Barriers to Increasing Energy Efficiency: Evidence from Small-and Medium-sized Enterprises in China

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Journal of Cleaner Production

Acknowledgements: The authors thank Marjan Stojiljkovic, Sarah Eaton, and Alexander Libman for their research support and incisive comments on earlier drafts. Furthermore we gratefully acknowledge funding from the Dr. Werner Jackstädt Foundation and the German Federal Ministry for the Environment within the International Climate Initiative under which the 'Climate Finance Innovation Facility'.

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Abstract – This paper analyzes financial, informational and organizational barriers to energy efficiency investments for small-and medium-sized enterprises (SMEs) in China. Its findings are based on a survey of 480 SMEs in Zhejiang province, and complemented by semi-structured interviews with enterprises contained in the survey sample. Responses reveal that only a minority of SMEs in China actively perform energy saving activities at a significant level. The survey data suggest, further, that informational barriers are the core bottleneck inhibiting energy efficiency improvements in China's SME sector. Financial and organizational barriers also influence a company's energy saving activities, with interview-based evidence stronger than statistical evidence. The interviews point out three additional barriers to energy saving activities: the role of family ownership structures, lax enforcement of government regulations and the absence of government support as well as a lack of skilled labour. More than 40% of enterprises in the sample declared themselves unaware of energy saving equipment or practices in their respective business area, indicating that there are high transaction costs for SMEs to gather, assess, and apply information about energy saving potentials and relevant technologies. One policy implication of the study is that the Chinese government could play a more active role in fostering the dissemination of energy-efficiency related information in the SME sector.

Keywords*:* energy efficiency, small and medium-sized enterprises, China, energy policies, information access, energy saving activity

1. Introduction

Energy security and the intelligent use of resources are important to China's continued, rapid development. China recently overtook the United States as the world's largest energy consumer (IEA, 2010) and, as China's citizens become wealthier, rising energy consumption has important implications for China and the world. Furthermore, in 2002, a trend of continuous energy efficiency improvements was reversed and China's energy intensity actually increased on average 5% per year during 2002-2005 (Price et al., 2011). China's energy intensity level now considerably exceeds the global average. [1]

In response to rising energy demand, China's central government has recently rolled out a series of ambitious energy savings programs. In its 11th Five-Year Plan (FYP), covering the period 2006-2010, China introduced energy intensity reduction targets, including setting the self-imposed goal of a 20% reduction in energy intensity against 2005 levels by 2010. As one of the core measures to meet this national target, the central government initiated the Top-1,000 Energy-Consuming Enterprises program in 2006. This program set energy savings targets for China's 1,000 most energy-consuming companies, which collectively account for about one-third of the country's energy consumption (Lewis, 2011).[2] The current 12th FYP (2011-2015) builds directly on the energy intensity target and associated programs outlined in the 11th FYP and includes a new national target to reduce

[1] Energy intensity is the energy consumption per unit GDP.
[2] For an overview of the national Top-1,000 Enterprise Program, see Price et al. (2010), Price et al. (2011), and Ke et al. (2012). For an overview of China's energy efficiency policies, see Kostka and Hobbs (2012, 2013), Li and Wang (2012), and Lo and Wang (2013).

energy intensity by an additional 16% by 2015. It has also broadened the scope of the Top-1,000 program to a Top-10,000 program. Under these recent energy savings programs, the largest and least efficient enterprises have already undertaken substantial efficiency improvements and smaller or more efficient enterprises are to be targeted in this second round. Current national programs and policies related to energy efficiency improvement in China need to broaden the scope beyond targeting larger, predominantly state-owned, enterprises. The same holds for the corresponding body of research literature. Previous studies analyzed barriers for large, state-owned enterprises to adopt energy-efficient measures (see for example, Price et al. 2010; Yang, 2010), yet, very little is known about what keeps private small-and-medium sized enterprises (SMEs) from improving energy efficiency.

There are several reasons why broadening our gaze to include private SMEs is worthwhile. First, China's 2.4 million SMEs make up 99% of all enterprises in contemporary China, accounting for more than half of all emissions and pollutants in the country (Teng et al., 2007). SMEs are typically less energy efficient than large enterprises (Cagno et al., 2010), implying a large energy-savings-potential in this segment of the economy. Second, existing research suggests that investment barriers vary systematically between large and small enterprises (Gruber and Brand, 1991). For one, financial barriers might be higher for SMEs as banks are biased in favour of larger enterprises and the investment does not pay back fast enough (Nagesha et al., 2006; Thollander et al., 2007). Furthermore, due to their size, SMEs typically have fewer technological options to save energy since their capital constraints are greater (Cagno et al., 2010). Additionally, in

comparison to larger enterprises, the smaller staff size of SMEs means that there is often less know-how of energy efficiency practices than in larger enterprises (Trianni and Cagno, 2012; Trianni et al., 2013). SME entrepreneurs often also perform multiple roles within a firm, and, as a result, no one single person is in charge of energy efficiency management such that only a limited amount of time is devoted to the cause of energy efficiency.

This paper takes a first step toward filling this research gap by analyzing barriers to energy efficiency investments for private SMEs in China. The objective of this study is to better understand factors driving the adoption of energy efficiency measures by private SMEs. We will study one province in depth and assess if and how financial, informational and organizational barriers for energy efficiency can be identified and vary across sectors. Based on survey data of 480 SMEs and a dozen semi-structured interviews conducted between 2010 and 2012 in Zhejiang Province, this study examines investments in the SME sector.

The paper is structured as follows: In the next section we review previous studies on barriers to energy efficiency investments globally in general and for SMEs in China specifically. The subsequent section discusses the methodology and data and is followed by the results and a discussion. We conclude by summarizing the key barriers for SMEs in China and offering possible policy implications.

2. Literature review

The literature has widely debated the energy 'efficiency paradox' (DeCanio, 1998), which refers to the puzzle of why business firms do not undertake energy-saving investments even though these investments would be cost-effective from the companies' economic perspective. Previous studies have identified a wide range of barriers to explain this paradox.[3] Barriers at the firm-level that hinder investments in cost-effective, energy efficient practices and technologies can be classified into the following three categories: financial, informational, and organizational barriers.[4]

Financial barriers include limited access to capital and lack of appropriate loan conditions and are often considered one of the most important investment obstacles (DeCanio, 1998; Fleiter et al., 2012; Trianni and Cagno, 2012). That is, firms do not undertake possible investments in energy efficiency improvements because they cannot access required investment capital at prices sufficiently low to offer sufficiently high returns. Typically, SMEs in China have limited access to credit, especially since the banking sector in China remains dominated by four large state-owned banks that devote less than 10% of loans to SMEs. Obtaining financing for energy efficiency is especially difficult for SMEs in China since no comprehensive credit certification system is in place to support SMEs' loan applications (Shen et al., 2012; Kostka and Shin, 2013).

[3] Barriers are defined hereafter as all factors that hamper the adoption of energy-efficient investments and technologies (Sorrell et al., 2004).

