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Energy conservation in China's energy-intensive enterprises: An empirical study of the Ten-Thousand Enterprises Program

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ABSTRACT

The Ten-Thousand Enterprises Program is China's keystone energy conservation and climate change program. The program has effectively created a class of energy-intensive enterprises that are regulated by the government for energy conservation purposes. Through an empirical study conducted in Changchun, this paper shows that the adoption of energy efficiency technologies and practices has been highly uneven in this class of enterprises because of two reasons. First, a de facto two-tier regulatory system has emerged within the framework of the Ten-Thousand Enterprises Program. Central state-owned enterprises are closely regulated by the State-Owned Assets Supervision and Administration Commission (SASAC) which is a central government apparatus, whereas local state-owned enterprises and privately owned enterprises are regulated by the local government, which has fewer resources and incentives to implement the program rigorously. Second, the Ten-Thousand Enterprises Program bundles together different types of enterprises. This approach places smaller enterprises at a disadvantage and limits their ability to conserve energy.

Introduction

As the world's largest energy consumer and CO_2 emitter, China is under increasing international pressure to control, if not reduce, its rapidly growing carbon emissions. Thus far, China has pledged to cut its carbon intensity by 40-45% by 2020 relative to its 2005 levels (Lo, 2014; Zhang, 2011). One of the most important policies for realizing the target is the Ten-Thousand Enterprises Energy Conservation Low-Carbon Program (hereafter Ten-Thousand Enterprises Program) in the 12th Five-Year Plan (2011–2015). In essence, the program has created a class of energy-intensive enterprises that are regulated by the government for energy conservation purposes. Given the large amount of energy consumed by these enterprises, their energy conservation behavior becomes crucial to the understanding of the governance of energy and climate change in China.

Despite increasing interest in the subject, there is little empirical research into China's energy-intensive enterprises and the Ten-Thousand Enterprises Program. The relevant literature is either technical in nature—examining the technologies and potential of energy efficiency at the firm level (Kong et al., 2013) and sector level (Ke et al., 2012b; Zhang and Wang, 2008), calculating the regional total energy efficiency factor of the industrial sector (Wang et al., 2012), and using input–output analysis to compute the embodied energy use in China's industrial sectors (Liu et al., 2012b)—or consists of policy-focused, macro-descriptive discussion with insufficient in-depth analysis. Although several case studies have provided in-depth and context-rich insights into energy conservation in Chinese enterprises (Chen et al., 2013; Zhao and Ortolano, 2010), the number and type of enterprises examined is limited, and the methodology does not allow for comparison between different types of enterprises.

The objective of this paper is to explore and explain energy conservation behavior among the "ten-thousand" energy-intensive enterprises. A special focus is on the diversity, in terms of size, operation, and ownership structure of the energy-intensive enterprises and how this diversity influences firms' behavior of energy conservation. The objective is pursued by: (1) characterizing the energy-intensive enterprises, (2) evaluating the adopted energy conservation measures; and (3) assessing the key drivers and barriers to energy conservation. The following section provides a review of the literature that has guided this research. Then, the Ten-Thousand Enterprises Program is explained and the method is described. This is followed by discussions about the energy conservation measures, drivers, and barriers. This paper concludes with recommendations for China's energy conservation policy.

Measures, drivers and barriers

Enterprises can improve their energy efficiency by technical and non-technical measures. Technical measures include, but are not limited to, reusing and recycling materials, retrofitting and replacing old equipment,

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reducing heat loss, reusing heat, changing to energy efficient processes, and increasing productivity (Tanaka, 2011). More specifically, energy conservation technologies commonly found in energy-intensive enterprises include variable-speed drive, waste heat recovery by economizer, high-efficiency motors, and leak prevention in air compressors (Abdelaziz et al., 2011). Non-technical energy conservation measures include energy performance measurement, energy consumption monitoring, energy auditing, and energy training for employees (Nisiforou et al., 2012; Sivill et al., 2012). Industrial energy conservation is context-specific because the choice of measure depends on firm-level factors such as product design, process choice, energy sources, and company size (Vikhorev et al., 2013). Large and energy-intensive enterprises by their very nature have more room for improvement than small- and medium-sized enterprises (SMEs). Geography is also a factor. Studies from developed countries, such as Greece (Markis and Paravantis, 2007), Italy (Cagno and Trianni, 2013), and Sweden (Thollander and Ottosson, 2010), often report the use of more energy conservation measures than studies from developing countries, such as India (Gielen and Taylor, 2009), Ghana (Apeaning and Thollander, 2013), and China (Kostka et al., 2013).

