ABSTRACT

Title of Dissertation: THE IMPACT OF ENERY SAVING POLICIES ON INDUSTRIES IN CHINA

Junming Zhu, Doctor of Philosophy, 2013

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Current design and implementation of China's energy saving policies are characterized by multiple, mixed policy instruments and spatially based regulatory disparity. The dissertation replies on interviews, firm-level data, and industry-aggregate data to examine the impact of energy saving policies on firm-level energy saving and industry location in China. Case study research, using interviews with 20 firms in four industries and four locations, is applied to explain firm energy saving behaviors. The case studies show that competitiveness and legitimation are major motivations for energy saving under the policy influence of energy-saving agreements and capacity control and elimination.

Extending from the case study findings, the dissertation examines on the basis of data of firms involved in the Top-1000 enterprise energy saving program the factors that contribute to energy efficiency improvements. Empirical results show that firms with less expansion and no new products are more likely to fulfill greater reduction of energy intensity for both existing and new production capacities. Their

energy savings are driven by the pressure of lower individual and industry profit, higher electricity price and more subsidies, but are not correlated with any behavioral features identified in the previous literature.

Spatially based regulatory disparity may direct industry growth to regions with lower regulation. Analysis of industry aggregate data from 2005 to 2010 confirms policy-induced industry location, and indicates that an 11% employment loss in manufacturing industries is associated with higher energy-saving regulation. The results suggest the need of future policy assistance for energy saving and resource conservation in regions with laxer regulations, and for the reallocation of labor and production.

The dissertation complements the literature on the explanations for the energy efficiency gap, implications of policy instruments on firm investment, and locational impact of environmental regulation. It suggests the effectiveness of combined mandatory, voluntary, and information policies designed to motivate firms and eliminate behavioral barriers, the usefulness of incorporating market-based policy in Chinese energy saving policies to encourage energy efficiency and mitigate relocation, and the need for further research into the cost effectiveness of financial incentives to meet efficiency targets for industries.

THE IMPACT OF ENERY SAVING POLICIES ON INDUSTRIES IN CHINA

By

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Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment of the requirements for the degree of Doctor of Philosophy
2013

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Dedication

to my family

Acknowledgements

I wish to express my deep appreciation to my advisor, Matthias Ruth, for his constant encouragement and support. Matthias provided me with great flexibility to explore my research interests while at the same time with invaluable intellectual guidance, specific comments and suggestions, as well as necessary support in the writing of the dissertation, designing and conducting relevant research, and getting research grants, both in College Park and in Boston.

I am grateful to my committee members – Nate Hultman, Klaus Hubacek, Anand Patwardhan, and Steve Fetter – for their insightful comments on the dissertation and suggestions for future research. The dissertation also benefited from conversations with Cen Qiu, Lei Shi, Elisabeth Gilmore, Yi Niu, Jianzhi Zhao, Weiqiang Chen, Nancy Lee, Onur Ozgun, Yuanhong Tian, Shoufeng Qiu, as well as all those who took the time for interviews and discussions.

I also would like to thank the School of Public Policy at the University of Maryland, and the School of Public Policy and Urban Affairs at the Northeastern University for providing nice environment for me to complete my doctoral studies and dissertation. Part of the data collection was funded by the National Science Foundation's doctoral dissertation research grant.

Finally, I am deeply indebted to my wife, Cen Qiu, for her continuous understanding and support throughout my doctoral study, my incoming daughter, for her quietness so far, and my parents for their encouragement at every step leading to this degree.

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

1.1 Background and research motivation

Reducing energy consumption in absolute terms or for the same amount of services provided has long been an important practice and policy focus in the industrialized countries since the oil crises in the 1970s, and is increasingly important in emerging economies, too. Along with fuel switch, energy conservation and efficiency improvement are also necessary approaches to climate change mitigation. Efficiency improvement has helped major OECD countries stabilize their energy consumption, which would otherwise have been about 50% more (Geller et al. 2006).

Here and throughout the dissertation, energy efficiency is defined as goods or services provided per unit of energy input, while the inverse of it – energy consumed per unit of services or goods – is referred to as energy intensity. Energy conservation is defined as a reduction in absolute amount of energy consumed. Energy saving is more loosely used, referring to energy efficiency improvement, conservation, or both.