[4] Other barriers - often external to the company - discussed in the literature but not elaborated in detail in this paper include market barriers, policy barriers, technological barriers, uncertainty about future energy prices/economic uncertainty. For a more complete literature review on energy efficiency barriers, see Sorrell et al. (2004), Schleich and Gruber (2008), Sardianou (2008), Trianni and Cagno (2012) and Cagno et al. (2013).

Informational barriers refer to high transaction costs in the process of gathering, assessing and applying information about energy saving potentials and relevant technologies. Previous studies have shown that firms did not undertake cost-effective energy efficiency measures because managers are often unaware of pertinent technologies or because managers did not recognize the savings potential since they failed to measure energy consumption systematically (Harris et al., 2000). For example, Velthuijsen et al.'s (1993) study of 70 Dutch SMEs shows that many managers lack knowledge about energy efficiency measures, which explains why many profitable investment opportunities are not utilized by SMEs. Schleich and Gruber (2008) and Schleich (2009) also find that information barriers are significant for SMEs in Germany and conclude that SMEs' lack of information about energy consumption patterns is the main factor explaining low adoption rates of energy efficiency measures among SMEs.

Empirical analyses exploring the nature of barriers to energy efficiency also point out the importance of *organizational barriers*. For instance, DeCanio's (1998) analysis of the United States Environmental Protection Agency's Green Lights program shows that, besides financial factors, a mix of organizational and institutional factors strongly influence firms' investment behavior. Recent studies on manufacturing SMEs in the US (Muthulingam et al., 2011) and similarly in Northern Italy (Trianni and Cagno, 2012) also conclude that insufficient managerial attention to energy efficiency helps to explain low adoption rates of energy-efficiency measures among SMEs.

Turning to the analysis of energy efficiency in China, several studies provide additional insights. Predominantly large, mainly state-owned enterprises were analyzed to pinpoint

existing barriers at the firm level. Yang (2010), for example, examines one of the Top-1000 enterprises, a large footwear manufacturer in Guangdong Province. The in-depth analysis of one company shows that even large enterprises often lack knowledge about energy efficiency benchmark standards in their relevant sectors and may be ill-informed about energy savings techniques. The company also lacked clear managerial responsibilities in this area as there was no full-time professional in charge of energy efficiency. Zhao and Ortolano (2010) study one state-owned electric power generation plant and describe the difficulties large enterprises face in raising capital for energy conservation projects because local governments often prioritize economic development over energy conservation.

While these case studies of large, mainly state-owned enterprises are informative, the basis for generalizing in a statistical sense is lacking and they do not cover SMEs. This is a significant omission given that China's industrial SME sector is one of the main energy-consuming segments of the economy. For example, according to a recent study by the IFC (2012), industrial SMEs account for 41% of the total energy consumption, followed by non-industrial enterprises (29%) and large industrial enterprises (17%) (IFC, 2012: 20). The IFC report concludes that SMEs consume about 2.5 times the amount of energy in total as compared to large enterprises (IFC, 2012: 28). Despite the high total energy consumption among industrial SMEs, the topic of energy efficiency improvements in SMEs has received very little attention so far. Three recent surveys (Liu et al. 2012, 2013a, 2013b) have begun to fill this research gap. Based on a survey from 2010 with 141 industrial companies in Jiangsu Province, Liu et al. (2012) identified the energy management level of competitors and regular internal training of energy saving as

important determinants of companies' energy saving and suggest "extend[ing] the regulative requirements of energy saving of large companies […] to SMEs gradually" (2012: 88). In a second survey from 2011 with 121 SMEs in Jiangsu, Liu et al. (2013a) show that the awareness of market-based energy-saving instruments increases with the education level of employees. The third survey is based on a sample of 171 SMEs in the iron and steel, cement, and chemical industries in two provinces (Shandong and Shanxi) and finds that awareness about energy saving technologies and knowledge about market-based instruments for energy savings increase with firm size (Liu et al. 2013b). Based on these three important studies, one can conclude that pressures from business competitors, frequent internal training, and high levels of information/education of employees increases energy saving activities in the SME segment.

The literature points to two additional barriers to energy efficiency investments for SMEs in China. With an average life expectancy of only 3.7 years, the planning horizons of Chinese SMEs are shorter as compared to their counterparts in Europe or the US; the average lifespan of an SME in the US and Europe is estimated to be around 8.2 years and 12.5 years respectively (Every China, 2011). The short lifetime of Chinese SMEs is partly attributed to enterprises' high-risk taking behavior as well as institutional barriers, such as restricted access to finance. Short lifespans are a disincentive to investing in energy saving equipment since the pay-back time might be much longer than the expected existence of the SME. Moreover, capped electricity prices in China discourage investments in energy efficient equipment, distorting SMEs' annual energy cost as share of total production. These two barriers are especially important since Cooremans (2011) and Harris et al.

(2000) note that most companies use payback time as a key investment decision criterion. This might be one reason, why, for example, the provincial government in Zhejiang has imposed punitive power prices on businesses that exceed certain consumption limits (Bloomberg, 2011).

Our paper builds upon and expands on these earlier studies in a number of ways. The existing surveys examine investment behavior of SMEs in Jiangsu, Shandong, and Shanxi Provinces, but "companies based in different places may behave quite differently" (Liu et al., 2013a: 11). By studying SMEs' energy saving activities in two municipalities in Zhejiang Province – Wenzhou and Taizhou – the findings of our study sheds light on another region. In addition, the three surveys are based on a very broad definition of SMEs, mixing together larger enterprises with annual turnover of 300 million RMB (37 million EUR) and more than 2,000 employees with smaller enterprises with an annual turnover of below 30 million RMB (3.7 million EUR) and less than 300 employees.[5] The survey conducted in Shandong and Shanxi (Liu et al. 2013b), for instance, includes 70 small enterprises and 97 medium and large enterprises with private, mixed, and state-owned firm ownership, which makes it difficult to differentiate barriers specifically relevant to smaller enterprises. Yet, since private SMEs in China are less well connected than state-owned enterprises, one would expect private SMEs to face quite different investment obstacles. Our analysis adds these additional issues to the body of literature by focusing only on 480 privately-owned small and micro firms with less than 300 employees.

[5] One RMB is equivalent to approximately 0.16 USD (conversion date as of September 2012). 100 Million RMB are equal to approximately 16 million USD.

3. Analytical framework and methodology

We examine the barriers to adopting energy-saving technologies and equipment for privately owned Chinese SMEs. Our hypotheses are derived from three themes highlighted in the literature – financial, informational and organizational barriers:

H1 - Financial barriers: Financial factors (e.g. access to bank loans) hamper the adoption of energy-efficient investments and technologies.

H2 - Informational barriers: Relevant information that could be used to gather, assess, and apply know-how about energy saving potentials and relevant technologies is lacking or insufficient.

H3 - Organizational barriers: Small and medium-sized firms that lack clear management responsibilities for energy efficiency show less investment activity in energy-efficient practices and technologies.