Governments are a key driving force of industrial energy conservation (Ke et al., 2012a; Kostka and Hobbs, 2012; Price et al., 2001; Price et al., 2010; Zhao et al., 2014). Tanaka (2011) reviewed over 300 energy efficiency policies worldwide and found that although negotiated agreements are the most common approaches, economic instruments such as carbon tax and emissions trading are increasingly used. There are significant variations among countries and within countries. For example, the United States federal government has taken a minimalist approach to industrial energy efficiency, mainly relying on support mechanisms such as loan guarantees and research and development (Dixon et al., 2010). Nevertheless, several emissions trading schemes are operating at the subnational level, such as the Regional Greenhouse Gas Initiative and the Western Climate Initiative (Lutsey and Sperling, 2008). The European Union Emissions Trading Scheme coexists with national schemes in Denmark, Finland, the Netherlands, Sweden, and the United Kingdom (Rezessy and Bertoldi, 2011). China has adopted a multifaceted approach mainly consists of negotiated agreement and financial support (Li and Wang, 2012; Lo and Wang, 2013; Price et al., 2010). Furthermore, China recently began to experiment with carbon trading by establishing regional markets in Beijing, Chongqing, Shanghai, Shenzhen, Tianjin, Guangdong, and Hubei that accounted for 27% of the national GDP in 2010 (Lo, 2012).

The literature has also identified the market as a key driver of energy efficiency (Apeaning and Thollander, 2013; Hang and Tu, 2007). Because energy costs typically account for 10–30% of the total production costs in energy-intensive enterprises (Sivill et al., 2012), these enterprises often focus on energy conservation. Thollander and Ottosson (2008) found that cost reduction significantly motivates energy efficiency in the Swedish paper and pulp industry. Cagno and Trianni (2013) found that increasing competition from developing economies that benefit from lower labor costs is a key driver of energy efficiency in the Italian manufacturing sector. Liu et al. (2012a) discovered that energy conservation among Chinese SMEs occurred primarily in response to market competition. Chen et al. (2013) studied a large state-owned enterprise (SOE) in the resource sector that reduced its energy consumption by more than 10%. The authors cited market conditions as the force encouraging energy conservation. However, other studies have found that energy efficiency does not necessarily lead to cost saving (Zhang et al., 2012) and energy-intensive enterprises may choose to pursue other priorities over energy efficiency (Thollander and Ottosson, 2010).

The literature on barriers to industrial energy efficiency is quite extensive, driven by the paradox that enterprises fail to adopt energy efficiency measures that appear to be cost-effective. In a recent review by Sorrell et al. (2010), the authors identified six categories of barriers: (1) risk, (2) imperfect information, (3) hidden costs, (4) access to capital, (5) split incentives, and (6) bounded rationality. Empirical studies in both developing and developed countries (Apeaning and Thollander, 2013; Sardianou, 2008; Trianni et al., 2013) suggest that enterprises everywhere face similar barriers, particularly with access to capital, imperfect information, and hidden costs. However, barriers may be more pronounced in developing countries (Sorrell et al., 2010). Furthermore, smaller enterprises may exhibit a greater perception of barriers than larger ones and are more likely to downgrade energy efficiency to a peripheral issue (Trianni et al., 2013). Zhao and Ortolano (2010) investigated a Chinese state-owned power plant that fell behind schedule for meeting its energy conservation targets in 2006 and 2007. Financial obstacles, bureaucratic red tape, and an unhelpful municipal government were identified as the key impediments. In another study from China, Kostka et al. (2013) surveyed 480 SMEs in Zhejiang province and found that information barriers are significant.