As a major energy consumer, industrial sector accounted for 37% of global primary energy use, and contributed for the same percentage of global anthropogenic greenhouse gas (GHG) emission (IPCC 2007). The overall industrial energy efficiency is low, and large potential for improvement is untapped (GEA 2012). Policies have been made to improve industrial energy efficiency and reduce industrial energy consumption in many countries. Like for other environmental and energy policies, industry response and behavior associated with energy efficiency and conservation policies are of great research interests. General themes include the relative effectiveness and mechanism of different policy instruments, the efficiency and cost of certain regulation, the explanations for energy efficiency gap and high implicit discount rate, and induced technological change. Such understanding helps design more effective and efficient policies to address major issues like climate change. While the understanding is ever evolving thanks to the expanding literature, empirical research findings are not always consistent and usually contingent to specific contexts. Innovative policy designs – such as voluntary programs – and policy applications in new institutional contexts complicate the situation.

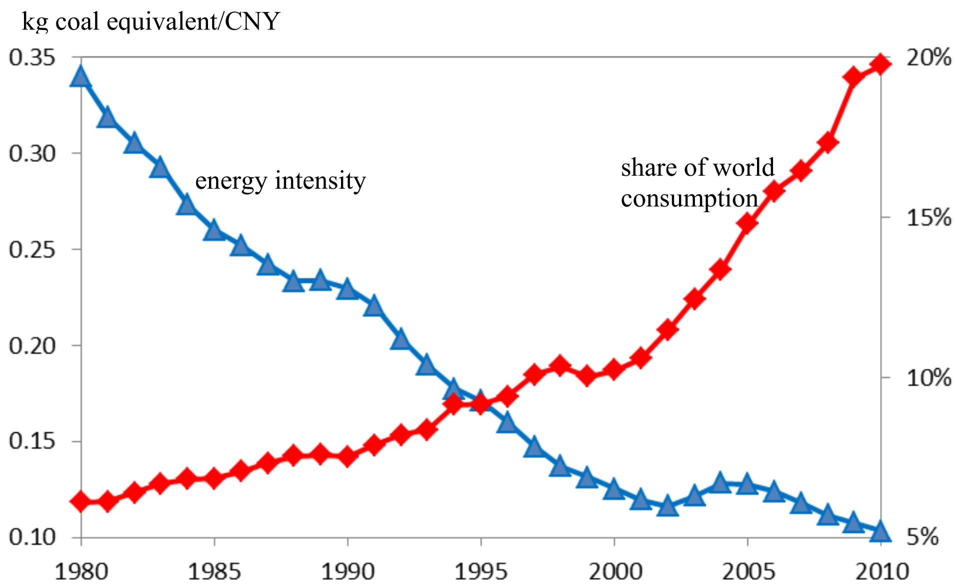

Figure 1.1 China's trend of energy intensity and share of world energy consumption. Energy intensity is measured in kilo gram coal equivalent per Chinese Yuan (kgce/CNY) in 2005. (Data Source: National Bureau of Statistics of China; US Energy Information Administration).

With an intense industrialization process, China experienced a dramatic reversal of long-term energy intensity decrease early this century (figure 1.1). The increase in energy intensity and a booming economy combined led to a greater increase in energy consumption, and associated GHG emission. The central government announced in 2006 an ambitious policy target of about 20% decrease in energy intensity in five years, with comprehensive supporting programs. The policy programs focused mainly on the energy saving in the industrial sector, because it has always been the main source of energy consumption in China (figure 1.2). Although the policies did not prevent China from becoming the largest energy consumer in few years, the increase in energy intensity was stopped and reversed again.