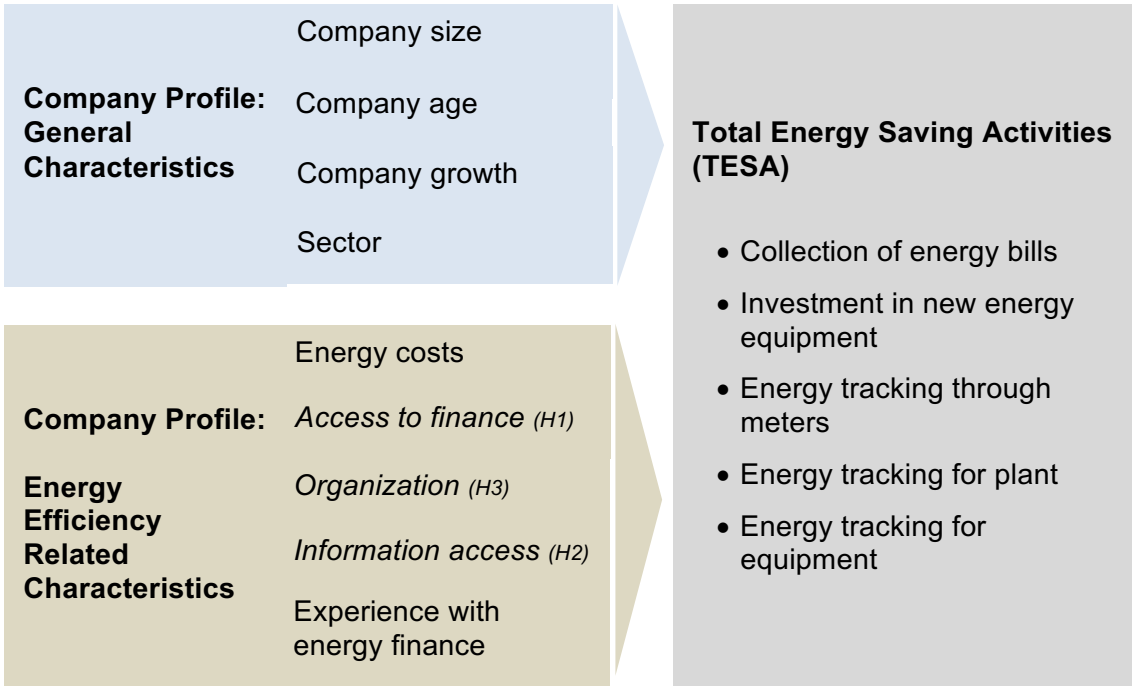

Fig. 1. Analytical framework

In order to test our hypotheses and to analyze the barriers to energy efficiency within SMEs in the respective region we apply a 'nested analysis' (Lieberman, 2005), whereby the statistical analysis of a large survey is combined with the in-depth investigation of a few company cases contained within the survey sample. In a first step we conduct a standard econometric analysis based on survey data. As illustrated in Figure 1, we assume that energy saving activities (ESA) of a given SME may, to a large extent, be driven by a number of general characteristics of a firm such as its size, growth, sector or age. On top of that we include other company profile characteristics more closely related to energy efficiency. These factors include the energy costs of the firm, access to loans in general,

access to information related to energy efficiency, organizational issues related to energy efficiency and previous experience with energy efficiency finance.

In a second step, we take a closer look at some of the more qualitative aspects of the survey such as sources of information or sources of finance. The resulting picture is finally complemented by a small number of personal in-depth case interviews among the survey participants. Combining survey analysis with interview data adds to our understanding of relationships between particular investment barriers and SMEs' investment behavior. Interviews with firm owners and managers pointed out additional relevant explanatory variables not considered in the survey. For example, interviews revealed that some small, family-owned companies are managed by multiple family members with different investment priorities. This fragmentation in firm leadership can delay or hinder investments in energy saving technologies, something that did not emerge as a finding from the survey analysis. The data is based on questionnaires completed in September 2010 and interviews conducted in February 2012 in Zhejiang Province. We will now provide a brief overview of the business environment for SMEs in Zhejiang Province and then present the survey and interview data.

3.1 Regional focus: Taizhou and Wenzhou

Zhejiang is located in the southern part of the Yangtze River Delta on the south-east cost of China. The total area of Zhejiang is 101,800 square kilometers and 70% of it is made up of hilly terrain. The province has a large number of bays with over 60 natural ports of

different sizes, among which the ports in Ningbo, Wenzhou, Zhoushan, Jiaxing, and Taizhou are the most important. The province is well known as the cradle for private SMEs in China. In Zhejiang alone, there are more than 500 industrial clusters, each of which has gross industrial output of over 100 million RMB (Zhejiang Government Website, 2012).

Within Zhejiang, we focused on SMEs in Wenzhou and Taizhou, since the majority of industrial enterprises center in these two municipal cities. Wenzhou's private-sector driven development path has become known as the 'Wenzhou Model' (*Wenzhou moshi*). By 2010, Wenzhou was home to over 4,300 enterprises in the shoe and leather products industries, 1,200 enterprises manufacturing low voltage electrical equipment, and 1300 enterprises engaged in light manufacturing (Zhejiang Government Website, 2012). Similarly, Taizhou is a newly developed harbor city with a total land area of 9,411 square kilometers. Taizhou is also home to many small private SMEs that have established production facilities in automobiles and automobile components, motorcycles, plastics, chemicals, home appliances, and textiles.

Fig. 2. Geographic Location of Taizhou and Wenzhou, Zhejiang Province.

3.2 Survey questionnaire and sample

The survey was administered with the help of a local bank in the Taizhou and Wenzhou area.

(1) First, together with bank officers, we discussed and determined the relevant sectoral classification, based on the so-called pillar-industries and products in Taizhou. Following from this analysis, we focused on SMEs in the following sectors: manufacturing, transport vehicles and specialized equipment, non-ferrous, specialized equipment manufacturing, glass or art manufacturing, toy production, general equipment manufacturing, and others.

(2) In order to ensure coverage of all relevant sectors in the region, 50 bank officers were selected to conduct interview-based questionnaires. With the help of the bank officers, we randomly selected 500 out of thousands of enterprises in the bank's database, i.e., 10 enterprises for each bank officer.

(3) The bank officers received classroom-style training to ensure a common understanding of the survey questions and a common standard for distribution of the questionnaire. Bank officers then completed the questionnaires using face-to-face interviews with one manager from the preselected small or medium-sized local enterprise. The questionnaire included 47 questions related to an enterprise's business and perceived core barriers to energy efficiency: type of business; company size; number of employees; years in business; energy cost as a percentage

of total costs; main usage of energy; presence or not of an energy manager; existing awareness of energy-saving measures and equipment; age of existing equipment; existing energy saving projects; future energy saving projects; financing; access to loans, amongst others.

(4) Of the 500 preselected companies, 480 Chinese SMEs completed the interview-based survey. The response rate was 96% as almost all selected firms accepted the interview invitation by bank officers. We used the STATA statistics package to analyze the questionnaire data.

