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Business Strategy Under Institutional Constraints: Evidence From China's Energy Efficiency Regulations

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ABSTRACT

This paper links theoretical perspectives from energy efficiency economics with those observed from corporate environmental strategy to develop a framework for explaining energy efficiency strategies by firms in response to national policies and local regulations in China. The framework is refined through analytic generalization of 20 cases from four industries and four cities in Jiangsu Province, and reveals two strategies: 1) firms with moderate institutional pressure seek incremental competitiveness by adopting energy-saving technologies, which is reinforced by their informational, organizational, and financing capabilities, and facilitated by voluntary policies and industrial competition; 2) firms with survival risk or development constraints under regulation seek a position favored by local governments by replacing old plant and equipment with larger, more efficient ones and contributing to the local community. The Chinese case studies reveal a strong institutional impact on firms' choice of business strategies and particularly the positioning strategy. The identified business strategies shed additional light on the effectiveness and implications of different policy instruments for energy efficiency.

1. Introduction

Decision making by firms regarding energy efficiency investment is often viewed as an economic problem. Being a factor of production, energy can be substituted by other factors of production, such as fixed capital. Energy savings, which are often recurrent, can reduce production costs and preserve financial assets over the long term. Although empirical evidence confirms that the adoption of energy-saving technologies is responsive to energy pricing, a gap has long been recognized between the current energy efficiency level and economic or social optimal levels (Jaffe and Stavins, 1994). Such an "energy efficiency gap" has been explained systematically in terms of market failures and non-market behavioral barriers (Gillingham et al., 2009; Jaffe et al., 2004). These broad-scale explanations, however, do not fully address how related policy mechanisms and behaviors are perceived within a specific institutional context and how firms vary in response to regulation and other inputs. In contrast, the management literature discusses institutional constraints more explicitly as well as strategic decision-making and organizational behavior of firms. Causal mechanisms can be identified to help build theories and propose propositions of firm behaviors for further examination and policy recommendations.

Building on the insight provided by the observation of the energy efficiency gap, then, this paper adds perspectives from the corporate environmental management literature, to define a model that helps to explain firms' motivations and decisions for energy saving in the context of substantive regulations on energy efficiency in China. The model considers how multiple policy instruments are interpreted and implemented, and explains how institutional and industrial contexts shape firms' behaviors, conditional on their capabilities. The model is developed based on interviews with industrial firms about their strategies during 2006–2015 and both within-case and between-case analyses.

The geographical setting is China, not only because of its magnitude of energy consumption and significance to global climate mitigation, but also, more importantly, because it offers researchers an ideal setting to confirm or extend previous discussions about energy efficiency decisions. Four case studies are included in the Appendix A to illustrate the decision-making process of example firms doing business in China. The policies that went into force in 2006 in China featured mixed use of policy instruments beyond simple command-and-control or market approaches and immediate tightening of industrial energy consumption. The findings herein are contingent on contextual factors identified explicitly, which help to advance the knowledge of firms' responsiveness in energy saving and inform policy makers on the effect of different policy instruments and their specific dynamics in China.

The remainder of the paper is organized as follows. Section 2 reviews the literature in economics and management about energy efficiency

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and environmental behaviors of the firm. Section 3 gives an overview of the regulatory background in China and a preliminary framework for explaining firm strategies. Section 4 describes the case study method applied in this research and data collection process. Section 5 presents findings. The implications of these findings for research and policy-making are further discussed in Section 6. Section 7 concludes this paper.

2. Literature

2.1. Energy Efficiency Economics

From an economic perspective, a firm's decision regarding energy efficiency is based on a balance of costs of initial investment and expected benefits of future cost savings, as well as expected profits from technology transfer (Jaffe et al., 2004). As a rational actor, a firm should invest in all of the energy efficiency technologies with a positive net present value. An energy efficiency gap is often observed empirically, however, revealing that firms do not adopt all of the profitable technologies. Rather, it appears that firms make decisions based on an implicit discount rate higher than other market interest rates and, as a result, the investment falls short of the optimal (Gillingham et al., 2009; Jaffe et al., 2004; Tietenberg, 2009).

The underinvestment in energy efficiency is often explained by market failures regarding accessibility to information and investment. Information about the existence of a technology and the act of adopting it – often called learning by using – creates positive externalities by letting others be more informed about the technology at little or no cost (Jaffe et al., 2004). Positive externalities indicate undersupply of the information that is essential to firms' ability to make investment decisions. Within an organization, imperfect information exacerbates principal-agent problems – managers who determine an energy saving investment may be evaluated before the benefit of the investment is fully revealed, and would likely choose not to invest suspecting that others do not understand and appreciate the benefit of investing in the technology. Additional principal-agent problems are manifested by capital costs being treated differently from operating costs in an organization, leading to similar underinvestment (Tietenberg, 2009).

Lack of access to financing for energy efficiency features another kind of market failure (Gillingham et al., 2009). Liquidity constraints apply not only to energy efficiency investments, but also to other potential investments a firm faces. Under a financing or credit constraint, a firm-as-rational-actor would choose only the most profitable investments with the shortest payback periods, or choose among those that lenders – without the same knowledge about energy efficiency – would consider to have low credit risks.

Policies can encourage technology adoption by directly addressing market failures. Positive information externalities associated with energy efficiency technologies can be internalized through financial incentives to technology adopters. Imperfect information and principal-agent problems can be mitigated through information programs that provide energy audits or information about certain technologies. Capital market failures can be solved by financing or loan assistance particularly for energy efficiency projects.

Deviating from the assumption of rational choice, behavioral economics sheds additional insights on the behaviors of energy users from their nonstandard preferences and nonstandard decision-making (Gillingham and Palmer, 2014). Nonstandard preferences include temptation and self-control that favor products with lower upfront costs and most often, lower energy efficiency (Tsvetanov and Segerson, 2013). The endowment effect and loss aversion under uncertainty also suggest a preference for the status quo (Gillingham and Palmer, 2014). Nonstandard decision-making includes bounded rationality, which implies a limited ability to process information, and heuristic decision making, which deviates from pure net-present-value or cost-benefit decision making (Gillingham et al., 2009).

Firms, as economic agents, experience and learn directly from an exchange institution and arbitrage, and may behave more rationally compared to individual consumers, but they are not fully immune to behavioral anomalies (Tversky and Kahneman, 1986). In economic terms, as long as these behavioral anomalies exist, their interaction with other market failures makes the policy efforts to "correct the multiple imperfections" far more difficult than addressing a single one (Shogren and Taylor, 2008). Policies can improve energy efficiency through investment incentives that reduce upfront cost, information programs that assist decision-making, and energy efficiency standards that mandate the use of more efficient technologies and products.

2.2. Strategic Behaviors Under Institutional Constraints

Empirical research shows that firms are heterogeneous in levels of investment inefficiency and preferences for energy efficiency within and across different geographic and institutional contexts, based on revealed preference (for example Anderson and Newell, 2004; Arvanitis and Ley, 2013; DeCanio and Watkins, 1998) or self-stated preference (for example De Groot et al., 2001; Hasanbeigi et al., 2010; Liu et al., 2012; Rohdin and Thollander, 2006; Schleich, 2009). This implies that universal policy efforts discussed above may lead to distortions especially for firms already close to efficient investment levels and not enhance overall welfare. To understand the heterogeneity across firms and contexts requires causal explanations of energy saving decisions that are built upon essential characterization of corporate responses on the one hand, and are embedded in detailed institutional contexts with accurate accounts of policy mechanisms on the other hand.

On broader environmental issues, the management literature often incorporates external contexts and internal organizational processes in rationalizing corporate responsiveness and strategy. Seemingly costly environmental practices can arguably bring competitive advantage to firms. From Porter's dynamic perspective of competitiveness, environmental innovation can create advantage for firms that are subject to well-designed regulations that induce innovation, moving the firms to a position of lower cost or greater differentiation compared with the offerings for non-subject firms (Ambec et al., 2013; Esty and Porter, 1998; Porter and Van der Linde, 1995).