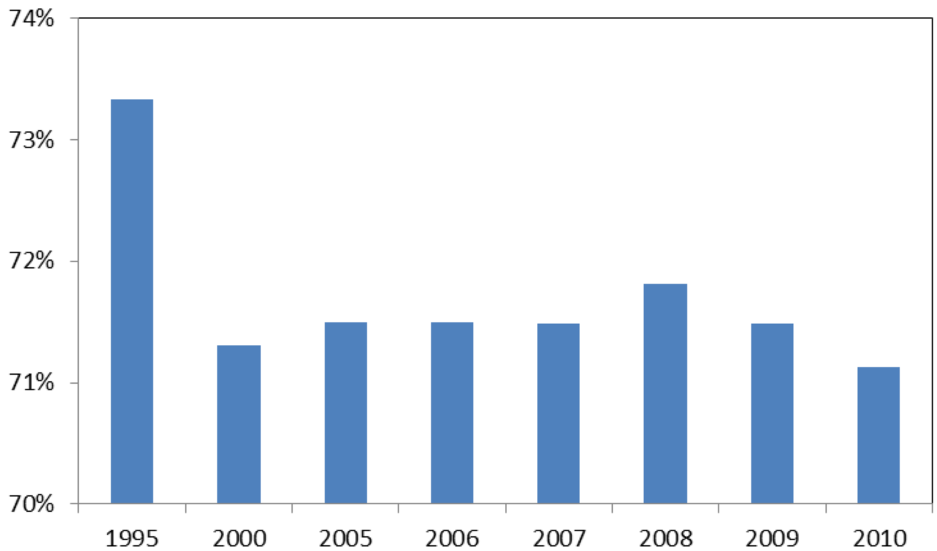

Figure 1.2 The share of industrial energy consumption in China.
(Data source: National Bureau of Statistics of China)

The policy design and implementation in China feature a mix of different policy instruments, multiple-level governance, and regional disparity, which expose challenges and opportunities in research. First, whereas the policy target was generally reached, it is not clearly understood how multiple governments and policy instruments affected industrial firms, and how the firms responded to the regulations. Second, with an accumulation of literature in environmental and energy policy, the transferability of insights in policy effects into the Chinese context is worth investigation, which contributes to the discussion of instrument choice in environmental policy. Finally, from a practical perspective, it is important to generalize the effectiveness and efficiency of the energy-saving policy, which may lead to better policy design in China and elsewhere.

1.2 Research questions

With the motivation to understand the energy-saving policy mechanism and firm response in China, to examine the transferability of insights in environmental policy effect, and to evaluate the cost and broad impact of the current regulation, the dissertation proposes three sets of research questions, each of which is addressed by a chapter below.

1. Why do firms embark on energy saving, according to their own motivations and the institutional contexts they face? This part of research traces the energy-saving practices and particularly the reasons for the practices in 20 firms from four energy-intensive industries in four representative cities of Jiangsu province, China. It establishes an explanatory framework for firm energy saving behaviors contingent to the Chinese context, based on case study research and the findings of firm environmental strategy and environmental policy effects in the literature.

2. What internal characteristics and external factors contribute to more energy savings in firms? This part of research explores the association of energy intensity decrease with different firm and contextual factors, by examining the outcome of energy saving by firms involved in the top-1000 enterprise energy saving program (Top-1000 program).

3. Is industry location sensitive to the spatial disparity of energy-saving regulations currently enforced? This part of research examines the effect of

provincially-differentiated, performance-based regulations of energy saving on manufacturing employment, based on a panel dataset of 20 two-digit industries in 29 provinces during 2005-2010. The magnitude of employment loss between provinces and between industries is measured.

1.3 Significance of the research

The dissertation research contributes to several strands of literature. First, it complements the current discussion of instrument choice and design in energy and environmental policies. While a cost-benefit analysis is highly valuable in this regard, other broader considerations of social and political contexts are also relevant, such as administrative and political issues, firm behaviors, and multiple and overlapping jurisdictions (Goulder and Parry 2008; Gillingham et al. 2009; Anthoff and Hahn 2010; Goulder and Stavins 2011). Especially difficult is the evaluation and design of voluntary policies (Segerson 2013; Blackman 2010). By employing multiple case studies, the dissertation research differentiate contextual factors – multiple governance, multiple regulations, and market structure – from firms' behaviors, motivations and capabilities, and thereby explain more accurately the effects of different policy instruments in a given institutional context. It sets the stage for quantitative analyses of energy-saving policies in China, and informs the discussion of instrument choice about the conditions under which more efficient policies will emerge. The analysis of the Top-1000 program extends the qualitative research by empirically estimating the influences policy and industry context on firm energy saving.

Second, the research relates to the discussion of the energy efficiency gap and investment decisions. The energy efficiency gap or "energy paradox" – allegedly profit-maximizing firms not to exploit all the energy-efficient investments with a positive net present value – has long been a research interest. The explanations have been well-grounded on both market failures and non-market behavioral barriers (Jaffe et al. 2004), but with limited empirical literature and evidence on the latter (Gillingham et al. 2009). By combining case studies and firm level econometric analysis, the research explores the influence of heterogeneity of firms on their behaviors of energy-efficiency improvement, and the effect of policy programs in assisting energy efficiency improvement.