The 480 industrial SMEs cover these sectors: metal manufacturing (20%), transport vehicles and specialized equipment (9%), non-ferrous (7%), specialized equipment manufacturing (3%), glass or art manufacturing (10%), toy production (12%), general equipment manufacturing (9%), and others (30%). Among the surveyed firms, the number of employees ranged from 1 to 300 employees, with an average of 28 employees. Revenue intake ranged from 81,000 RMB (10,000 EUR) to 100 million RMB (12 million EUR). Figures 3 and 4 display the distribution of revenues and the number of employees across our sample. They demonstrate that the majority of the firms rate as small on both measures; 70% have revenues below one million RMB and more than 75% of the enterprises have less than 30 employees. Following Trianni and Cagno's (2012) division of SMEs into Small Enterprises (SEs, 10 to 49 employees), Medium Enterprises (MEs, 50 to 90 employees), and Medium-Large Enterprises (MLEs, 100 to 249 employees), the majority of our sample (60%) belongs to the SE

category. Our analysis therefore has a focus on small and even micro firms rather than medium-sized enterprises. In any case, the vast majority of the firms are compatible with almost any of the common definitions of an SME, including definitions by China's National Development and Reform Commission and the European Union.[6]

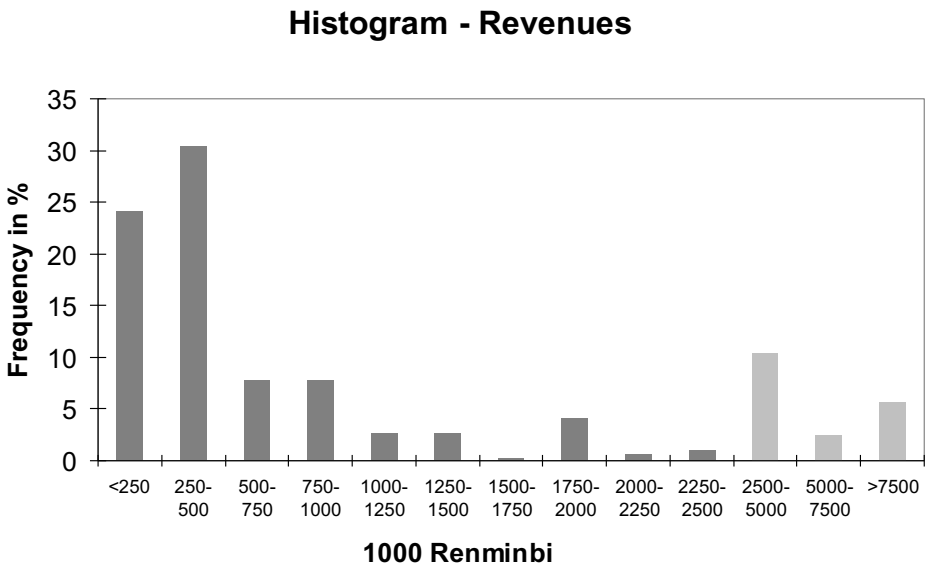

Fig 3. Distribution of the firms' revenues across the sample (N=480).

[6] The EU classification system defines SMEs as enterprises with revenues up to 50 million EUR (or 400 million RMB) and with a workforce up to 250 employees. According to China's National Development and Reform Commission, an industrial small enterprise is an enterprise with 300 employees, annual revenues below 30 million RMB, and registered capital of 40 million RMB. A medium-sized enterprise is an enterprise with between 300 and 2000 employees; annual revenues between 30 and 300 million RMB, and registered capital between 40 and 400 million RMB.

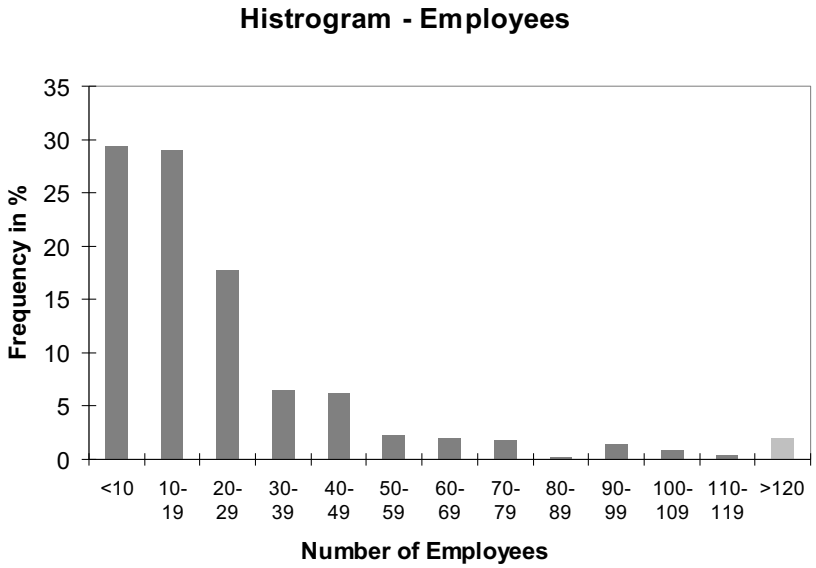

Fig. 4. Distribution of the number of employees across the sample (N=480).

Since the literature has identified the short life-expectancy of SMEs in China and capped electricity prices as important barriers to energy efficiency investments, we examined the relevance of both barriers for our sample firms. Figure 5 shows that 40% of the firms are older than five years and almost 30% are older than 10 years. Given that the majority of all firms in our sample are above the average SME life-expectancy of 3.7 years, we expect the short life-expectancy effects to be rather small in our sample. Figure 5 further demonstrates the importance of energy in the firms' total production costs: in nearly 50% of all firms, energy accounts for more than 5% of the total production costs. For about 20% of SMEs, energy makes up more than 10% of the production costs. The results show that, while energy is subsidized in Zhejiang province, energy certainly represents an important part of the total production costs.

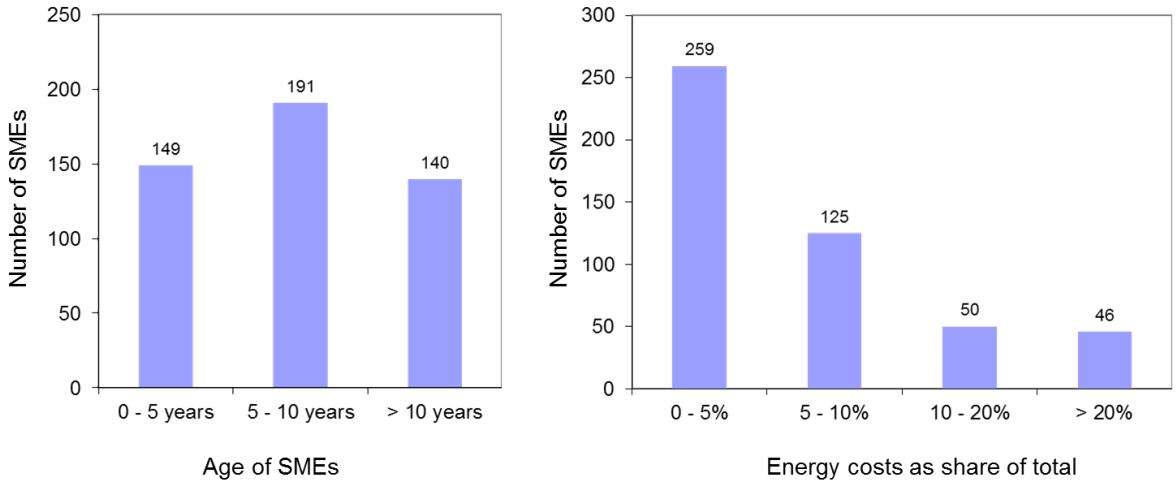

Fig. 5. Age distribution of the surveyed SME and energy costs as share of total production costs across the sample (N=480).