Reinhardt (2000) explores alternative conditions for environmental behaviors to be economically viable – environmental externalities coexisting with asymmetric information and oligopoly. Reinhardt (2000) also explains additional competitive advantages of environmental behaviors beyond direct economic returns, including managing competitors through new rules and regulations, managing environmental risk, differentiating the environmental characteristics of products, and redefining markets.

The literature also invokes institutional theory, which helps to explain the coercive, mimetic, and normative influences of institutions on organizations (DiMaggio and Powell, 1983; Scott, 1987). How firms act upon these influences and position themselves on environmental issues depends on their motivation (Bansal and Roth, 2000), interpretation of the issues (Naffziger et al., 2003; Sharma, 2000), perception of stakeholders (Henriques and Sadorsky, 1999), social networks (Pulver, 2007), and organizational structures (Delmas and Toffel, 2008). Institutions are not unidirectional influential forces, but are also affected by the strategic behavior of firms that have larger bargaining power and more proactive positions (Child and Tsai, 2005).

The effect of firms' internal capabilities on their environmental decisions is more thoroughly explored in research based on the resource-based view of the firm. In contrast to the view of competitive advantage of firms' positioning in an industry, the resource-based view of the firm argues that competitive advantage is sustained by valuable, rare, imperfectly imitable, and non-substitutable resources and capabilities (Barney, 1991), among which environmentally oriented ones are important (Hart, 1995; Hart and Dowell, 2010). The empirical research indicates that environmental performance and strategies are positively correlated with economic performance (Russo and Fouts, 1997), capabilities for stakeholder integration, higher-order learning, continuous innovation (Sharma and Vredenburg, 1998), and process innovation and implementation (Christmann, 2000).

3. Policy Background and Preliminary Framework

With a reversal of national energy efficiency improvement in China in the beginning of the new century and a continuous increase in absolute consumption, the national government enacted a set of policies for energy efficiency. The most significant change was the very first mandatory target of reducing energy consumption per GDP by 20%, which was written into the 11th Five-Year Plan to guide resource allocation and evaluation of government performance (Young et al., 2015). The new policies provide a unique setting to explore business strategies for energy efficiency investment: the policy framework consists of a comprehensive set of policy instruments and detailed policy measures; local government implements and enforces national policies strategically; and firms are likely to have divergent decision-making processes because of their diverse characteristics, such as size, technology level, and relationship with the government. While a detailed review of relevant policies and local implementation can be found elsewhere (Zhou et al., 2010; Zhu and Ruth, 2015), we highlight here the policy setting with regard to the energy efficiency literature, followed by a preliminary framework of firm strategies for further refinement.

3.1. Policies and Local Regulation for Energy Efficiency

The policy measures identified that affected firms' decisions for energy efficiency were examined across four cities in Jiangsu Province of China. These measures are categorized below and introduced in ways that describe how they address market failures and behavioral anomalies that have been found in the literature of energy efficiency economics to cause underinvestment as summarized above.

- **Incentives for adoption**. Both the national and local governments provide firms with *subsidies* as a small portion of their energy efficiency investment, and *rewards* according to the amount of energy saved. The subsidies and rewards help to internalize positive externalities of technology adoption and use. Specifically, efficiency measures that result in the use of industrial waste energy and steam are considered under the same law governing reuse of industrial waste, and, therefore, qualify for annual *tax relief* through the “comprehensive utilization of resources” policy (Zhu and Chertow, 2016b). The repeated tax relief not only facilitates the information dissemination about technology adoption, but also reduces negative externalities associated with using energy, which are not well internalized through Pigouvian taxes or a similar instrument in China.
- **Financing support**. Investment in energy efficiency is encouraged and supported by loan and financing assistance, which may address potential failures in capital markets. In some cases, *loans* are preferentially provided to energy efficiency projects through local government coordination. A more popular financing mechanism is *Energy Savings Performance Contracts* (*ESPCs*). Through ESPCs, Energy Service Companies (ESCOs), exempted from taxation under the national policy, provide financing and sometimes initial management to energy efficiency projects; in exchange they collect all of the cost-savings from the investment or share with the firms during the contract period. Working as a financing mechanism, ESPCs and ESCOs also help to mitigate behavioral concerns about high upfront cost and provide expertise about energy efficiency. ESPCs and ESCOs are a growing part of the finance and management mix in China.
- **Information provision**. Asymmetric information especially in the context of principal-agent problems within an organization is addressed through multiple channels. The largest energy consumers are required and other energy consumers are encouraged to propose their own energy efficiency targets and design energy saving plans, usually through *energy-saving agreements* signed with the governments. As part of an agreement, an *energy saving audit* is conducted to identify energy saving potential and recommend efficiency measures. In less formal *communications*, local regulators also introduce advanced technologies and stress energy saving as an important national policy. These formal and informal channels all help energy efficiency become exposed and important to organizational decisions.
- **Standards and mandates**. Both the national and local governments use standards and direct intervention for energy efficiency and other purposes. Nationally, technical *elimination standards* are designed as a floor below which existing facilities must be retired, or new facilities are prevented from being installed, especially for industries with overcapacity, such as cement and steel. In those industries, total *production capacity caps* are set for a province and its subdivisions that are not allowed to exceed. More broadly, *energy efficiency levels* are set for major energy consuming processes and specific technologies are *mandated* for use. Local governments use *electricity quotas* or *rolling blackouts* to curb industrial electricity use in summer to guarantee residential supply. They also have direct *requirements* for individual firms to upgrade plant and equipment for local environmental management, which sometimes improves energy efficiency, too.

Local authorities not only implement these policy measures for energy efficiency actively, but also can lower the enforcement stringency in some cases of mandatory regulation to respond to firms' behaviors and demands (Zhu and Chertow, 2016a). This derives from the regionally decentralized authoritarian system in China (Xu, 2011), where local authorities are appointed, evaluated, and promoted by the higher authorities and at the same time autonomously take care of economic and administrative governance and policy reforms under their jurisdiction. By taking an authoritarian but responsive approach, they coordinate the progress in achieving local energy efficiency targets with other regulatory issues, such as environmental management, economic development, and employment, seeking to optimize among the regulatory issues (Zhu and Chertow, 2016a).

3.2. A Preliminary Model of Firm Responsiveness

While local governments are in a much stronger position regarding implementation of energy efficiency policies relative to other stakeholders (Eichhorst and Bongardt, 2009; Hu, 2007; Zhu and Chertow, 2016a), firms are not simply reactive. They sometimes assume more proactive positions (Child and Tsai, 2005), take advantage of their political connections (Wu et al., 2012) and lobby (Yu et al., 2014) in policy implementation. Empirical evidence in China shows that firms' responsiveness is not only contingent on policy incentives and enforcement (Liu, 2009; Shi et al., 2008), but also on firm size (Zhang et al., 2008), ownership (Christmann and Taylor, 2001; Wang and Jin, 2007), cost (Eichhorst and Bongardt, 2009; Liu, 2009; Shi et al., 2008), concern for reputation and parent company targets (Eichhorst and Bongardt, 2009), as well as pressures from supply chains (Zhang et al., 2008), communities and NGOs (Liu, 2009).

Combining the institutional context and firm features, a preliminary framework for explaining energy saving behaviors of firms is summarized and proposed for further examination and refinement (Fig. 1). A firm's decision making is contingent on national policies related to energy saving, local interests, and industrial dynamics. These external contexts, combined with internal capabilities of firms, affect their overall motivations. The motivations and contexts, in turn, shape the final choices firms make regarding energy efficiency investment.