Third, the research complements the examination of the cost of spatially differentiated environmental regulations, and particularly the pollution haven hypothesis, in the interregional and international trade context. While empirical literature concerning the effect of Clean Air Act regulations or the international trade or investment flows usually found significant evidence, other literature usually found insignificant or inconsistent evidence. Departing from the previous literature, this research compares the location effect of regulatory policy with that of market policy, explores different measures of regulatory stringency, takes into consideration spatial linkages of manufacturing location, and uses a panel dataset that corresponds to the regulatory variation across provinces, across industries and through time.

Besides the intellectual aspect, the research also helps evaluate the effectiveness and broad impact of the current energy-saving regulations in China, by investigating the policy effect on firm energy savings as well as on industry location.

More effective policy making will help China, the largest energy consumer, reduce energy demand and mitigate GHG emission. Large co-benefits can also be expected, because reduced energy consumption associate with less emission of pollutants, such as particle matters, SO_2, and NO_x. Understanding the location effect of the policy is important too, because the redistribution of energy-intensive industries in provinces with laxer regulations, generally the west, will raise the demand for water and other resources in those regions, cause a threat to the local sustainability, and reduce long-term energy saving potential. In addition, the cross-country effect of increased regulation may lead to potential carbon leakage and loss in competitiveness. Depending on the magnitude of inter-province relocation and cross-province decrease in energy-intensive industries, additional policy programs may be needed.

1.4 Organization of the dissertation

The organization of the dissertation is as follows. Chapter two is a comprehensive review of the energy-saving policies in China that affect industries. It begins by briefly introducing energy-saving policies in other countries, and then reviews individually the policy programs in China. Because multiple policy instruments are employed, the policy programs are classified according to the policy instruments they rely on. The introduction of another policy feature – spatially based disaggregation of policy targets and implementation – ends the chapter.

Chapter three explains why firms make energy-saving practices in China according to their motivations and the contexts they face, based on case studies of 20 firms from four energy-intensive industries in four representative cities of Jiangsu province, China. It begins by reviewing previous, relevant explanations and research, and thereby setting up an explanatory framework. The research method is introduced next, including research design and strategies, case selection and description, data collection, and data analysis. The findings – major motivations of firms, major policy contexts, and a refined explanatory framework – are demonstrated. The chapter is ended with a brief discussion and summary of policy implications.

Chapter four explores the association of the decrease in firm energy intensity with firms' internal and external contextual factors, by combining the outcome of energy saving in firms involved in the Top-1000 program with the China industrial enterprise database. It begins with a brief review of the previous literature concerning energy demand and investment decisions in firms. The following two sections introduce the data used and empirical specifications, respectively. The fourth section shows the results for the factors that explain firms' energy intensity change through time. The chapter is ended with a brief discussion and summary of policy implications.

Chapter 5 examines whether provincially-differentiated, performance-based regulations of energy saving affect manufacturing employment in China, based on a panel dataset of 20 two-digit industries in 29 provinces during 2005-2010. It begins with a brief review of the previous literature regarding the pollution haven hypothesis and the cost of differentiated regulations. Data and empirical specifications are explained next. Results are then displayed, with one set from baseline specification, one set taking into account spatial autocorrelation, and one set with qualitative policy measures and estimation for nation-wide effect. Similarly, a brief discussion and summary of policy implications ends this chapter.

Chapter 6 concludes the whole dissertation, with discussion of its contribution to the literature and implication for policy making.

Chapter 2 Review of the energy saving policies in China

2.1 Energy saving policies for the industrial sector around the world

Before introducing the energy-saving policies in China that affect industries, this section reviews energy-saving programs for the industrial sector in other countries, because these predecessors are likely prototypes for the policy-making in China, and share some similarities with the programs in China. They help understand the policy in China, and the research about these policies help develop propositions and explanations for the policy effect in China.

To foster a policy comparison, these policies are organized by the instruments used, rather than the countries where they are implemented. In general, the types of energy-saving policies include mandatory regulations and standards, financial incentives, voluntary programs and agreements, as well as information and technology programs.