3.3 Data analysis

To empirically assess to what extent firms have adopted energy saving activities and practices in the past, standard OLS models were estimated. Similar to the work of Liu et al. (2012) and Suk et al. (2013), as our dependent variable we constructed a proxy measuring a company's total energy saving activities (TESA), where 1 indicates that a company has previously introduced and employed a wide range of energy efficiency promoting activities, and 0 indicates that it did not. A company's TESA-value is determined as the normalized sum of simple dummies indicating whether specific activities are performed. Table 1 displays the individual energy saving activities (ESA) of which the TESA is composed.

Table 1
Individual energy saving activities (ESA) as dummies. Dependent Variable: Total Energy Saving Activities (TESA) is determined as the normalized sum of the dummies (Max. value = 1).

Item	Proxy	Description	Valuation
ESA 1	**Investment in energy equipment**	Measures if a company has previously invested in energy efficiency equipment: if yes = 1; if no = 0	0 or 1
ESA 2	**Metering**	Measures if SME has more than one electricity meter installed. (yes: 1; no: 0)	0 or 1
ESA 3	**Energy bills**	Measures if SME is keeping past 3 years energy/ electricity bills. (yes: 1; no or missing some: 0)	0 or 1
ESA 4	**Indicator premises**	Measures if SME have an indicator to measure energy efficiency in the plant premises. (yes: 1; no: 0)	0 or 1
ESA 5	**Indicator equipment**	Measures if SME have an indicator to measure energy efficiency in the equipment. (yes: 1; no: 0)	0 or 1

The analysis shows that only 21% of surveyed enterprises have installed energy efficient equipment in their premises to date. Figure 6 displays the distribution of the TESA score (before normalization to 1) across the whole survey.

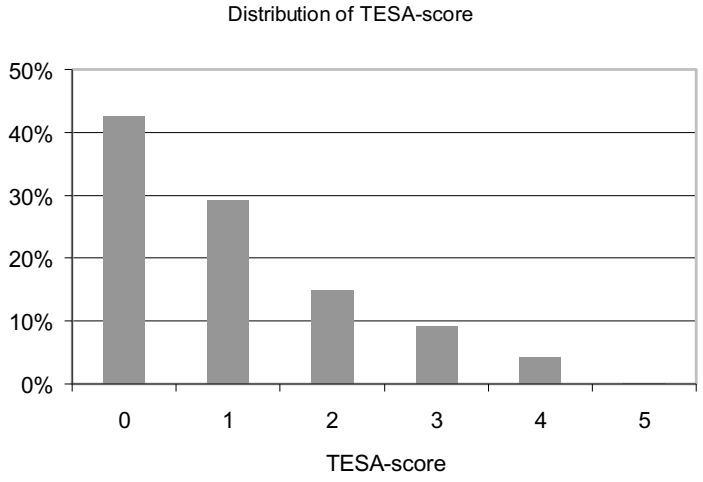

Fig. 6. Distribution of the TESA score across the survey sample (N=480).

Figure 6 above reveals that more than 40% of the SMEs are performing none of the selected energy saving activities. Roughly 30% perform at least one of the activities and

just one survey participant claims to be engaged in all five energy saving activities. In order to identify the relevant drivers of the total level of energy saving activities we estimate a simple OLS model of the form

$$TESA = const + \beta_1 \cdot LOANFIN + \beta_2 \cdot INFORM + \beta_3 \cdot ORG + \beta_4 \cdot SIZE + \beta_5 \cdot GROWTH + \beta_6 \cdot AGE + \beta_7 \cdot SECTOR + \beta_8 \cdot ENERGYCOST + \beta_9 \cdot ENERGYLOAN + \varepsilon$$

where Table 2 summarizes the selected dependent and independent variables.

Table 2
Dependent and independent variables.

	Proxy	Description	Expected sign
Total energy efficiency activities	*TESA*	Measures a company's energy saving activities: score of 1= high level of energy saving practices; a score of = 0 = lo level of energy saving practices	Dependent variable
Access to finance	*LOANFIN*	Measures how whether a company typically finances existing machineries & facilities with a bank loan, if yes= 1 (loan); if no = 0 (other)	+
Access to information	*INFORM*	Measures if business manager is familiar with latest energy efficiency practices/equipments in their respective business area, if yes= 1; if no = 0	+
Organization	*ORG*	Measures if SME has appointed an energy manager, if yes= 1; if no = 0	+
Company size	*SIZEREV*	Actual amount of revenues in RMB	+
Company growth	*GROWTH*	Measures if a company plans to expand current capacities in the new future	+
Company age	*AGE*	Measures age of a company. If older than 10 years=1, else: 0.	-
Sector	*SECTOR*	Measures if company is in capital-intensive or labour intensive industry. If capital intensive =1, if labour intensive=0,	+
Energy costs	*ENERGYCOST*	Measures the share of energy costs relative to total production costs. 0-5%: 0; 5-10%: 1; 10-20%: 2; >20%: 3.	+
Access to energy finance	*ENERGYLOAN*	Measures if a company has previously received a bank loan for energy efficiency improvements, if yes= 1; if no = 0	+

4. Statistical analysis

The estimation results for our OLS model are shown in *Table 3*. The first column displays an estimation using all characteristics, the second and third column leave out the explanatory variable reflecting experience with energy loans in the past or the variable reflecting the energy intensity of the sector. To test whether a correlation between previous access to energy finance (ENERGYLOAN) or sector-specific characteristics (SECTOR) with the finance-access (LOANFIN) is driving the insignificance of the latter we run three regression scenarios for each model: the regressions with all variables (column 1) but also without SECTOR and ENERGYLOAN, (columns 2 and 3, respectively).

Results are fairly robust across the scenarios and provide strong support to *Hypothesis 2* (information barriers). In other words, the lack of information about energy saving technologies and practices – as captured by the variable INFORM – constitutes a statistically significant barrier. This finding is in line with previous studies that identified lack of information as a key variable to explain energy efficiency investments in SMEs in Germany (Gruber and Brand, 1991; Schleich and Gruber, 2008) and in Italy (Trianni and Cagno, 2012).

Support of *Hypotheses 1* (financial barriers) and *3* (organizational barriers) based on the dataset is less strong. Access to loan finance – captured by the variable FINANCE, which measures whether the SME typically finances equipment and machinery through bank loans or via other sources—is significant at the 5% level in the scenario including all variables and near significance at that level in the other scenarios. When examining the

impact of access to loans based on this dataset it is worth keeping in mind that the enterprises for the survey were selected from a bank's database, i.e. they typically have already been customers of a bank in the past, implying that they most likely represent a group with better access to loan finance. Still, a closer look at the raw data reveals that 46% of SMEs typically uses 'cash accruals' and 15% uses 'own funds' to finance existing equipment. This seems typical for Chinese private SMEs (Tsai, 2002). Statistical support for *Hypothesis 3* (organizational barriers – captured by the variable ORG) is mixed: in one of the three scenarios the variable reflecting whether the firm has appointed an energy manager is statistically significant at the 5%-level but is insignificant in the other two scenarios. The second part of our analysis examines the puzzling results on information and finance and organizational barriers by taking a closer look at responses to the qualitative questions in the survey and the semi-structured interviews.