The implementation of national energy efficiency policies is delegated to the local governments, affects industrial dynamics – the two larger boxes with dotted lines – and affects firms indirectly. The national policies also directly motivate and shape firms' choices – the small box with

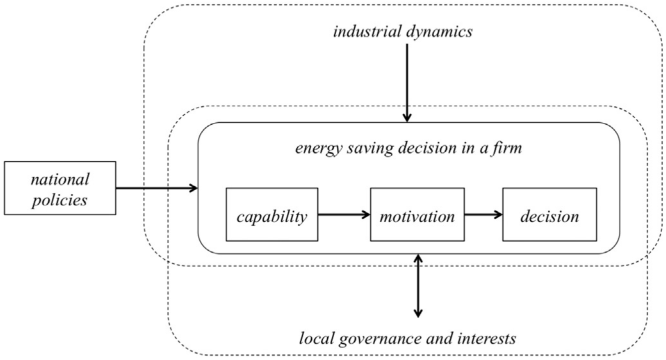

Fig. 1. A preliminary framework explaining firms' responsiveness toward energy efficiency. In the small solid-line box are factors within a firm, and outside the box are industrial, local and national policy influences. A firm is embedded in overlapping contexts of industrial dynamics and local governance and interests, which may differ across industries and locations and are shown by the boxes with dotted lines. National policies influence firms directly and indirectly by affecting the industrial and local contexts.

solid lines – through clearly designed measures. Local governments, while committed to energy efficiency targets, interpret and implement national policies with consideration of their own interests, thereby placing additional impacts on the firms. Policy enforcement is also dependent on firm behavior. Industrial characteristics matter to firm decision-making because different industries feature different market dynamics, expectations and policies, upon which firms observe and respond.

While responses by firms to regulations are associated with a few of their internal characteristics particularly revealed in econometric analysis, the commonly observed characteristics mentioned above – such as firm size and ownership – likely affect final decisions only indirectly. Rather, the decisions are assumed to be driven directly by firm motivations and shaped by their capabilities as the management literature suggests. The capabilities and motivations are in turn dependent upon those indirect factors.

4. Methods

The research objective is to develop structured explanations of firms' energy efficiency decisions contingent on the institutional context. To accommodate the existing literature and the preliminary model, we apply a multiple-case design for analytic generalization. A case is defined as a firm's energy saving strategy over recent years, embedded in which are one or multiple energy saving decisions by the firm as units of analysis. Analytic generalization is based on strategies of descriptive explanations, pattern matching, within-case comparison, and cross-case comparison (Yin, 2014). Through this process, the preliminary model is revised and refined to provide analytic explanations for the energy efficiency decisions by firms.

4.1. Case Selection

The study area is Jiangsu province, which features a diverse industrial economy of extremely large scale, relatively high capacity for policy enforcement, and large regional disparities between the north and south. This single province with a population of 80 million within China is selected for a simple, yet representative institutional setting: national policies are uniformly interpreted from the province to cities, but cities vary in implementation and enforcement according to their interests.

For analytic generalization, 20 cases are selected as in Table 1 based on theoretical replication (Yin, 2014). That is, firms are carefully selected with contrasting internal features or external contexts, so that one would anticipate different energy-efficiency decisions according to the preliminary framework. The important contexts and internal features that guide case selection include location, industrial sector, firm size, ownership, organizational level, and age. The names of case firms and locations are coded to preserve anonymity. Four cases are described in more depth in the Appendix A offering an empirical observation of Chinese firm behaviors.

- The case *locations* consist of one city in the industrializing north (A), with more interest in economic development and less obligation in energy efficiency, and three cities in the industrialized south. Among the southern cities, B has a relatively smaller share of industries in the local economy and a more stringent energy-efficiency target; C has already achieved a high level of energy efficiency; D enjoys more advanced economic development and a stronger industrial sector.
- The four case *industries* are all energy intensive but face different regulatory stringency and industrial dynamics. Cement and steel industries, both experiencing serious overcapacity, follow strict technical

Table 1
List of cases studied.

Industry	Location	Ownership	Number of employees	Corporation subsidiary	Age (years)	Interviewee	Observed number of energy efficiency actions
Cement 1	A	State	800	Yes	15	1	2
Cement 2	A	Private	300	No	35	1	3
Cement 3	B	Private	250	No	30	1	2
Cement 4	B	Foreign	300	Yes	5	2[a]	1
Cement 5	C	Private	800	No	12	3	2
Cement 6	C	Foreign	800	Yes	20	2	2
Steel 1	A	Private	2000	No	5	2[a]	3
Steel 2	B	Private	5500	No	55	2	4
Steel 3	C	Private	400	No	12	2[a]	4
Steel 4	D	State	4000	No	55	2	4
Paper 1	A	Private	500	No	35	1	1
Paper 2	C	State	1400	No	65	1	1
Paper 3	C	Foreign	5600	Yes	20	1[a]	1
Paper 4	D	Foreign	300	Yes	18	2	7
Paper 5	D	Foreign	550	Yes	20	1[a]	4
Chemical 1	B	Foreign	20	Yes	10	1	1
Chemical 2	C	State	4300	No	55	1	7
Chemical 3	C	State	1700	No	65	1[a]	3
Chemical 4	C	Private	700	Yes	35	1	2
Chemical 5	C	Private	400	No	10	1	2

Note: "A" is a city in the north, and "B, C, and D" are three cities in the south. The observed number of energy efficiency actions in each case depends on how an interviewee explained energy saving initiatives in a firm, and therefore may be smaller than the actual number of actions taken by the firm.
[a] Indicates that the interviews were documented by taking notes instead of audio records.

standards to retire old facilities and to control production capacity below regionally based caps. The cement industry is under even higher pressure for capacity control, is extremely homogenous in production, and competes in smaller regional markets. Fewer mandates and more diverse products exist in the paper industry. The chemical industry is much more diversified in technologies and products with higher technical barriers to entry, except for only several processes that experience overcapacity, such as the chloral-alkali process.

- The *internal characteristics* are selected according to their potential to affect a firm's motivation and capability in decision-making. Managers in state-owned firms, for example, may differ from those in private and foreign firms with regard to their interest in energy efficiency investment, and in their formal and informal connections to acquire information and financing support (Wu et al., 2012). Large firms are generally more capable of making economically efficient decisions and are preferred in the financial markets (DeCanio and Watkins, 1998). Independent firms are likely to be more concerned about profits and also more flexible in decision-making processes than subsidiaries of corporations (Rohdin et al., 2007; Schleich, 2009). New firms with recent capital investments are less likely to upgrade their entire plant and equipment than old firms.

4.2. Data Collection and Analysis

The main data source was semi-structured interviews conducted in the 20 firms with 29 interviewees during 2012–2015. Interviewees were firms' chief executives, directors in charge of production, energy management, or environment and safety. Twenty interviews were allowed to be audio-recorded, and for the others, detailed notes were taken. All interviews were in Mandarin Chinese and usually lasted for 1 h in the interviewees' offices. An interviewee was asked first to briefly introduce the firm and its position in the industry, and then to introduce all the energy efficiency initiatives the firm took in the past, and when the decision to undertake each initiative was made. The interviewee was encouraged to describe the decision-making process supporting each initiative in detail, and to highlight the reasons and determinants for the decision, as well as any interaction with the government or the firm's headquarters in the process. For comparison, material conservation and pollution control initiatives and their decision-making processes were also queried. Finally, the interviewee was asked to comment on the general relationship with the regulatory authorities, overall performance of the industry, any potential investments the firm did not make, and barriers to capturing those foregone opportunities.

Before firm-level investigation, interviews were conducted with two provincial officials and nine local officials in the four cities that were in charge of energy saving and related areas, to understand the policy framework, implementation and effects. Background materials about the firms were gathered online throughout the research period, mainly from firms' websites, media coverage, and government archives. These materials include firms' production processes and products, energy and environmental protection initiatives and reports, significant investments, as well as other previous events and future visions. The interviews and materials helped both to set the context for each case and to triangulate evidence from different sources.