2.1.1 Voluntary programs and agreements

The voluntary programs, particularly negotiated energy-saving agreements between a government and industries, are widely endorsed by policy makers over the world (Segerson 2013). Other initiatives of similar nature – unilateral self-regulation of firms, and public programs unilaterally designed by regulators to invite firms to follow standards and enjoy rewards – are less relevant in the industrial energy saving context and not focused in the review. The agreements usually cover a period of five to ten years so that strategic energy-saving investments can be planned and implemented. Depending on the presence of binding policies or future regulatory threat, these programs can be classified as completely voluntary programs, programs that use the threat of future regulations or taxes as motivations for participation, and programs that are implemented in conjunction with existing tax policies or regulations (Price 2005). Detailed programs usually vary in their coverage of industries, target-setting, complementary policies, and program performance.

A typical voluntary program with only threatened regulation is the Long-Term Agreements in the Netherlands, with a goal to reduce energy intensity for the whole manufacturing industry by 20%. Individual agreements were negotiated between the Dutch government – the Ministry of Economic Affairs and the Netherlands Agency for Energy and the Environment – and 30 industry sectors which in aggregate accounted for 90% of the Dutch primary energy use, with most of the targets for 20% energy-intensity reduction; the sector associations in turn encouraged member firms to join the program by signing a letter of accession, and the participating firms covered on average 92% of the primary energy use in these sectors (Farla and Blok 2002). In exchange for their energy-saving efforts, the firms enjoyed tax rebates, subsidies, technology support, and a relief from additional regulations (Geller et al. 2006; Price 2005; Abdelaziz et al. 2011). The final reduction in energy intensity is 22.3% (Abdelaziz et al. 2011), and a survey indicates that 27-44% of the firm energy savings can be attributed to the program (Rietbergen et al. 2002). A successor policy – Covenant Benchmarking Energy Efficiency – requires the energy-intensive industries to belong to the most efficient in the world, with the government refrain from introducing additional policies (Phylipsen et al. 2002).

Denmark and the UK both implemented voluntary programs with the presence of a tax policy. In Denmark, individual firms can choose to make agreements with the Danish Energy Agency, usually lasting three years, to invest in energy-saving projects identified by energy audit report and to improve energy-management activities; in return, they enjoy a lower CO_2 tax rate (Bjørner and Jensen 2002; Johannsen 2002). The agreements are found to yield a significant reduction in energy demand of the participating firms empirically (Bjørner and Jensen 2002); they are considered effective in preventing free-riders , but the search costs and the administrative costs are considered high and the diffusion of knowledge between firms limited (Johannsen 2002). In the UK, the targets were negotiated between the government and 44 industrial sectors, with firms individually signed up within the sectors. Depending on the sectors' choice, the targets were set as either an absolute reduction or a reduction in intensity, and either for energy use or for carbon emission. Firms and sectors achieving their targets can enjoy reduced rate of Climate Change Levy. The fulfilled reduction is much larger than the initial targets, and the overall environmental and economic benefits are larger than that from a flat-rate tax, because of an "awareness effect" arising from the focus on the potential for cost-effective improvements (Ekins and Etheridge 2006; Barker et al. 2007). Such an awareness effect, however, is inconsistent with the experience in Denmark.

In general, completely voluntary programs are considered relatively weak and ineffective due to the lack of existing or threatened regulatory structure and strong political will (Segerson 2013). For example, no significant difference is found between participants and nonparticipants in the reduction of their emissions for the

Climate Challenge program in the US (Delmas and Montes-Sancho 2010). An exception is Japanese Business Federation's voluntary action plans, for which empirical research shows 7% increase in energy-efficiency investment due to targets of absolute reduction in energy use or CO_2 emission, and no effect from intensity reduction targets (Sugino and Arimura 2011).

2.1.2 Financial and economic incentives

These policies include tradable emission allowance, energy taxes, tax breaks, and investment subsidies and loans. The biggest tradable emission allowance system is the European Union Emissions Trading System, which has a positive but at most moderate effect on reducing carbon emissions. The experience with taxing GHG emissions or energy use is still limited (Worrell et al. 2009). Notable examples, as mentioned earlier, are the Climate Change Levy in the UK, which applies to all non-household use of fuels by their type, and the CO_2 tax on trade and industry in Denmark, corresponding to around 15% of electricity cost, 23% of the fuel oil cost, and 35% of the coal cost. Investment-based incentives – tax breaks, subsidies, and loans – are more popular and often used along with voluntary programs.