Table 3
OLS Regression Results.

	(1) **all variables**	**(2)** **w/o loan-access**	**(3)** **without sector**
H1: LOANFIN	0.047	0.039	0.043
	(2.10)*	(1.74)	(1.94)
H2: INFORM	0.069	0.081	0.076
	(3.32)**	(3.86)**	(3.67)**
H3: ORG	0.078	0.106	0.083
	(1.41)	(1.99)*	(1.53)
SIZEREV	$3.29*10^{-7}$	$3.22*10^{-7}$	$2.94*10^{-7}$
	(2.53)*	(2.40)*	(2.31)*
GROWTH	0.045	0.051	0.049
	(2.20)*	(2.48)*	(2.37)*
AGE	0.025	0.022	0.027
	(1.11)	(0.95)	(1.19)
SECTOR	0.052	0.061	

	(2.52)*	(2.94)**	
ENERGYCOST	0.043	0.041	0.045
	(4.21)**	(4.05)**	(4.29)**
ENERGYLOAN	0.252		0.263
	(3.97)**		(4.08)**
Constant	0.037	0.035	0.062
	(1.74)	(1.67)	(3.23)**
Observations	480	480	480
R-squared	0.19	0.15	0.18

Note: Robust z statistics in parentheses, * significant at 5%; ** significant at 1%

The parameters associated with an enterprise's revenue size (SIZREV) or with its growth ambitions (GROWTH) are both found to be statistically significant in explaining the level of energy saving activities of a company. This confirms findings from previous studies (Schleich, 2009) and stands to reason, since larger and growing firms will typically be investing more in general. As well, larger firms might also be more concerned with rising energy prices or applying state of the art technology.

Likewise, the parameter associated with energy costs (ENERGYCOST) was found to be statistically significant, which is consistent with findings from previous studies (e.g., Schleicher and Gruber, 2008; Schleich, 2009; Fleiter et al., 2012). This also suggests that for the case of Zhejiang province the barrier due to capped (and artificially low) energy prices is less relevant. Again, this is unsurprising since higher energy costs introduce an immediate incentive to care about reducing energy use and invest accordingly. The question about whether or not a company had previously accessed energy finance

(ENERGYLOAN) is also plausibly significant. Signs and significances are robust across these scenarios.

5. Qualitative analysis: survey and interviews

To round out the findings from statistical analysis of our three hypotheses, we now examine qualitative aspects of the survey and provide additional materials from our semi-structured interviews to highlight specific issues that are hard to capture through quantitative data. In the following, we distinguish between four core business categories – metal manufacturing, transport vehicles and equipment, art and glass manufacturing, and toys production – to assess if and how financial, informational, and organizational barriers vary across sectors.[7] While the (not-normalized) TESA score varies substantially, we find different average scores across the core business categories. TESA scores ranked highest for toys production (1.4), second highest for metal manufacturing (1.3), followed by transport vehicles and equipment (1.2) and arts, glass and other manufacturing (1.0). As the subsequent analysis shows, SMEs in the core business categories face individual financial, informational, and organizational barriers.

5.1 Financial barriers

[7] These categories are based on common core business activities of selected firms in the sample, which largely mirrors enterprise clusters found in the Taizhou-Wenzhou area or some of their so-called pillar industries.

We first turn to the sources of finance. Access to loans is often a prerequisite for energy efficiency investments (DeCanio, 1998). For SMEs in China, however, loans are frequently not the typical source of financing (Shen et al., 2012). Across our sample, less than a third (32%) of all the companies regard loans as their typical source of funding. The majority (48%) is using so-called 'cash accruals' (similar to equity) and about 14% use 'own funds' as the major source, i.e. they are waiting to accumulate profits and re-inject them into their business. Figure 7 illustrates that typical sources of funding differ substantially across core business categories. While half of SMEs (50%) producing toy products use bank loans as a major source of funding, in metal manufacturing only slightly more than a quarter of the companies (28%) typically use bank loans.

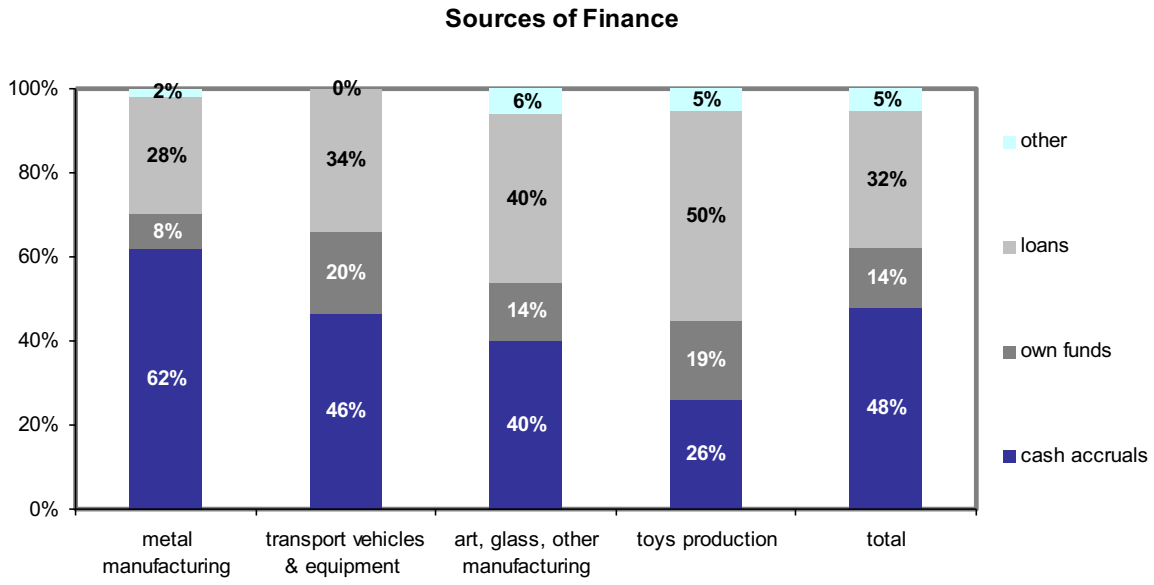

Fig. 7. Major sources of finance across core business categories.

The higher share of loans provided to SMEs in the toy producing sector is partly because it is the only sector in both Taizhou and Wenzhou that is identified as a strategic

'pillar industry' (*zhizhu chanye*).[8] Enterprises in designated pillar industries usually have easier access to bank loans as local government and bank officials are eager to cultivate these particular sectors.