The Ten-Thousand Enterprises Program

The Ten-Thousand Enterprises Program regulates the energy consumption and energy conservation behavior of enterprises. In contrast to overseas experience where similar objectives are usually achieved through voluntary agreements or market-based instruments, the Ten-Thousand Enterprises Program takes a command-and-control approach which remains the preferred policy instrument in China. The program not only allocates energy-saving targets to the regulated enterprises but also demands the enterprises to meet a number of energy management requirements, such as conducting energy auditing, collecting, analyzing, and reporting energy statistics, hiring qualified energy management professionals, and the long-term planning of energy conservation. The program defines energy-intensive enterprises as those that consume 10,000 tce (ton of coal equivalent) or more annually. Using this benchmark, the program regulates 16,018 enterprises that collectively account for approximately 60% of the country's total energy consumption (in comparison, the European Union Emissions Trading Scheme regulates approximately 11,000 entities and 40% of total energy consumption). Enterprises can fail their assessment by either achieving less than 60 marks in total or failing to meet the energy saving targets, which is a veto criterion. However, the central government has not made the punishment clear, thereby leaving room for local variations. Overall, the program is expected to deliver an energy saving of 250 Mtce over five years.

Method and data

The fieldwork for this study was conducted in Changchun, the capital of Jilin province, from September to November 2012. Changchun was chosen because it is a large industrial city with a high concentration of energy-intensive enterprises, with 45 industrial enterprises enlisted in the Ten-Thousand Enterprises Program, and because of the availability of contact.

A key design feature of the study is the selection of samples that are large enough to reflect the diversity of energy-intensive enterprises in Changchun but small enough to allow for in-depth qualitative analysis. To this end, we adopted theoretical sampling, which stresses the iterative nature of data collection and analysis, both of which are guided by the emerging theory. Following this method, we examined 11 enterprises that we believed sufficiently reflect the diversity of energy-intensive enterprises in Changchun. Our data are primarily drawn from interviews with managers from these enterprises. The semi-structured interviews lasted approximately one hour and focused on the following topics: characteristics of the enterprise, energy conservation practices, driving factors, and key challenges. Interviews were also conducted with government officials in charge of the implementation of the Ten-Thousand Enterprises Program to gain an understanding of energy conservation from the government's perspective. Additional information was collected from corporate and government documents and media reports.

The studied enterprises can be categorized into three groups by their ownership structure: state-owned enterprises owned by the central government (central SOEs), state-owned enterprises owned by the local governments (local SOEs), and privately owned enterprises (POEs). Table 1 lists the names, basic information, and energy conservation targets of the enterprises chosen for this study. Three of the enterprises are owned by the central government: (1) First Auto Works, (2) Changchun Railway Vehicles, and (3) Changchun Second Cogeneration Power Plant. One of the defining features of China's economic reform is the emergence of super-large state-owned enterprises in strategic sectors (Chan, 2009). Accordingly, the three central SOEs are mammoth in size and are key energy users in Changchun. First Auto Works is one of China's largest automakers and is by far the largest employer and energy user in Changchun. Established in 1953 as one of the key national construction projects during the 1st Five-Year Plan, the company has prospered in recent years through joint ventures with foreign carmakers, particularly Volkswagen. In 2012, it is ranked 141th in the Fortune Global-500 for 2013. Changchun Railway Vehicles was established in 1954, also as part of the 1st Five-Year Plan's national construction project, to produce railway carriages. The company is now an internationally leading manufacturer of rail-based mass transit systems and high-speed trains. Changchun Second Cogeneration Power Plant was established in 1990 and is Changchun's largest cogeneration plant (rated at 1200 MW). Following the 2002 electricity sector reform, it became a subsidiary of China Datang Corporation, which is one of the Big Five electric power enterprises in China and ranked 376th in the Fortune Global 500.

Four of the examined enterprises are owned by local governments: (1) Changchun Water, (2) Changchun Heating, (3) Changchun Public Transportation, and (4) Changchun High-Tech Heating. The first three SOEs are owned by the municipal government and the fourth by a district government, which is subordinate to the municipal government. Changchun Water was established in 1990 as a water monopoly for the city and is responsible for the drinking water supply and sewage treatment. Its energy consumption mainly comes from the operation of 5 water purification plants, 5 sewage treatment plants, and a waste mud treatment plant. Changchun Heating is one of the largest providers of district heating in Changchun, covering an area of 17.3 million m^2. Changchun Public Transportation is Changchun's primary public transport provider, with a network including buses, trams, and urban light-rail transit. Changchun High-Tech Heating is a small provider of district heating. Compared to the large central SOEs, the local SOEs are smaller in scale and have different functions as public utility undertakings.