Although not as popular as voluntary programs, these financial instruments should be more cost-effective than mandatory regulations in conventional economic terms, because they can more flexibly engage more channels for emission reduction and lead to similar marginal costs of abatement across firms. However, their cost savings compared to mandatory regulations vary greatly depending on the detailed policy arrangement and the heterogeneity between firms (Anthoff and Hahn 2010).

Particularly, investment subsidies, tax breaks and loans for energy savings may encourage excess entry and thereby cause too much savings from technology change and input substitution, and too little from output reduction, compared to using taxes or tradable allowance (Goulder and Parry 2008).

2.1.3 Mandatory regulations

Mandatory, command-and-control regulations for energy saving are even less used. They include technology mandates and performance standard, which usually apply to specific facilities, such as motors and boilers. Examples include the Federal Motor Efficiency Performance Standards in the US and the Energy Efficiency Regulation in Canada (Abdelaziz et al. 2011). While the mandatory regulations are the least flexible instruments, performance standards are relatively more flexible and cost-effective than technology mandates at the firm level, because a firm can reach the same emission reduction without necessarily using certain required technologies.

2.1.4 Information and technology programs

Unlike the previous policy instruments which address the negative environmental externalities directly, the information and technology programs tackle the externalities in technological change and behavioral barriers, which associate with the innovation, diffusion, and adoption of energy-saving technologies.

Information is important for technology diffusion and adoption, because on the one hand, inadequate information may cause uncertainty and underinvestment in energy-saving technologies, and on the other hand, information flow may lead to positive externalities associated with learning by using that benefit later adopters (Jaffe et al. 2004). One example of information program is industrial energy audits, which are usually provided to small and medium sized firms at a lower price or for free, like in Japan, to help them identify energy-saving potentials and adopt appropriate technologies in a cost-efficient way.

There are also positive externalities in initial innovation and later improvement through learning-by-doing that spill over from the firm making innovations to other firms. Because of the externalities, private firms do not have enough incentives to invest in innovation to the level of social optimum. Therefore, the government tends to fund research, development, and demonstration projects, usually in partnership with the industries, such as in the US, Japan, and some European countries (Geller et al. 2006). Support is also given to the adoption of major energy-saving technologies, such as the combined heat and power.

2.2 Recent energy-saving policies in China

Energy conservation policies have been implemented and evolved greatly since the 1980s, as shown in Table 2.1. They include generally proposed ones like in the national social and economic development plan every five years by the state council, and specifically designed ones for different sectors and industries. The policies focus mainly on the industrial sector, especially heavy industries, which consume most of the energy. Three policy programs in China are worth highlighting: the energy saving and emission reduction target and its comprehensive work plan, the top-1000 enterprise energy saving program, and closing outdated production capacities. The latter two programs are designed to ensure the fulfillment of energy saving target proposed in the first program, and can be considered as part of the first program. They jointly encouraged great energy savings in industry.

Table 2.1 Selection of comprehensive energy conservation policies in China.

Time	Policy
1986	Interim regulation of energy-saving management
1990	Plan of energy saving in the 8th five year
1991	Regulation of grading and upgrading of energy-saving management for enterprise
1995	Plan of energy saving in the 9th five year
1996	Regulation of technological innovation projects of energy saving and utilization
1996	Regulation of supervision of energy saving of the ministry of coal industry
1997	Law of the People's Republic of China on Energy Conservation
1999	Regulation of energy saving of key energy-using units
2000	Regulation of energy-saving utilization of civil construction
2001	Regulation of electricity saving
2005	Medium and long term plan for energy conservation
2006	11th five year plan
2006	Implementation measures of the 10 key projects in the 11th five year plan
2006	Implementation guidelines for top-1000 enterprise energy saving program
2007	Comprehensive work plan for energy saving and emission reduction
2007	Revision of the energy conservation law
2010	12th five year plan
2011	Comprehensive Working Plan of Energy Saving and Emission Reduction in the 12th five year plan
2011	Top-10000 enterprises energy saving and decarbonization implementation plan

(Source: Yuan et al. 2009; Zhou et al. 2010 and author composition)

2.2.1 Energy Saving Target and Comprehensive Work Plan

As the most important part of China’s energy saving and emission reduction (ESER) target, a 20% reduction in energy intensity, measured as coal equivalent consumed per unit GDP, by 2010 relative to 2005 base was set, first by the Chinese Politburo in November 2005 and then officially written in the 11th Five Year Plan (FYP) for the National Economic and Social Development in March 2006. The 20% national target was disaggregated into provincial targets in late 2006, ranging from 12% to 22%, through a negotiation process between central and provincial governments based on 2005 provincial energy intensities (Price et al. 2011).