Interviews revealed that the majority of SME owners and managers perceive access to bank loans as extremely difficult as "banks are more willing to give loans to larger companies" (INT1_220212). In addition, for many bank officers, when evaluating loan applications, it is difficult to assess and verify the project value based on the amount of energy saved. However, with local commercial banks such as the Bank of Taizhou, Huishang Bank in Anhui, and Bank of Chongqing starting to devise new 'green loan' programs, this skepticism might change overtime. For example, at the Bank of Taizhou, Zhejiang, the starting phase of a new green loan program already shows substantial lending activity; in the initial implementation period during 2010 until 2012, 27 SMEs were provided with energy efficiency loans of a total volume of more than 3 million USD, suggesting that Bank of Taizhou's new product is attractive to the customers (INT12_240912). The few SMEs that were able to secure a bank loan under the new SME energy efficiency lending programme had usually received loans between 0.5 – 1.5 million RMB, but 10% to 30% of the financing had to come from their own sources. This initial first investment is, however, quite difficult for many smaller enterprises. An electric motor engine company, for instance, complained that they "would like to invest in automatic

[8] In Taizhou, the 10 pillar industries include automobiles, motorcycles & toys, plastic and mould, pharmaceutical products & chemical industry, household appliances, clothing machinery, valves & water pumps, handicrafts, and shoes, hats & garments (Zhejiang Government Website, 2012). Note that Taizhou does not list metal manufacturing or transport equipment as pillar industries. In Wenzhou, the 10 pillar industries include electrical machinery, leather products, general equipment, power supply, plastic manufacturing, textile and garment, transport equipment, chemical products, metal products and metal processing (Wenzhou Government Website, 2012)

winding machines but cannot afford to finance initial investment costs" (INT2_240212). In addition, bank loans were usually short-term loans with repayment ranging from 1 to 1.5 years, a too-brief period for many SMEs and one that is often misaligned with the energy saving cash flow stream (INT1_220212).

5.2 Information barriers

The survey also offers additional qualitative insights regarding the level and sources of information related to energy efficiency. Figure 8 shows the typical sources of energy-efficiency-related information of all survey participants and by selected business activities.

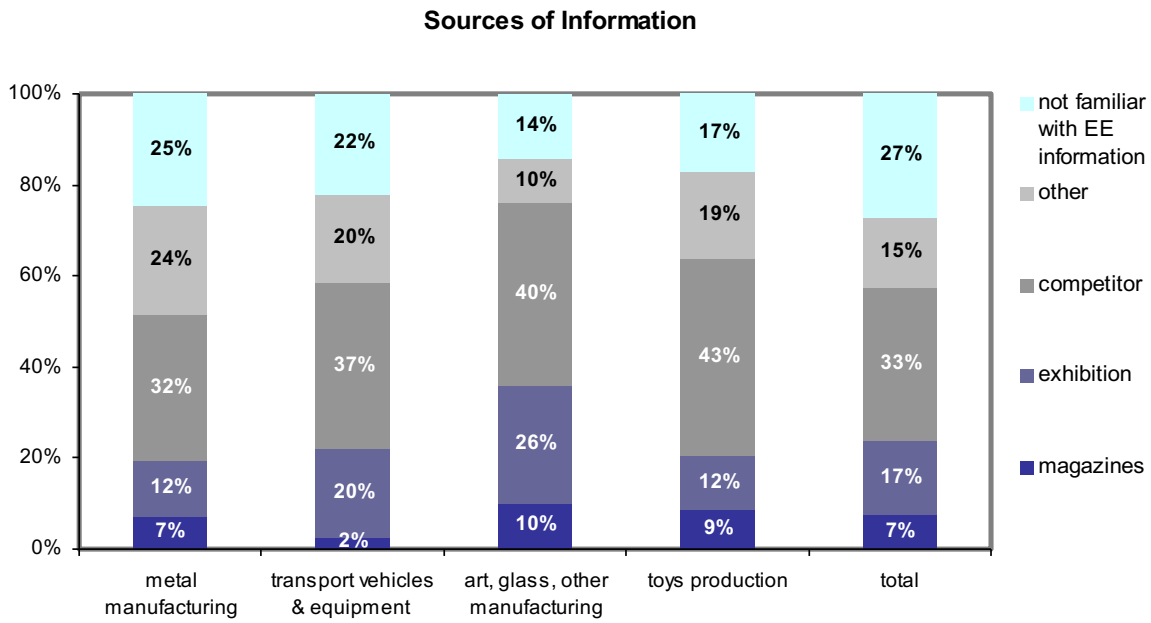

Fig. 8. Sources and level of information about energy efficiency.

Figure 8 illustrates that more than one quarter of the survey participants (27%) state that they are unfamiliar with the latest information on energy efficient technology. This varies across sectors with comparatively high level of information in the toys production and in the art and glass sector but lower levels of information in the metal manufacturing sector. Between 32% and 40% of all firms receive information on energy efficiency technologies from competitors, which helps to explain how the energy management level of competitors can influence firms' ESA (a key finding from Liu et al. 2012). Besides information from competitors, firms familiarize themselves with the latest energy efficiency technologies by attending trade exhibitions and reading relevant magazines. Perhaps due to the nature of the sector, in 'art, glass and other manufacturing', trade exhibitions play a more important role (26%) as compared to toy products and metal manufacturing (12% each). In some sectors, however, unspecified 'other' sources are quite important.

Based on the interviews, other information channels for SMEs include the internet, company visits, or personal contacts. Many firm owners and managers stated that energy-efficiency-related information obtained from equipment suppliers and machine manufacturers is particularly helpful (INT4_230212; INT5_240212). A few SMEs have also relied on personal connections with government officials. The manager of a boiler-producing company, for instance, receives "all kind of information ahead of time from his connections with the Quality and Technical Supervision Bureau of Zhejiang" (INT3_230212). Although general information is publicly accessible, a plastic manufacturer notes that often it is difficult to get sector-specific knowledge, especially in terms of very advanced equipment (INT4_230212). Surprisingly, SME managers

interviewed, with the exception of one, were unaware of the work and role of Energy Saving Companies (ESCOs), which is further evidence of an 'information gap'. The information-sharing role of industry associations varied across sectors with some interviewees describing them as 'empty shells' and others seeing them as more active organizations. The more vibrant associations, such as the Taizhou Plastic Industry Association or the Taizhou Machine Tool Manufacturing Association, organized frequent meetings and an annual fair for their respective members in Taizhou (INT4_230212; INT5_240212).

5.3 Organizational barriers

The statistical analysis found mixed results on the effect of organizational barriers on investment outcomes: in one of the three scenarios it is statistically significant whether a firm had appointed an energy manager or not. In light of the weak statistical support a closer look at the realities in Chinese SMEs may provide more insight. Of the 480 enterprises only 13 enterprises (less than 3%) had actually appointed a designated energy manager. This is just too small a number from which to generate statistically significant results. For roughly half (7) of those 13 enterprises with an appointed energy manager, energy costs constituted more than 10% of the production costs. This is notable given that energy accounted for more than 10% of costs for just 20% of all 480 enterprises. The average number of employees in firms with an energy manager is only marginally higher (about 31.8) than for the whole sample (about 28.6). The low number of employees may

also suggest that most enterprises – being small and privately-owned – see organizational tasks including energy usage as still manageable without specialized personnel. The accuracy of this belief can actually be challenged by our data, since 43% of all enterprises admitted that they are not aware of energy saving equipments or practices in their respective business area, indicating that there are high transaction costs for SMEs to gather, assess, and apply information about energy saving potentials and relevant technologies. On the whole, we can conclude that energy managers are, as yet, very uncommon in Chinese SMEs.