Four of the enterprises are privately owned: (1) Dacheng, (2) Xiuzheng Pharmaceutical, (3) Changchun Gas, and (4) Jilin Longqing Property Services. Dacheng is a large corn deep-processing company, producing starch, sugar, amino acids, and ethanol. The company is one of the world's largest manufacturers of lysine—an amino acid essential to humans and animals that allows for more efficient feed use. Xiuzheng Pharmaceutical—a producer of drugs, health products, and cosmetics—is one of China's largest pharmaceutical enterprises with an annual revenue exceeding RMB 17 billion. Changchun Gas is a privatized state-owned enterprise (SOE), with the municipal government owning a minority stake (25%). The company is the largest provider of natural gas, town gas, and liquefied petroleum gas in the city and is also a large coke producer. Lastly, Jilin Longqing is a small district heating provider with approximately 100 employees.

Overall, 4 enterprises are manufacturing and 7 enterprises are public utility companies of various types. The diversity of the enterprises, even in our small sample, is significant. The relationship between this diversity and energy conservation is thoroughly explored in the remainder of this article.

Energy conservation measures

Even though the studied enterprises are all regulated under the Ten-Thousand Enterprises Program, they exhibit a high level of variety in energy conservation behavior, with the central SOEs outperforming the rest by a substantial margin. Significant progress has been made to replace old equipment with energy-efficient facilities, especially among the central SOEs, which are the oldest and therefore have the largest number of outdated facilities. For example, until recently, First Auto Works used steam boiler systems built in the 1950s, which had poor energy efficiency because of their low condensation rates. In 2011, First Auto Works invested approximately RMB 100 million to replace the antiquated system with energy-efficient hot water boilers, estimated to save 17,000 tons of standard coal every year. Another example is Changchun Gas, which retrofitted its decades-old top-charged coke ovens to stamp-charged coke ovens that are 35% more energy efficient. Retrofitting old equipment is also common and is less expensive than replacement. For example, Changchun Second Cogeneration Power Plant has improved its energy efficiency by 1.7% through minimizing air leakage from their boilers and improving the heat exchange between the water tower and the condenser.

Replacement and retrofitting are not limited to production facilities. As a legacy of the planned era, the central SOEs still engage in many nonproduction-related activities, such as the operation of hospitals and schools. They also frequently provide accommodations for their workers. These nonproduction-related facilities have also become targets of energy conservation. For example, First Auto Works has recently invested RMB 140 million in a district heating upgrade project, which includes replacing the direct connection system with an indirect system of 32 heat exchangers, replacing outdated pipework and control valves, and computerizing the control system.

Compared to investing in energy efficiency, the deployment of renewable energy technologies has been far less common, with only a few enterprises utilizing renewable energy and only on a very limited scale. Both First Auto Works and Changchun Railway Vehicles recently installed solar water heating for staff welfare facilities. However, high costs have

Table 1
Characteristics of the studied enterprises.

Enterprise	Ownership	Sector	Number of employees	Energy conservation target (tce)
First Auto Works	Central SOE	Auto manufacturers	132,000	150,000
Changchun Railway Vehicle	Central SOE	Rail and transit	12,000	20,000
Datang Changchun Second Cogeneration Power Plant	Central SOE	Electricity utilities	1,700	5,000
Changchun Public Transport	Local SOE	Transport utilities	11,000	19,000
Changchun Water	Local SOE	Water utilities	4,000	10,000
Changchun Heating	Local SOE	Heating utilities	2,400	10,000
Changchun High-Tech Heating	Local SOE	Heating utilities	150	3,500
Xiuzheng Pharmaceutical	POE	Pharmaceutical	80,000	5,000
Changchun Gas	POE	Gas utilities	3,000	15,000
Changchun Dacheng Industrial Group	POE	Agricultural chemicals	1,400	100,000
Jilin Longqing Property Services	POE	Heating utilities	100	5,000

Source: Data collected during interviews.

limited the investment of renewable energy in production-related activities. Reusing and recycling materials is another common strategy. For example, Xiuzheng Pharmaceutical has recently completed a project to reuse the waste from its drug production processes. Dacheng captures and reuses methane generated from its fermenting processes to generate electricity. Lastly, a few enterprises have been able to improve energy efficiency by increasing productivity, which results in the more efficient use of resources. Dacheng has extended its product lines, and First Auto Works and Changchun Railway Vehicles have both increased their output dramatically. In fact, according to a First Auto Works manager's statement, the increase in productivity has been the greatest factor in the company's increased energy efficiency.