The information collected was transcribed, and inputted into the qualitative analysis software NVivo. Chinese transcripts were directly coded into English concepts, to minimize inaccurate translation introduced in the whole research process. Coding started from more descriptive concepts, based on interviews in cement (a sector with highly varied ownership structures) and steel industries (the only sector represented in all four cities examined). Among the major categories of concepts were motivations, policy and government influences, and capabilities as in firms' decision-making frameworks shown in Fig. 1. When too many descriptive concepts were identified in a given category, similar concepts were aggregated and replaced by a new set of concepts at a more abstract level. The causal links were also identified between different categories of concepts within a single unit of analysis, i.e. an energy-efficiency decision process. Follow-up calls with the interviewees were made at this stage when a statement was not clear enough for coding. The process stopped when two to five abstract concepts were identified within each major concept category, and when a consistent causal framework linking different categories of concepts could explain energy saving behaviors.

The descriptive concepts coded for cases in the cement and steel industries were applied to several interviews in the paper and chemical industries to develop descriptive explanations for energy saving. Through aggregation of the concepts again in new cases, alternative analytic explanations were explored, selected, or revised with aggregation or disaggregation. This process was repeated for additional cases and finally led to a robust explanatory framework, whose variations could accommodate all of the cases.

5. Findings

The results suggest that there are two types of firm strategies for energy efficiency, each associated with different sets of motivations, contexts, capabilities, and results. One can be foreseen from the literature of energy efficiency economics, and the other is greatly affected by the local institutional contexts. Whether a firm makes one type of decision or the other depends on the type of policies applied to the firm, which, in turn, mainly depends on the firm's production technology and capacity. Generally, the second strategy involves much more investment in energy efficiency than the first one, but firms with the same strategy invest in different levels of energy efficiency according to the external and internal factors, too. While the general strategies are explained below, four detailed case reports are presented in the Appendix A to provide more specific information about individual firms, including original quotes from the interviewees.

5.1. Type 1: Compliance for Incremental Competitiveness

The first type of decision process, shown in the upper part of Fig. 2, is in alignment with the literature of energy efficiency economics and that of competitiveness described and cited in the beginning of this paper. To improve competitiveness incrementally, firms are willing to make moderate changes to their production by incorporating additional energy-saving equipment, which is based on their informational, organizational

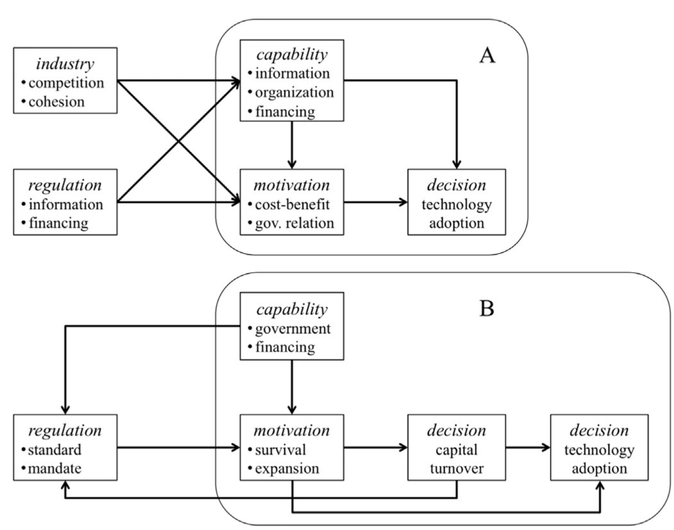

Fig. 2. Two sets of energy efficiency strategies and associated factors in China. Enclosed in the two big boxes are internal capabilities, motivations, and decisions of firms, and outside are external institutional and industrial contexts. Arrows indicate causal mechanisms.

and financing capabilities and driven by policy support and industrial contexts.

The final *decisions* are adoption of energy-saving technologies, which are added to the existing production processes. While some technologies are firm specific, most of them are commonly used within an industry or across industries. As listed in Table 2, the technologies include variable speed drives, waste heat to power, direct heat recovery or insulation, efficiency lighting, materials recycling, furnace gas reuse in the steel industry, and energy management systems for big firms. Most of these technologies have been shown to improve energy efficiency in other firms and usually have short payback periods.

The *motivation* for firms to adopt these technologies is to improve their competitiveness in an incremental way, as shown in Table 3. All but one interview respondent explained their investments in energy-saving technologies as ways to lower production costs and sometimes to improve efficiency and maintain stable production under temporary electricity quota; in a few cases, the respondents could explicitly point out the payback time for the investments. Many respondents considered investments in energy efficiency not only within the framework of cost-benefit calculation, but also as a way to maintain a good relationship with the local governments, which is perceived valuable to long-term competitiveness. In four cases (Steel 2, Paper 1, Chemicals 3, 5), energy efficiency investments were part of the efforts to learn from the leading firms and improve product quality to move ahead and catch up in the industry.

Table 2
Common energy-saving technologies, their payback periods, and financing support in the interviewed firms.

Technology adopted	Firm	Payback in years	Financing support
Variable speed drive	Cement 1	0.5–2	No
	Cement 2–4, 6	N/A	ESPC
	Cement 5	1.5	ESPC
	Steel 1, 2, 4	N/A	ESPC
	Steel 3	0.5	ESPC
	Paper 2, 3	N/A	No
	Paper 4	0.5	No
	Paper 5	0.5	No
	Chemical 2	2	ESPC
	Chemical 5	1	No
Waste heat to power	Cement 1	2.5	CDM
	Cement 2, 4	N/A	ESPC
	Cement 5	2.5	CDM
	Cement 6	3.5	Headquarters
	Steel 2	5–8	Loan/ESPC
	Steel 4	N/A	ESPC
	Chemical 2	4.5	ESPC
Heat recovery/insulation	Cement 3	N/A	No
	Cement 5	2.5	No
	Steel 1	2	No
	Paper 3	2	No
	Paper 4	1	No
	Paper 5	0.5–1	No
	Chemical 1	N/A	Headquarters
	Chemical 4	2.5	No
	Chemical 5	N/A	No
Furnace gas reuse	Steel 1	2	No
	Steel 2	N/A	CDM
	Steel 4	N/A	No
Efficiency lighting	Steel 3	N/A	No
	Paper 4	<1	ESPC
	Paper 5	0.2	Subsidy
Material recycling	Steel 2	N/A	ESPC
	Chemical 1	N/A	Headquarters
	Chemical 2	N/A	No
Energy management system	Steel 2	3	No
	Chemical 2	3	No
Production facility replacement	Cement 2	N/A	No
	Cement 3	4	No
	Steel 2	>2.5	No
	Steel 4	N/A	No
	Paper 1, 2	N/A	No
	Chemical 2	8.5	No

Note: ESPC – energy savings performance contract; CDM – clean development mechanism.

Table 3
List of energy-saving motivations. A firm may have multiple motivations for energy saving and be listed in multiple categories.

Motivation	Examples
Incremental competitiveness	
• Operational profitability	
➢ Lower cost	Cement 1–6, Steel 1–4, Paper 2–4, Chemical 1–5
➢ Quick payback	Cement 1, Steel 1, 3, Paper 3–5, Chemical 2–5
➢ Efficiency improvement	Cement 5, 6, Paper 5, Chemical 2
➢ Stable production	Cement 1, Cement 6, Steel 1
• Government relations	
➢ Energy-saving agreement	Cement 1, 4, Steel 2, 4, Paper 3–5, Chemical 2
➢ Response to government communication	Cement 5, Steel 2, Paper 4, Chemical 1, 2
➢ Response to the policy agenda	Cement 1, 6, Paper 3
• Market position	
➢ Learn from leading firms	Steel 2, Paper 1, Chemical 5
➢ Product quality	Chemical 3
Aversion of risk in survival or development	
• Survival	
➢ Mandatory facility retirement	Steel 4
➢ Expected facility elimination	Cement 2, Steel 2–3, Paper 1, Chemical 2
➢ Local capacity cap and relocation	Cement 3, Steel 2
• Expansion and development	Cement 2, 4, Steel 2, Chemical 3
• New facility approval	
➢ Technology mandate	Cement 2, Steel 2, 3, Paper 2
➢ Performance standard	Cement 2, Steel 4
Others	
• Environmental image	Steel 3, Chemical 4–5
• Compliance within the organization	Cement 4, 6, Paper 5
• Employee working conditions	Paper 4

The motivation is strengthened and final technology choice is shaped by firms' *capabilities* of knowing the technologies, making organizational decisions, and getting finance. Firms vary in their technical knowledge about certain energy-efficiency technologies and the perceived possibilities and potential of energy saving from those technologies. This capability comes from the firm's previous experience in related technologies (Cement 3, Chemical 2), its employees' experience with the technologies from their former employment in other firms (Cement 4, Steel 1, Chemical 5), or its collaboration with institutions of technology expertise (Cement 1, 5, Steel 3, Paper 4, Chemical 3). Making transparent decisions in an organization is important for mitigating the principal-agent problems and prioritizing energy efficiency investments. The capability is strengthened through the use of environmental management systems (Steel 2, Paper 3), conducting cleaner production audits (Cement 5, Paper 5), and being in an organization with energy saving considered an important issue by the headquarters (Cement 4, 6, Paper 5). The firms also vary in the ability of getting desired energy-efficiency investments financed, where lack of financing support, for example, led to delay or failure to adopt heat recovery devices (Paper 4, Chemical 3).