Interviews shed further light on why this is the case. One manager notes that hiring an energy manager is a luxury and "we are not planning to set up such a position in the future, only if the economy is booming" (INT1_220212). Another manager said: "As the general manager I oversee the overall advancement of the firm, but I am also very busy and am in charge of many things, so sometimes I cannot pay as much attention to energy efficiency advancement as I want to" (INT2_220212).

Furthermore, interviews revealed that the majority of SME managers and owners often perceive energy savings from a managerial and not a technical perspective and have only a limited comprehension of what 'energy saving' or 'energy efficiency' is. When prompted to define it, they often referred to it as 'technological upgrading', 'cutting labor costs', and 'reducing total electricity costs in absolute terms' but rarely argued in 'per unit costs'. For example, a manager of a hydraulic engine manufacturing company notes that the first and most important factor that he considers is labor costs because they are increasing rapidly in Zhejiang, followed by concerns about production speed and efficiency, and finally concerns

about reduction of carbon emission (INT5_240212). Similarly, when asked about what type of energy saving activities they do, most owners or managers provided examples of investing in new machinery such as using computer numerical control (CNC) machines. Only a few interviewees discussed methods such as optimizing energy usage in production and logistic processes, installing monitoring devices, or switching to cleaner energy (e.g., using LED lights; solar heaters for employee showers).

5.4 Additional EE investment barriers for SMEs

Interviews flagged three additional determinants of energy saving activities, namely the role of ownership structures, government regulations and support, and skilled labor.

Many of the micro and small firms are family-owned, which influences decision-making in a number of ways. A general manager of a family-owned plastic manufacturing company in Taizhou, producing plastic and rubber hoses of all kinds, explains: "As the general manager I have the final word but I will always have to consult with my sister, the co-owner, about the final decision. We do not always agree" (INT4_240212). Splintered management responsibilities can also hinder decision-making processes and a manager from a boiler-producing company in Taizhou notes: "I am the production manager but also the nephew of the company's owner. It is hard to persuade my uncle to invest in energy efficiency. He is always very busy and does not have the time to really look deep into the company" (INT3_230212).

Another barrier is lax enforcement of energy efficiency regulations by local government bureaucracies, who do not have the incentives and capacities to supervise many of the

thousands SMEs located in the Taizhou-Wenzhou area. It is a common understanding among SME owners that SMEs are 'not on the radar screen' of local Development and Reform Commissions and Economic Information Commissions, the two many bodies responsible for the implementation of energy efficiency policies. This is a double-edge sword. On the one hand, there is little pressure on private SMEs to prioritize energy saving and they enjoy a lot more freedom than larger, often state-owned enterprises in energy management. For SMEs, the only restriction is that there are agreed limits on of how much electricity any particular company can use, which is determined on the basis of firm size, but these limits are quite generous (INT6_240212). On the other hand, it is almost impossible for SMEs to apply for energy-saving subsidies at the national or local level. Subsidies from the national level reserved for large enterprises, since a company usually needs to invest more than 10 million RMB in energy saving in order to qualify and investments ordinarily have to be paid upfront since it takes between three and five years to receive the fund. Funding sources from provincial or municipal governments is equally limited and they also have high minimum investment thresholds. Our findings are consistent with a recent study of 66 industrial enterprises in South Korea, which concludes that lax government regulation of SMEs provide little incentives for companies to adopt energy saving practices (Suk et al, 2013).

Finally, a shortage in skilled labour also hinders energy saving activities. Business leaders across the board complained that it is hard to find educated workers who have the skills to manage new energy efficient equipment and this was often listed as the biggest obstacle when interviewees were prompted to rank various ESA barriers. A manager in a

marine electrical equipment manufacturing company also complains that "it is hard to retain educated people who have skills to operate more advanced technology and who can solve technological problems. We try to keep talented staff by offering them insurance and higher salaries but engineers and technical equipment operators frequently leave for other companies after a short amount of time and we cannot find someone new easily" (INT1_220112). This finding confirms previous studies that found the shortage of skilled labour to be a key bottleneck for energy saving activities in SMEs in manufacturing firms in the US (Anderson and Newell, 2004).

6. Conclusions and Policy Implications

Based on survey data and the supplementary interviews, this study sheds light on barriers to energy efficiency investment in privately-owned small-and-medium-sized enterprises in China, a neglected topic in the literature, despite the fact that China's SMEs account for more than half of emissions in the country. We find that only a minority of SMEs in China are actively performing energy saving activities at a significant level. For example, just 21% of surveyed enterprises have installed energy efficient equipment in their premises to date, while only 4% of SMEs have ever taken a loan for financing energy-efficient measures, and less than 3% have appointed an energy manager. Yet the data also reflect firms' significant demand for energy-efficiency-related investments in the SME sector. For example, 54% of firms plan to either purchase additional equipment or replace the existing stock.

The findings thus reinforce the view that there is a potential for cost-effective, energy-saving investments that is not being realized because of barriers specific to smaller enterprises. Statistical analysis suggests that informational barriers are the core bottleneck inhibiting energy efficiency improvements. Hypotheses related to access to finance and organizational structure were less strongly supported. The interviews flagged three additional determinants of energy saving activities: the role of ownership structures, government regulations and support, and skilled labour.

It is rather challenging to establish a representative dataset focusing on micro and small-sized privately owned firms in China. In particular, our sample may represent companies in Taizhou and Wenzhou (Zhejiang Province) but, given disparate economic and industrial backgrounds, the findings may be different for SMEs in other regions. Zhejiang is one of the most developed regions in China and one could assume that the implementation rates of energy efficiency measures in SMEs in other provinces are even lower. Furthermore, as with any survey, our database may in theory suffer from the so-called 'social desirability bias', where answers are partly influenced by what the respondent thinks the interviewer wants to hear. In addition, further research is needed to distinguish further between self-assessed, perceived barriers and real barriers (Cagno et al., 2013). These shortcomings further motivated personal in-depth interviews to cross-check and deepen our findings.

Despite these potential shortcomings of this research, several policy implications can be drawn. First, given that SME managers tend to feel poorly-informed about energy-efficient investment opportunities, policy makers may aim to find systematic means for disseminating energy-efficiency information to SMEs. Helpful efforts might include

technology-specific databases, software tools or energy-efficiency handbooks perhaps distributed in forums where firms meet their competitors as this is shown to be their dominant source of information. Second, the finding that growth ambitions are a significant driver of energy-efficiency investments suggests that growing SMEs may be particularly open to introducing energy reduction measures; as such, it may be wise to explicitly target this group in policy initiatives. In addition, training could be offered to personnel in SMEs to improve their technical know-how and skill level. Finally, along with efforts to help SMEs modernize their financing structure, it may also be beneficial for financial institutions to combine informational efforts with introducing energy efficiency loan programs for SMEs. This would involve special training for loan officers, who need a high degree of specialized local knowledge in order to offer and understand appropriate loan products for energy efficiency investments.

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