The enterprises have also, again to different degrees, engaged in non-technical energy conservation projects. The central SOEs are again the clear leaders, and their non-technical initiatives appear to have three foci. The first emphasizes the institutionalization of energy conservation through organizational measures. All three central SOEs have established an Energy Conservation Leading Group spearheaded by general managers and an energy conservation office as an implementation body. These organizational changes send a clear signal to employees that energy conservation is a strategic and long-term objective of the companies.

The second focus emphasizes strengthening the collection and analysis of energy statistics, and Changchun Second Cogeneration Power Plant is the forerunner in this regard. Although all the enterprises measure and monitor their monthly and annual energy consumption, Changchun Second Cogeneration Power Plant has implemented a platform to monitor real-time energy consumption, which allows the company to detect any abnormal fluctuation of energy consumption and react in a timely manner, as well as to create daily energy reports that inform future energy conservation plans.

The third focus of non-technical initiatives is on promoting energy conservation behavior among employees, particularly the frontline workers who handle energy-intensive equipment. This objective aims to address the split incentives problem, whereby energy users, such as frontline workers, lack incentives to reduce energy consumption because they do not actually pay for the energy (Sorrell et al., 2010). All three central SOEs have established the energy conservation responsibility system, which breaks down the energy conservation targets for each factory, production line, shift, or even individual employee. At the end of the year, the results are evaluated, and rewards and penalties are given. The three central SOEs have implemented the system at different levels of thoroughness. First Auto Works established the responsibility system down to the subsidiary level, whereas Changchun Second Cogeneration Power Plant established it down to each shift. The enterprises frequently promote energy conservation and educate their employees. For example, every year Changchun Second Cogeneration Power Plant conducts an energy conservation knowledge contest and a no-car day. The company also opens a platform for sharing energy conservation ideas and promotes energy conservation practices such as using the staircase instead of elevators, turning off unused lights, and using public transportation.

Overall, the studied enterprises have implemented an impressive mix of energy conservation projects in recent years, which have contributed to the decrease in Changchun's energy intensity. However, the adoption of energy efficiency technologies and managerial practices has been highly uneven, and clear leaders and laggards emerge among the studied enterprises. In general, the central SOEs have been at the forefront of energy conservation, with First Auto Works the clear leader. In the last few years, First Auto Works invested over RMB 400 million in approximately 500 energy conservation projects. In comparison, the local SOEs and POEs have implemented far fewer energy conservation projects. An exception to this rule is Dacheng (a POE), which has consistently made energy conservation a priority and has invested over RMB 250 million in approximately 300 energy conservation projects in recent years.

Drivers

Turning first to regulatory drivers, the Ten-Thousand Enterprises Program plays a catalytic role in energy conservation. However, the impact of the program is felt unevenly among the enterprises because of the emergence of a de facto two-tier regulatory system.

At the first tier are the central SOEs. Notwithstanding the reforms that have modernized the state-owned sector, the central SOEs still to some extent resemble a government ministry rather than a modern corporation because the central government exercises strong political and personnel control through the State-Owned Assets Supervision and Administration Commission (SASAC) (Naughton, 2008). The SASAC plays a key role in the enforcement of the Ten-Thousand Enterprises Program through its annual performance evaluation of central SOE managers, which determines the size of their year-end bonus and career advancement. According to the energy manager of First Auto Works, energy conservation affects the performance evaluation in three ways. First, up to 20% of the performance score is now determined by energy conservation. Second, managers of SOEs that achieved outstanding energy conservation results are eligible for additional honorary awards. Third, if an SOE is caught reporting false energy statistics, its managers are penalized. Together, these mechanisms provide strong incentives for central SOEs to comply with the Ten-Thousand Enterprises Program, which is reflected in their leadership position in energy conservation.

