Cooremans, C. (2011). "Make it strategic! Financial investment logic is not enough". *Energy Efficiency*, Volume 4 (4), pp. 473–92.

Costa-Campi, M.T., García-Quevedo, J. and Segarra., A. (2015). "Energy efficiency determinants: an empirical analysis of Spanish innovative firms". *Energy Policy,* Volume 83, pp. 229–39.

Czarnitzki, D., Ebersberger, B. and Fier, A. (2007). "The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany". *Journal of Applied Econometrics*, Volume 22, pp. 1347–66.

Dixit, A.K. and Pindyck, R.S. (1984). *Investment under uncertainty*. Princeton, N.J.: California, Columbia and Princeton University Presses.

European Environment Agency (2018). "Trends and projections in Europe 2018". Report No 16/2018.

European Commission (2016a). "A study on energy efficiency in enterprises: energy audits and energy management systems". Brussels: Directorate-General for Energy.

European Commission (2016b). “Impact assessment accompanying the document proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency.” EC SWD(2016) 405.

Eyre, N. (1997). “Barriers to energy efficiency: more than just market failure”. *Energy and Environment* Volume 8(1), pp. 25–43.

Fleiter, T., Gruber, E., Eichhammer, W., Worrell, E. (2012a). “The German energy audit program for firms: a cost-effective way to improve energy efficiency?”. *Energy Efficiency*, Volume 5(4), pp. 447–69.

Fleiter, T., Schleich, J., Ravivanpong, P. (2012b). “Adoption of energy-efficiency measures in SMEs: an empirical analysis based on energy audit data from Germany”. *Energy Policy*, Volume 51, pp. 863–75.

Gruber, E. and Brand, M. (1991). “Promoting energy conservation in small and medium sized companies”. *Energy Policy*, Volume 19(3), pp. 279–87.

Harris, J., Anderson, J., and Shafron, W. (2000). “Investment in energy efficiency: a survey of Australian firms”. *Energy Policy,* Volume 28(12), pp. 867–76.

Horbach, J., Rammer, C. and Rennings, K. (2012). “Determinants of eco-innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull”. *Ecological Economics*, Volume 78, pp.112-22.

Howarth, R.B. and Andersson, B. (1993). “Market barriers to energy efficiency”. *Energy Economics*, Volume 15, pp. 262–72.

IEA (2017a). “World energy investment 2017”. Paris: International Energy Agency.

Jaffe, A.B. and Stavins, R.N. (1994a). “Energy-efficiency investments and public policy”. *Energy Journal*, Volume 15(2), pp. 43–65.

Jaffe, A.B. and Stavins, R.N. (1994b). “The energy-efficiency gap: what does it mean?” *Energy Policy*, Volume 22 , pp. 804–10.

Moya, D., Torres, R. and Stegen, S. (2016). “Analysis of the Ecuadorian energy audit practices: a review of energy efficiency promotion”. *Renewable and Sustainable Energy Reviews*, Volume 62, pp. 289–96.

Nagesha, N., Balachandra, P. (2006). “Barriers to energy efficiency in small industry clusters: Multi-criteria-based prioritization using the analytic hierarchy process”. *Energy*, (31:12), pp. 1969-1983.

Nair, G., Gustavsson, L. and Mahapatra, K. (2010). “Factors influencing energy efficiency investments in existing Swedish residential buildings”. *Energy Policy,* Volume 38, pp. 2956–63.

Petek, J., Glavic, P. and Kostevsek, A. (2016). “Comprehensive approach to increase energy efficiency based on versatile industrial practices”. *Journal of Cleaner Production*, Volume 112, pp. 2813–21.

Rennings, K. and Rammer, C. (2009). “Increasing energy and resource efficiency through innovation: an explorative analysis using innovation survey data”. *Czech Journal of Economics and Finance*, Volume 59, pp. 442–59.

Roy, A. (1951) “Some thoughts on the distribution of earnings”. *Oxford Economic Papers*, Volume 3, pp. 135–45.

Rubin, D. (1974). “Estimating causal effects to treatments in randomized and non-randomized studies”. *Journal of Educational Psychology*, Volume 66, pp. 688–701.

Sardianou, E. (2008). “Barriers to industrial energy efficiency investments in Greece”. *Journal of Cleaner Production*, Volume 16, pp. 1416–23.

Schleich, J. (2004). “Do energy audits help reduce barriers to energy efficiency? An empirical analysis for Germany”. *International Journal of Energy Technology and Policy,* Volume 2(3), pp. 226–39.

Schleich, J. (2009). “Barriers to energy efficiency: a comparison across the German commercial and services sector”. *Ecological Economics*, Volume 68(7), pp. 2150–9.

Schleich, J. and Fleiter, T. (2017). “Effectiveness of energy audits in small business organiszations”. *Resource and Energy Economics*. Forthcoming. Available at: https://doi.org/10.1016/j.reseneeco.2017.08.002.

Schleich, J. and Gruber, E. (2008). “Beyond case studies: barriers to energy efficiency in commerce and the services sector”. *Energy Economics*, Volume 30(2), pp. 449–64.

Sorrell, S., Schleich, J., O'Malley, E. and Scott, S. (2004). *The economics of energy efficiency: barriers to cost-effective investment*. Cheltenham: Edward Elgar.

Stern, P.C. (1986). “Blind spots in policy analysis: what economics doesn’t say about energy use”. *Journal of Policy Analysis and Management*, Volume 5(2), pp. 200–27.

Thollander, P., and Palm, J. (2013). Improving energy efficiency in industrial energy systems: an interdisciplinary perspective on barriers, energy audits, energy management, policies and programs. Berlin: Springer.

Thollander, P., Ottosson, M. (2008). “An energy efficient Swedish pulp and paper industry: exploring barriers to and driving forces for cost-effective energy efficiency investments”. *Energy Efficiency*, Volume 1, pp. 21–34.

Thollander, P., Rohdin, P. and Danestig, M. (2007). “Energy policies for increased industrial energy efficiency: evaluation of a local energy programme for manufacturing SMEs”. *Energy Policy*, Volume 35(11), pp. 5774–83.

Tonn, B. and Martin, M. (2000). “Industrial energy efficiency decision making”. *Energy Policy,* Volume 28(12), pp. 831–43.

Trianni, A., Cagno, E. and Worrell, E. (2013). “Innovation and adoption of energy efficient technologies: an exploratory analysis of Italian primary metal manufacturing SMEs”. *Energy Policy*, Volume 61, pp. 430–40.

Van Soest, D.P. and Bulte, E.H. (2001). “Does the energy-efficiency paradox exist? Technological progress and uncertainty”. *Environmental and Resource Economics,* Volume 18, pp. 101–12.

Velthuijsen, J. (1993). “Incentives for investment in energy efficiency: an econometric evaluation and policy implications”. *Environmental and Resource Economics*, Volume 3(2), pp. 153–69.

Worrell, E., Laitner, J.A., Ruth, M. and Finman, H. (2003). “Productivity benefits of industrial energy efficiency measures”. *Energy*, Volume 28(11), pp. 1081–98.

Worrell, E., Martin, N. and Price, L. (2000). “Potentials for energy efficiency improvement in the US cement industry”. *Annual Review of Energy and the Environment,* Volume 26(1), pp. 303–29.

How energy audits promote SMEs' energy efficiency investment

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