Both the motivation and capabilities are enhanced by external *regulations*, which serve as information provision and financing support. Agreements and informal communications with the governments about energy efficiency prioritized the issue of energy saving. The formal and informal commitments were considered by the interview respondents as essential to their firms' relationship with the governments (Cement 1, 4, 5, Steel 2–4, Paper 3–5, Chemical 1, 2). Energy-saving performance contracts (ESPCs) directly relieved firms' financing constraints and helped to compensate for their weakness in technical knowledge: energy service companies (ESCOs) invested in new technologies, and often provided technical expertise for installation and operation of the technologies (Table 2). Even when firms did not experience any constraint in financing, ESPCs were helpful in reducing the behavioral barriers and concern over uncertainty in expected savings, as firms would not need to make any financial investment. In contrast, investment subsidies showed only minimal effects on technology adoption in individual cases, although these subsidies might have helped to raise awareness more broadly about positive externalities associated with information and technology adoption at an aggregated level.

Industrial contexts matter to firms' internal motivation and capabilities, too. More serious competition makes firms more inclined to adopt energy saving technologies and accept longer payback periods for competitiveness, as in the cases of cement and steel firms. Some respondents (Cement 1, 3, 5, Steel 1, 2) explicitly expressed their concern about overcapacity and low profit in their industries, and the need for energy efficiency to build entry barriers. As a stark comparison, capacity closure, local regulations, and national investment in infrastructure greatly changed supply and demand for cement and has boosted the industry's average profit rate since 2010, which coincided with our interview results that no major energy saving projects were identified after the increase of profit. Those paper and chemical firms (Paper 4, Chemical 2, 3) with more serious competition in their subsectors and worse business performance were also identified with stronger motivation for and more practices of energy saving to reduce cost. In addition, industrial cohesion helps to strengthen the technical capabilities of individual firms, through flow of employees among firms (Cement 4, 5, Steel 1, Chemical 5) and informal communications (Cement 1, 3, Steel 2). Within the most cohesive industry, most cement firms adopted similar energy-saving technologies, and their staffs were familiar with energy efficiency statistics and technology adoption of other cement firms in their region and even in other regions.

5.2. Type 2: Strategic Positioning for Risk Aversion

The second type of decision process, shown in the lower part of Fig. 2, represents the strategic response of firms to local regulation on energy efficiency. To survive or increase market share under strict control of local production capacity, firms bargain with local authorities and seek a preferred position under local regulation, based on their capabilities and superior performance in energy efficiency. Such performance relies on substantial investment in new, more efficient production facilities and adoption of additional energy-saving devices.

Unlike simply adopting additional energy-saving technologies in the first type that yields incremental competitiveness, the second type of *decision* involves replacement of old, small-scale production facilities with new ones of larger scale and higher energy efficiency. In some cases, firms maintained the same overall production capacity by replacing a few of its small facilities with a large one (Cement 3, Steel 2–4, Paper 1, Chemical 2). Elsewhere, a firm's expansion (Cement 2) or entry (Cement 4) into the market was associated with closure of other firms in the same industry and region because of local capacity caps. The use of new production facilities usually was accompanied by installation of other energy-saving technologies, such as variable speed drives and waste-heat-to-power facilities.

The extensive efforts to invest in more efficient technologies are driven by the *motivation* to avoid the risk of being closed or restrained from future development, which, in turn, is primarily caused by local *regulations* that eliminate old, inefficient production facilities and control total production capacity from increasing. The construction and operation of new plant and equipment needs approval, whereby the local government usually mandates additional technology or performance requirements. Because facility replacement (final type of "technology adopted" in Table 2) is firm specific and usually cannot be financed through ESPCs, firms' own financing *capabilities* are essential for them to make the decision of facility replacement or expansion.

Under the Type 1 strategy of energy efficiency, compliance for incremental competitiveness, external factors have unidirectional impacts on the internal decision processes of firms. Under Type 2, the firms' internal capabilities and investment also affect external regulations. Capabilities are not only important determinants for internal decisions, but also indicators that reveal to the local government the firms' prospects in future development or their value to the local community. With a mine, sufficient land, technical experts, and financing capability, a cement firm (Cement 2) managed to get government support by demonstrating its "advantage in the region," and expanded its capacity greatly with the closure of the other 19 cement firms lacking similar capabilities in the same region. By supplying furnace gas for residential use at a price lower than the market level – a contribution to the local community – one steel firm (Steel 4) was able to replace its old furnaces with new ones right above the elimination standard rather than adopt a large-scale furnace as usually required by the government. Lacking this type of contribution to the local community, another steel firm (Steel 2) faced great pressure from the local government to relocate, which was only relieved after its decision to replace old plants and equipment with much more advanced ones and to adopt energy-saving and environmental protection technologies more extensively.

The strategic positioning of firms under local governance is clearly part of the competition for survival and expansion among these actors. One cement firm (Cement 3) was able to survive during the first round of plant closures because of its decision to treat local industrial waste. Such a contribution to the local community, however, diminished as other cement firms could treat not only industrial waste but also municipal solid waste. The firm's production facility was finally suspended in exchange for the expansion of another firm that was larger in scale, had been treating municipal solid waste and wastewater-treatment sludge, and committed to treat hazardous waste, the combination of which was more valuable to local environmental management and local government overall.

Because of great regulatory pressure and strong motivation, firms that fell in the second type of decision process usually invested much more in energy efficiency than firms in the first type, through both replacement of production facilities and adoption of energy-saving devices. But unlike the first strategy where higher external pressures always lead to more energy efficiency investment, strategic interaction in the second type of decision-making suggests that energy efficiency investment is only one type of leverage that firms can use to bargain with local governments to increase opportunities for survival or development. When a firm can make a greater contribution to the local community in other aspects, such as Steel 4 in residential energy supply, it may make relatively less investment in energy efficiency than a firm without this type of contribution, as was the case with Steel 2.

Aside from the two major types of decisions and motivations, there are also cases where firms made energy efficiency investments with concern for their public image, headquarters' requirements, and/or employee satisfaction. These firms are mainly subsidiaries of large corporations, especially multinational corporations. These motivations by themselves, however, did not cause energy efficiency decisions to be made, but rather they were coupled with the motivation for incremental competitiveness.

6. Discussion

Our findings suggest that insights from both energy efficiency economics and corporate environmental management contribute to explanations of firms' investment decisions in the context of energy efficiency regulation. The framework combining these factors helps to improve the understanding of firms' strategies and policy effects. We have been able to contribute to this literature by testing examples from businesses in Jiangsu Province that help to reveal how these results occur "with Chinese characteristics." While confirming common explanations from economics and the management literature, we show particularly that "positioning" in corporate management is not only a strategy in market competition but also a dynamic response to local governance.