At the second tier are the local SOEs and POEs, which are regulated by the local government of Changchun instead of the SASAC. Given the lack of resources and incentives, the local government has taken a less rigorous approach to the implementation of the Ten-Thousand Enterprises Program. A key problem is the lack of punishment for non-compliance. Although energy conservation targets have been allocated to the enterprises and annual evaluations are conducted according to the central government's requirement, there is no financial, administrative, or legal penalty for local SOEs and POEs that fail to comply with the program. Without proper punishment, as a local official puts it, "the enterprises can choose to comply if they want to, can choose not to comply if they do not want to". Therefore, the Ten-Thousand Enterprises Program is not a key driver of energy conservation in local enterprises.

In addition to the problem of the two-tier regulatory system, the Ten-Thousand Enterprises Program also suffers from several design problems. The energy conservation targets, which were allocated quickly and without any consultation with the enterprises, have been criticized as unrealistic and undeliverable. This critique is mainly raised by smaller enterprises, regardless of the ownership type or operation. Another problem is the use of energy intensity, defined as the ratio of energy consumption to the value of output, to calculate energy conservation. Calculating energy intensity is a complex and ill-defined process that creates confusion among non-manufacturing enterprises (i.e., the public utility companies). This is because, for these enterprises, it is unclear how to define a unit of output. Furthermore, energy intensity is vulnerable to factors not related to energy conservation, such as the quantity of output and the price of the products. For example, enterprises could record an increase in energy intensity if the prices of their main products decline, regardless of their efforts in energy conservation.

Another design problem is that the Ten-Thousand Enterprises Program bundles together energy-intensive enterprises of different types and treats them as a homogenous group. With the exception of energy conservation targets, large and small enterprises alike are required to adopt the same set of energy management practices. However, many managerial requirements are inappropriate for small enterprises. For example, the requirements of hiring qualified energy management professionals, researching new energy efficiency technologies, and establishing a dedicated energy conservation budget can be very expensive and are of dubious value for small enterprises. Unlike the energy saving target, the energy management tasks are not mandatory. Nevertheless, because

the completion of each task yields points in the annual evaluation, achieving a certain percentage of tasks is important for enterprises. Indeed, enterprises that fail to score 60 points are classified as having failed. Considering that achieving the mandatory energy saving target awards 40 points, enterprises only need to earn 20 points out of the total 60 points in energy management to achieve a passing grade. This low requirement to some extent makes it easier for small enterprises to comply with the program, but it also reduces incentives for large enterprises to implement the more difficult requirements. The bundling of energy-intensive enterprises thus creates two types of problems: it places at a disadvantage and ignores the needs of small enterprises and at the same time reduces the incentives of large enterprises to pursue challenging energy management requirements.

In addition to government regulation, the enterprises are also driven by the need to lower energy costs. All of the studied enterprises rely on coal and oil as their primary energy sources. Consequently, they are all affected by the rise in coal and oil prices following recent market reforms (Yang et al., 2012). However, enterprises that have a highly energy-intensive production process and are subjected to intense price competition are most vulnerable to rising energy costs. This explains why Dacheng has a long-standing commitment to energy efficiency even though it is a privately owned enterprise. The utility companies are also under heavy pressure from rising energy costs. Despite the monopoly status of these companies, their product prices are controlled by the government due to fear of inflation and increases in the cost of living. Therefore, utility enterprises often suffer from low profitability or loss. The problem is most severe with the coal-fired electricity generation sector, which suffers from the growing price difference between coal and electricity. In 2008, China's major generators suffered a record 117% decline of net profit (Wang and Chen, 2012). Changchun Second Cogeneration Power Plant is no exception and has lost millions of RMB in each of the last few years. First Auto Works, Changchun Railway Vehicles, and Xiuzheng Pharmaceutical are the least sensitive to increases in energy prices because their business is capital and knowledge intensive.

Barriers

Access to capital is a common barrier among the studied enterprises, though the local SOEs and POEs are more susceptible. The problem is due to both insufficient capital through internal funds and the reluctance or inability to raise additional funds through external sources, such as borrowing or government subsidies. Obviously, the ability to invest in energy conservation is a function of the financial health of the enterprise, and many of the studied enterprises are in poor financial condition because of the increase in energy costs previously mentioned. However, the lack of internal investment in energy conservation also reflects the presence of other investment priorities. For example, Xiuzheng Pharmaceutical reinvests most of its profit into the research and development of new products, whereas the utility enterprises tend to prioritize the quality and reliability of their services. With the introduction of tougher government regulations, these companies may shift their investment priorities toward energy conservation. Due to favorable market conditions, the three central SOEs and Dacheng are less vulnerable to problems accessing capital. First Auto Works, Changchun Railway Vehicles, and Dacheng have all performed exceptionally well in recent years. However, because the favorable market conditions are not guaranteed to continue, these enterprises may one day face the same financial barrier. Changchun Second Cogeneration Power Plant was a special case. Although it was unable to generate a profit in recent years because of high coal prices, the company was able to obtain sufficient funding from its parent company to invest in energy conservation.

The bundling of enterprises by the Ten-Thousand Enterprises Program has created an unfair distribution of government funding in support of energy conservation, which further aggravates the financial barrier. The central government provides funding to support energy conservation projects at a rate of RMB 300 per ton of standard coal saved. However, the funding is very competitive, and projects are evaluated based on the size of savings and the degree of technological advancement. Both criteria make it difficult for the smaller enterprises to compete with the larger enterprises. In fact, the four enterprises that have successfully applied for government funding (i.e., First Auto Works, Changchun Railway Vehicles, Dacheng, and Xiuzheng Pharmaceutical) are also the largest enterprises in Changchun. Furthermore, the amount of subsidy is too little to stimulate the interest of SMEs. For example, the boiler replacement project by First Auto Works, estimated to cost approximately RMB 100 million, was eligible for a subsidy of RMB 5.1 million, or approximately 5% of the project cost. However, the fact that both SOEs and POEs have received funding suggests that the central government is not biased toward its own enterprises when allocating funding.

A number of enterprises expressed that identifying new opportunities for energy conservation is becoming more difficult after having already made significant improvements over the years. These enterprises believe that their energy efficiency levels have reached international standards and that they may experience technical barriers to energy conservation. However, it is possible that the enterprises are unaware of energy conservation opportunities, which is an information barrier. Judging whether the enterprises have sufficient information on energy conservation is difficult without conducting a thorough energy audit. Nevertheless, enterprises that lack an energy conservation specialist and have not conducted an energy audit are likely to suffer from information barriers. A surprising number of the studied enterprises fall into this category. Only First Auto Works, Changchun Railway Vehicles, and Dacheng have established an energy conservation office staffed with professional energy managers. For the others, the norm is to have only one employee working on energy issues on a part-time basis, mainly focusing on the collection and reporting of energy statistics to satisfy the government regulations. Therefore, it is likely that information barriers are significant among most of the studied enterprises, particularly the smaller and less-resourceful enterprises.

Finally, energy service companies (ESCOs) provide comprehensive services to enterprises to improve energy efficiency and help overcome financial and information barriers (Marino et al., 2011). Recognizing the potentials of ESCOs, the Chinese government has put in place a subsidy program to help promote ESCO-based projects. The amount of subsidy was quite generously set at RMB 300 per ton of standard coal saved, though none of the studied enterprises have used the services of the ESCOs. The main concern appears to be the issue of trust. For example, one manager expressed concern that the enterprise would be forever held captive by the ESCO if the enterprise adopted the ESCO's proprietary technologies. Others have questioned the ability of the ESCOs to deliver the project on time without disrupting normal production. This lack of trust perhaps reflects the fact that China's ESCO industry is new and underdeveloped, and the industry mainly consists of small companies with limited technological and financial capacities (Kostka and Shin, 2013). Furthermore, the failure to engage with local business networks and the lack of legal and regulatory institutions have also been cited as reasons for the ESCO industry's lack of progress in China (Kostka and Shin, 2013).

Conclusion

The Ten-Thousand Enterprises Program is a significant step toward controlling the rapid growth of energy consumption and carbon emissions among Chinese enterprises. This study shows that the "ten thousand" energy-intensive enterprises are diverse in size, operation, ownership type, and, consequently, energy conservation behavior. An analysis of the drivers of energy conservation reveals that ownership type is a key factor in government intervention, with the central SOEs subject to stronger regulatory oversight than both POEs and local SOEs. In contrast, the rapid increase in energy prices has become a near-universal market driver of energy conservation for energy-intensive enterprises, though the intensity of the driving force depends on the sector.