6.1. Business Strategies Under Institutional Constraints

Despite the high upfront costs usually required, energy efficiency investment is a win-win practice that brings benefit to firms through long-term cost savings. In a broader sense, many of our cases perform beyond-compliance activities (Portney, 2008) – more energy savings than negotiated targets, more advanced technology adoption than mandates, higher process energy efficiency than standards, and so forth. While compliance is an important driver, so, too, is profit maximization, which, in this case, is focused on reducing production costs. Firms could over comply with what appear to be extremely aggressive policies because the original basis of energy efficiency was relatively low. As predicted by energy efficiency economics, most of the technologies adopted by the firms have been used somewhere else before and demonstrated short payback periods. The managers' concern for uncertainty in payback, lack of financing methods and information are greatly mitigated by ESCOs through ESPCs and to a lesser extent, by government assistance. External influence from the local governments and markets can facilitate energy saving investments by reinforcing firms' motivations for cost saving and good relationships with the government. While aligning business strategies with government interests can be considered to be a motivation for legitimation (Bansal and Roth, 2000), adoption of energy-saving technologies is still an incremental effort, where a single failure in adoption does not raise a concern for legitimation or incur risks of survival or development.

Our explanatory framework suggests that common causal explanations in the literature – firm motivations, resources and capabilities, and institutional contexts – also apply to the Chinese context. But institutional contexts – particularly energy efficiency regulation of the local governments – dominate firm choices between the two energy efficiency strategies by determining the motivations and final decisions. There are minimal, if any, impacts from other stakeholders on decision making for energy saving, which is different from the literature of corporate environmental behaviors in China which finds impacts from customers, local community (Zhang et al., 2008), and large corporations safeguarding their reputations (Child and Tsai, 2005).

We examined active local governance of energy efficiency elsewhere and found it was characterized both by authoritarian implementation and responsive enforcement toward firms' performance and contribution to the local community (Zhu and Chertow, 2016a). This work illuminates behaviors of firms that operate under the authoritarian and responsive regulation of the local governments. Within the context of authoritarian implementation of mandatory instruments, firms cannot mitigate well the risk of being suspended or restrained from expansion through the decision for incremental competitiveness. Rather, they have to be more active and strategic in seeking a better position under local regulation by having larger, more advanced production facilities, higher energy efficiency performance, and sometimes contributions to the local community in other aspects, such as utility supply and waste treatment. More broadly, quite a few interviewees expressed that they would welcome more stringent regulations to eliminate small, inefficient firms and increase entry barriers. While positioning is a common business strategy, firms in our cases seek a distinct position in the context of local governance, rather than the market.

The dominant motivation for competitiveness through energy efficiency investment suggests that firms would keep making energy savings unless or until the external contexts offset the motivations or weaken firms' capabilities. Examples of such external barriers to energy efficiency are subsidies for energy production, macroeconomic plans that stimulate excessive demand for energy-intensive goods and boost the price, or liquidity constraints in capital markets. Generally, larger external pressure leads to a stronger motivation for competitiveness and more investment, but excessive pressures may cause a shift from a decision of compliance for incremental competitiveness to one that features strategic interaction and positioning. While firms usually invest even more to acquire a better position for survival or development, in some cases the leverage from their contributions to the local community in other aspects can be used to compensate for less investment in new, more efficiency facilities (Steel 4).

6.2. Policy Implications

Industrial energy efficiency has been improved at a very rapid pace in China, not only because of firms' motivation for competitiveness, but also for increasingly effective policy design. The multiple policy instruments used in energy saving, however, are not equally effective.

With ESCOs being promoted through tax relief, ESPCs greatly assisted firms to adopt energy saving technologies, especially those with broad application. Three ways that ESPCs were found to be effective were identified in the interviews and are consistent with the insights from energy efficiency economics as follows: first, providing a financing solution for firms not capable of investing in energy-saving projects (Cement 4, Steel 4, Chemical 2), second, reducing firms' risk of investing in projects where payback periods are uncertain or long (Paper 4), and third, informing firms about new technologies and their energy-saving potential (Chemical 2, 4). More direct incentives – energy saving rewards and investment subsidies – were admitted as a factor only marginally influential to decisions in a few firms. Where they were found to be useful, it was usually within organizations where the managers of environmental protection or energy saving could showcase their contributions to the firms (Steel 2, 4, Paper 5). Most other firms enjoyed these incentives, too, but they were free riders and did not consider the incentives large enough to affect their decisions. While these incentives may facilitate information dissemination about energy-saving technologies, this has not been revealed in our research.

Other policy instruments featured more active government engagement and interaction with the firms. On a relatively voluntary basis, negotiated agreements and informal communications between the local government and firms, as well as the general policy agenda for energy saving facilitated firms to prioritize investment in energy efficiency, which mitigated the issue of imperfect information and principal-agent problems. The presence or possibility of other mandatory and coercive approaches available to the government, such as mandatory facility retirement in our cases, has been suggested as a key to the success of voluntary approaches (Segerson, 2013).

Strict mandates to eliminate inefficient, small-scale facilities and establish regional capacity caps not only strengthened the voluntary approach, but also directly raised firms' motivation for risk aversion. To avoid being suspended or restrained from development, firms had to make themselves more valuable to the local government by investing more extensively in larger and more efficient plant and equipment than those seeking incremental competitiveness, and more actively offering services that would benefit the local community. With such active responses from firms, local governments can coordinate among different, fragmented regulatory issues and improve their overall governance for the local community (Zhu and Chertow, 2016a).

While these policy instruments address failures of energy efficiency investment by affecting firms' motivations and capabilities, they also have shortcomings. The positive incentives for energy efficiency – both for financing assistance and for information dissemination – would send the wrong signal to encourage firms to increase output and cause excess entry (Goulder and Parry, 2008), which is especially bad for the cement and steel industries already experiencing overcapacity in China.

As the main measure to curb production capacity expansion, mandatory facility retirement and capacity caps have been generally effective in controlling total capacity, encouraging new, advanced production technologies, and improving energy efficiency. But radical mandatory approaches may also greatly change market structure and reduce competition, which discourages incumbent firms' motivation for cost reduction from efficiency investments. The most telling example is that no major technology adoption was identified in our cases of cement firms in 2010–2012, after the gross profit rate changed from a few percent to as high as 30% due to extensive capacity closure and economic stimulus plans. With large expected profits from the market, firms are likely to ignore energy efficiency investment, which may require temporary suspension and change of production processes and allocation of inputs to activities other than gaining immediate revenue.

Considering the major motivation for competitiveness, market-based instruments, such as energy pricing, can play a more important role in future energy saving: on the one hand, a higher energy price increases the share of energy in production cost, and strengthens the motivation of energy saving for competitiveness; on the other hand, an appropriate design of the policies can internalize the social cost of pollution emissions associated with energy production and consumption, adjusting industrial production to an efficient level rather than encouraging entry and expansion.

7. Conclusion

This paper reconciles the literature of energy efficiency economics and that of corporate environmental management within an analytic framework, and explains firms' energy efficiency strategies under multiple policies based on cases in China's Jiangsu Province. The use of Chinese examples also opens a window on how industrial firms respond to energy efficiency policy directives. Two types of decision processes are identified, featuring different motivations, capabilities, and external factors, especially the regulatory context. In most cases, firms invest in energy-saving technologies incrementally to reduce operational cost, and to maintain positive government relationships when facing voluntary programs or informal requirements. Their decisions are supported by informational, organizational, and financing capabilities, and are facilitated by financing programs and a more competitive and cohesive environment. Alternatively, firms facing stringent regulations on their plant and equipment try to survive or expand with a better position under local governance, through complete facility replacement and technology adoption, and sometimes by making contributions to the local community.

Our cases are collected in four industries from four cities with observations spanning multiple years. Because the four selected industries feature heterogeneity in production processes, products, market dynamics, and regulatory contexts, the cases should be generalizable to other energy-intensive manufacturing industries, such as textiles, nonferrous metals, and petroleum. Similarly, the huge gap in development levels and regulatory stringency across the cities make the findings generalizable to many other regions outside Jiangsu Province. Future research can rely on the dichotomy of firm motivations and decision processes to quantify the effect of external and internal factors on firms' energy efficiency investment.

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Appendix A. Four Selected Case Reports

This appendix consists of four case reports of individual firms, representing different industries, locations, firm sizes, and ownerships. The firms were exposed to different institutional constraints and choice sets. Firms responded to these institutional constraints with alternative energy saving strategies, based on their specific motivations and capabilities.

A.1. State-owned Cement Firm in Location A (C1)

The cement firm was previously a subsidiary of a large privately-owned cement corporation, and acquired by a large state-owned cement corporation in 2006. Up until the interview, it was the largest cement clinker producer in the region, with a total of 20,000 tons per day of capacity on two lines. Cement clinker is an intermediate product formed by forging together clay and limestone in a kiln in the early stage of cement production. One of the two lines was newly established and put into operation in 2012. Because of its scale and stable operation, the firm's profitability was greater than other plants in the region. Its energy efficiency was 105 kilograms coal equivalent (kgce) per ton of clinker produced, much lower than the national agenda to reduce from 115 kgce/ton in 2010 to 112 kgce/ton in 2015 according to the *Industrial Energy Saving Plan in the 12th Five Year*.

The interview respondent from the firm identified two major energy-saving initiatives: a waste heat to power generator being operated since 2008, and variable-frequency drives, which had been sequentially put into operation for multiple production processes since 2008. While power generation using low temperature waste heat was not new in small-scale production lines of cement clinker, the firm was an early adopter among the production lines of 10,000 tons per day capacity. It learned directly from the first adopter, which is a subsidiary of its former parent company. The project's payback period was two and a half years. The adoption of variable-frequency drives was gradual, because efforts had to be made in each production process to evaluate operational status, estimate energy saving potential, and finally estimate the payback period. The payback periods lasted between half a year and two years in different production processes.

According to the respondent, the two initiatives were generally determined in the same framework of incremental competitiveness, with consideration given to three aspects.

- *Energy-saving agreement*. “Because our firm was a demonstration site of Jiangsu Province for energy saving and emission reduction in the 11th five year, we had our own five-year plan for energy saving and emission reduction … without these initiatives, the target could not be achieved… after the adoption of the waste heat to power generator and variable-frequency drives, we achieved the five-year energy-saving and emission-reduction target early.”
- *Payback period*. While the respondent did not explain energy saving in terms of cost reduction directly, he was very conscious of and mentioned the payback periods without being asked when introducing the two energy saving initiatives. He also commented, “to the firm, our payback periods were very short. The investments were paid back in two years, and after two years came benefits … generally if [payback periods are] longer than five years, we won't do it and firms have no incentives. We can accept if it is about three years.”
- *Broader cost-benefit consideration*. Beyond the simple calculation of payback periods, the consideration draws on more stable energy supply and cement production in the context of restrained local electricity quota. “Because in recent years the country was short of energy supply, and especially because a series of constraints on electricity supply was mandatorily enforced in 2009 and 2010, we adopted these initiatives, which were very effective in mitigating our electricity shortage.”

As a state-owned subsidiary firm with large-scale capacity and steady profits in a relatively less developed region, the firm experienced no pressure for turnover of plant and equipment and possessed better capability in making investments. Its payback cut-off of three years is already longer than what many other firms without concern for survival would accept. State ownership not only helps to strengthen the firm's capability in making energy saving investment, but also matters to its motivation. As the respondent commented, "[investment in energy saving] is much larger [in state-owned firms]. State-owned firms not only consider profits, but also, more importantly, national policy and social responsibility. State-owned firms should be role models in their industries."

A.2. Privately-owned Iron and Steel Firm in Location B (S2)

This iron and steel firm is among the top-20 iron and steel firms in China by revenue, with a capacity of more than seven million tons of steel production per year. It was formerly state-owned, became publicly traded in 2000, and its shareholder structure changed from state-held to privately-held in 2003. It had two production lines in operation since 2010, based on two blast furnaces with volumes of more than 2000 m^3 each. It was replacing other small, old furnaces with new furnaces of larger scales at the time of the interview.

After 2000, the firm started to focus beyond pollution control and on cleaner production, environmental management systems, and circular economy. It obtained ISO 14001 certification, conducted cleaner production audits every three years, and became a demonstration site for energy-saving and emission-reduction and a trial site for circular economy standardization.

Because of the firm's large scale and well established environmental management system, its investment in energy saving, like investments in environmental protection and resource efficiency, is usually based on recommendations from cleaner production audits and consistent with the firm's five-year environmental protection plan (which proposes general ideas that correspond to the national five-year plan). The proposed projects, after careful evaluation, are written in the firm's annual fixed capital investment plan. A few major considerations and associated energy saving initiatives implemented between early 2000 and 2012 were identified in the interview, where the decisions involved both strategic positioning and incremental competitiveness:

- *Survival* and *development*, by replacing production facilities, to preempt future mandates for facility retirement or environmental regulation. "Our previous blast furnaces – one of 500 cubic meters volume, another of 450 cubic meters volume – are still consistent with national industrial policy. But one or two years from now, they may not be allowed, so this will put us in an awkward position." "For such a [small] furnace, its gas recollection rate [is low], has no top-gas-pressure recovery turbine, and its product quality is not good, which greatly affects the development of our firm." "Such a [small] blast furnace needs more control for particulate emissions, more control for the input system, so the pollution control is usually not perfect. Therefore, if such furnaces are not replaced in the 12th five year plan period, and are still used, especially considering our proximity to the city … the government will not let you survive, although you may not be in the elimination list."
- *Following additional technology mandates*, by adopting Coke Dry Quenching and electricity generation from steam, after the firm's proposal of facility installation. "The coke dry quenching equipment was a requirement by the environmental protection agency. To be honest, at earlier times the firm always said the less investment the better … when we applied for approval [for new coke ovens] the government said, since you built new ones, you should have everything [that represents high technology, environmental protection, and materials and energy efficiency] prepared."
- *Seeking cost reduction* and *policy incentives*, through electricity generation based on waste heat from the sintering process and waste pressure from the blast furnace based on top-gas-pressure recovery turbine. "The sintering process creates high-temperature flue gas, and we thought if it could be used to generate electricity, the profit would be great … after construction [of the sintering process], waste heat was not used immediately. A few years ago its potential for energy saving was identified, and the firm thought there would be profit and decided to build it." "On the other hand, these efforts have practical effects, because the government not only supports them orally, but also with funding … for example for waste heat and pressure reuse, the government would certify the products for comprehensive utilization of resources, and provides tax exemption … so for our department, doing this brings money, and relieves our firm's burden." "The project for waste heat and pressure utilization, … we financed through government loans for energy saving."
- *Improving profit* and *preempting environmental issues*, through furnace gas reuse and elimination of coal-fired boilers, based on long-term technological experience. "In 20 years, residual gas reuse has been considered of importance [in the firm] … at the beginning only coke oven gas was used, then blast furnace gas … since 1995 or so blast furnace gas was used for steel casting … after 2000 when new basic oxygen furnaces were built, basic oxygen furnace gas was immediately used … [we] signed a contract with the World Bank to use the clean development mechanism, first for one basic oxygen furnace, and then the other." "Through the use of furnace gas, we gradually eliminated coal-fired boilers … From our environmental perspective, a big problem was solved, and we no longer needed to address sulfur dioxide emissions."

In addition to the explanation of four initiatives, one respondent commented on the importance of communication with government, the influence of leading firms, energy-saving agreements, and performance standards.