Furthermore, despite the variation in energy-intensive enterprises with regard to size and operation, the Ten-Thousand Enterprises Program bundles together different types of enterprises. This unified approach places at a disadvantage and ignores the needs of smaller enterprises and reduces the incentives for large enterprises to conserve energy. An analysis of barriers to energy conservation reveals that smaller enterprises are clearly more susceptible to financial and information barriers, though all the studied enterprises are skeptical of collaborating with ESCOs.

China is a very large and diverse country, and it is therefore difficult to make sweeping generalizations based on the study of a single locality. It is possible, for example, that the enforcement of POEs and local SOEs is stronger in other locations, and therefore the problem of the two-tier regulatory system is less pronounced. Given the paucity of empirical studies on energy-intensive enterprises, it is difficult to judge the applicability of the findings from Changchun to other areas in China. Having said that, the Changchun experience also captures some essential characteristics of the Ten-Thousand Enterprises Program that are likely shared by other localities, such as the diversity of the energy-intensive enterprises, the bundling of enterprises for regulatory purposes, and the different drivers and barriers. Therefore, this study reflects some of the basic problems with the current approach to regulating enterprises with regard to energy conservation and climate change mitigation in China.

In conclusion, we consider some possible solutions to improve the Ten-Thousand Enterprises Program. First, the target allocation process can be improved. A problem with the Ten-Thousand Enterprises Program is that the government failed to consider energy efficiency potential at the industry or firm level during the target allocation process. The government should incorporate information collection and/or negotiation for the next phase of implementation (2016–2020). Given that the number of enterprises regulated by the government will increase, it is vital that the local governments are given more time to complete this task. Second, and relatedly, the energy conservation targets need to be better defined to avoid confusion and loopholes. The best option is to use total energy consumption and hence avoid the use of energy intensity as a metric, as it has been shown to be problematic.

Third, the compliance mechanism should be strengthened. Considering that SMEs already face strong barriers to energy efficiency, creating extra punishment may further antagonize the relationship between the government and enterprises and create extra burdens on these enterprises. Therefore, an award-based compliance mechanism (e.g., offering tax-break incentives) is recommended. Fourth, small enterprises could benefit from a simplified requirement for energy management because of their lack of resources. A simple energy management regime that only requires small enterprises to measure, plan, and act is often best for small enterprises with limited resources (Hrustic et al., 2011). Furthermore, eliminating unsuitable demands can also help small enterprises focus on more important tasks. By creating a separate set of requirements for small enterprises, the government can increase the minimum passing score without fear of overburdening the small enterprises. An increase from the current 60 to 80 points would mean that large enterprises need to complete at least two-third of the energy management tasks.

Fifth, in light of the finding that financial and information barriers are more significant among SMEs but that existing policy support is skewed toward large corporations, we recommend providing small enterprises with more support. A free or subsidized energy audit is important for overcoming information barriers for smaller enterprises that lack the resources to complete the audit independently. Financial support for energy conservation projects is also important. The competition mechanism promotes efficiency and should remain: the key is to ensure fair competition among similar types of enterprises. A higher funding rate than the standard rate should be offered to help small enterprises overcome the financial barriers.

Sixth, both the findings of this study and other published works (Gan, 2009; Kostka and Shin, 2013) indicate the problem of China's energy service companies, which is unfortunate because ESCOs can help to overcome the financial and information barriers to energy conservation, particularly for small enterprises. The policy recommendation suggested by Kostka and Shin (2013) are worth reiterating. The government must help ESCOs earn the trust of companies by sponsoring networking events and establishing a rating system of accredited ESCOs. This policy recommendation is insightful and, once implemented, can stimulate the growth of the ESCO industry in China and facilitate enterprises to achieve their energy conservation targets.

Finally, the introduction of emissions trading as a replacement or supplementary system to the Ten-Thousand Enterprises Program is worth considering. The flexibility introduced by emissions trading would allow wealthy enterprises with less room for energy efficiency improvement to pay others to improve. This policy would help smaller enterprises that are cash-strapped but have many improvement opportunities. Currently, China is experimenting with regional carbon markets. Although this is a positive step, although many challenges remain, including China's tendency toward excessive state intervention in markets. If the regional markets prove successful, a nationwide emissions trading scheme should follow because it would offer a higher degree of flexibility.

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