- For *communication with the government*, he said: "There is an issue of how firms and governments communicate and agree with each other. Such communication and agreement comes from how we understand government's policy needs. If our initiatives can fulfill governments' needs, or even if we can think [about the future needs] in advance, then our communication with the government will be harmonious. You cannot be passive. If you are not on track with [government] policy and thinking, you do everything less easily and cannot develop." "They wanted us to relocate. Later on, after we reported ... our facility replacement plan, our general plan, and our detailed measures and thoughts, they now basically agree with our development plan."
- For *influence from the leading firms*, he said: "Great influence from the industry. When we make plans, aside from the needs of the government, we set our own benchmarks and goals … where are those advanced indicators from? Probably from Jinan Steel Corporation, Baoshan Steel Corporation, maybe not entirely, but we will follow their good indicators."
- For *energy saving agreement*, he said: "The energy saving and emission reduction target is locally disaggregated, and disaggregated to our firm. Our firm will do according to our real situation."
- For the *performance standard*, he said: "Energy consumption per ton of steel production for the 12th five year plan is [required to reach] 580 [kgce]. We were at 619 in 2011, and our plan is to go down to 580."

A.3. State-owned Chemical Firm in Location C (Ch2)

This chemical firm is fully state-held, and produces acetic acid, ethyl acetate and sodium hydroxide. Its production of acetic acid is among the largest in the world. It obtained ISO 14001 certification and had a strategy for a green chemical industry area based on integration of its supply chain.

Seven energy saving initiatives between 2008 and 2012 were identified from the interview, involving both types of decisions.

- *Reducing material consumption and cost*, by collecting and reusing carbon monoxide. "[the respondent's description of the carbon monoxide collection process] this is the entire process, with the major consideration of reducing material consumption… no concern for pollution, because the waste gas used to be flared before being released, but now it relates to carbon emissions too … the project was done in 2008, when carbon emission was not an issue."

- *Improving efficiency*, through boiler replacement with cogeneration. "We had an ethyl acetate facility with large steam consumption, and used three small boilers to supply steam, which had no power generation … we changed in 2008 … the overall efficiency improvement was 20% due to the current cogeneration of heat and power … the major consideration was to improve boiler efficiency."
- *Improving efficiency under production capacity cap*, through production facility replacement. "Later, a new production process … was built in the west [of our plant], and our old cogeneration was in the east … the pressure was not enough, and heat loss in the pipe was huge. So we built a new cogeneration facility in the west … the replacement had to be at the same level of total capacity, because otherwise the government would not approve it… previously the boilers' combustion efficiency was about 75%, and now with fluidized bed boilers the efficiency is 96%. As the pressure increases, the efficiency for electricity generation increases. [Changing] boilers was ultimately to improve combustion efficiency and to improve the efficiency of using coal."
- *Reducing operational cost*, through waste heat to power generation, assisted by technological and financing support. "We collaborated with a US company, because the domestic equipment was not corrosion-resistant enough … It was also done in 2008, when few [firms] did so because of [investment] cost … a lot of water was consumed, and heat was wasted … [investment was paid back] roughly in four to five years, which was forward-looking at that time … because we used an energy-saving performance contract … we did not invest much, and the foreign partner invested more … now almost all firms are doing this, because otherwise your production cost would be high and not competitive with others. Without the benefit of using the low-pressure steam, there is no profit from selling sulfur acid." "The forward-looking view was mainly about reducing consumption and not wasting heat … because Jiangsu has no coal production, our coal is basically transported from northern ports … at a cost of at least more than 100 RMB [per ton of coal] for transportation."
- *Reducing operational cost*, through a few small projects with the help of energy saving performance contracts. "Recently for energy-saving technological changes, because of the firm's funding issue, most of them were done via energy saving performance contracts. For example, adoption of variable-frequency drives for the boiler in the cogeneration plant, adoption of variable-frequency drives for fans, and a customized pump in the methanol plant all have energy saving effects. These projects are relatively smaller than others, have relatively smaller investment, and relatively smaller energy savings. Payback periods are generally two years or so. Our longest energy saving performance contract is for three years."
- *Survival* by replacing the diaphragm cell with a membrane cell in producing caustic soda, to preempt future regulation. "Our diaphragm cell technology was improved … relatively advanced, so it had not been on the elimination list. But following the general trend, it would be eliminated … [as energy consumption for] the membrane cell… is greatly reduced." "Recently the firm's [economic] situation was not very good, but [the project] could not be delayed … the payback period is relatively longer [about eight years according to the estimated energy saving by the respondent]. The upfront cost is relatively large … it was a little bit difficult to finance by ourselves."
- *Achieving the energy saving agreement* through maintaining an energy information management center, based on communication with the government and previous technical experience. "Investment is large, but our firm has invested some. For basic information collection, we have been prepared, so [the government of] the city only recommended that we use this new management system now. Because our technology information has been collected in the centers of every plant … except at the corporate level, our following investment will not be that high. [The government of] city C is also very clear about this, because [the government] came to examine our firm very often and supervise our energy saving, and understood our data collection clearly."

The respondent also commented on the *energy saving agreement* as an important policy constraint: "Every single initiative was not directly connected to each other, but the ultimate goal was to greatly reduce energy consumption and thereby to make sure that we exceed the energy saving target from the province [government]." "[for energy saving in the 12th FYP] we cannot be optimistic, and have relatively a lot of pressure to perform."

A.4. Foreign-owned Paper Firm in Location D (P4)

This paper firm was originally established by an American company in 1996 and acquired by a large Japanese paper producer in 2002. It uses its original papermaking machine with a width of 2670 mm, which was imported from Italy, and produces 18,000 tons of consumer tissue paper per year. Pulp used for papermaking is not locally produced but purchased from overseas.

Seven energy saving initiatives were identified from the interview, mainly following the decision for incremental competitiveness.

- *Reducing operational cost* and *improving the working environment*, through insulation for drying, which benefited from technology dissemination. "Its payback period is one year or so … with current new technology, insulation can help us save energy." "On the other hand, heat was disseminated into the work space and affected the working environment. With the initiative the entire environment is better, and the risk of fire is reduced." "In addition, thanks to the current new technology, which we never thought of but was recommended by the provider. [From the provider] we learned that the technology has matured [and decided to adopt it]."
- *Reducing operational cost* and *following the local environmental requirement*, through fuel switching from fuel oil to gas for a boiler. "First, the market price for fuel oil was increasing rapidly … according to calculations switching fuel would save a lot of money … the city government of D assigned a carbon dioxide quota to firms, and those unused could be traded for additional revenue." "On the other hand, the district had a control requirement for sulfur dioxide. By using natural gas, the stack was removed."
- *Reducing operational cost* by adopting variable-frequency drives. "Of course we considered the payback period of roughly half a year or so. Generally investment within one year [to break even] would be supported." "And to consider maintenance cost, with variable speed, motors do not need to run at full load, maybe 40–50%, which is very effective for protecting motors."
- *Reducing operational cost* by suspending a redundant vacuum pump and using it as backup. "This saved a lot of energy … according to our production process, we tried this new change … for saving energy, and also from the perspective of maintenance … maintenance cost would decrease."
- *Reducing operational cost*, by using evaporative air conditioners. "There was only investment cost, and maintenance cost is just water … the cost of regular air conditioners is much higher."
- *Reducing operational cost*, to follow the trend in the industry to use fewer motors. "… for our industry, some new [firms] use only one motor, and we use two … with one for 300 kilowatts, you think how much [electricity cost is there] for one day."
- *Achieving the requirement for absolute energy consumption reduction* and *improving profit*, through reducing the quantity of output. "Energy saving was required by the city [government], to decrease total energy consumption by 20% … we reached the target. Absolute energy

consumption decreased a lot, but not so much for energy consumption per ton of paper." "We have different product categories, and the average [product weight] has been reducing gradually … with lower per unit product cost, market sale would be easier."

Aside from these initiatives, the respondents commented about *pressure and motivation from the firm's chief director for energy saving*. "The firm's per unit energy consumption is high, so [energy saving] is a concern. The boss has been focusing on this … our machine was imported, relatively better than domestic ones. But compared to the best performance in the industry, compared to Japan, it is not good." On the other hand, the poor economic performance seemed to limit the *financing capability* of the firm, reflected by very short payback cutoff generally and particularly for a financing difficulty in one potential project. "Our boss is supportive of investment with payback periods in one year." "[Talking about one specific technological change] If we could change, we would. But this relates to investment, and relatively big investment is needed."

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