The 11th FYP and the following comprehensive work plan of ESER by State Council incorporated and proposed a few programs to guarantee the reduction target to be met: ten key conservation projects, buildings energy efficiency standard, top-1000 enterprises energy saving program, structural optimization and small plant closures, appliance standards and energy-efficiency labels, and so on (Price et al. 2011). The 12th FYP proposed a reduction of energy intensity of 16% by 2015 on the 2010 base (State Council 2011).

For industries, the national and provincial energy-intensity targets were fulfilled through administrative and voluntary, financial, and information and technology measures. The provincial targets were disaggregated along the administrative levels into cities and counties; firm-level energy-saving agreements were reached between large energy-consuming firms and the local governments where they locate; and the fulfillment of these regional and firm targets were linked to annual rewards, honors and officials’ evaluation and promotion (Zhou et al. 2010).

Financial instruments included energy saving rewards and rebates, tax exemptions for energy-saving investment, and surcharges in electricity price for inefficient facilities (Zhou et al. 2010). Industrial instruments included product-specific and technology-specific energy-intensity targets and the elimination of outdated production capacity.

2.2.2 Top-1000 Enterprise Energy Saving Program

In the 11th FYP period, the Top-1000 Enterprises Energy Saving Program (Top-1000 program), launched by the National Development and Reform Commission (NDRC), set conservation goals for 1,006 large-scale enterprises that each consumed a minimum of 180,000 ton coal equivalent (tce) in 2004 in nine major energy-consuming industries, including iron and steel, non-ferrous metals, coal mining, electric power generation, petroleum and petrochemicals, chemicals, construction materials, textile, and pulp and paper (NDRC 2006). The final energy consumption of these enterprises was 670 million tce (mtce) in 2004, accounting for 33% of the national energy consumption and 47% of industrial energy usage (NDRC 2006).

The Top-1000 program intends to significantly improve the participating enterprises' energy efficiency, with the energy intensity reaching domestic advanced level and some enterprises reaching international or industry advanced levels, so that to realize savings of 100 mtce during 2006 and 2010. All the enterprises with energy consumption of 180,000 tce in 2004 were included; firms were dropped out of the program only under the condition of mandatory closure, bankruptcy, mergers, or major changes in production and energy use.

The energy-saving targets for each firm were preliminarily set by the NDRC because of the time constraint, and aggregated for each province. Each participating enterprises then negotiated and signed an agreement with its corresponding government for the detailed target and energy conservation plan. The main measures include energy audit, conservation plan, energy-saving technology promotion, and replacement of inefficient production processes. Because the program is seriously implemented and the participating enterprises accounted for a large share of total energy consumption, the Top-1000 program is estimated as the largest contributor among the energy saving programs (Price et al. 2011), and has saved 165 mtce during 2006 and 2010 (NDRC 2011b). The corresponding program during the 12th FYP period, 2011 to 2015, expands to roughly 17,000 enterprises, each of which consumes more than 10,000 tce annually, with a goal of saving 250 mtce (State Council 2011; NDRC 2011a).

2.2.3 Industrial structure adjustment and outdated capacity closure

Like the Top-1000 program, closing outdated production capacity is planned clearly and consistently during the recent years. It has been focusing on 13 energy-intensive industries in the 11th FYP period (State Council 2007), and 19 in the 12th FYP period (MIIT 2011). The closure is part of the comprehensive energy saving plan, and they are disaggregated into industries, as shown in table 2.2. These targets are also reflected in each industry’s development plan, with detailed technology-based capacity control and elimination. Further disaggregation of the industry-specific targets to years and enterprises and serious implementation by the governments were required.

Table 2.2 List of planned closure of outdated capacity.

Industry	Unit	11th FYP targets	12th FYP targets
Electricity	GW	50	-
Iron	Mt	100	48
Steel	Mt	55	48
Electrolytic aluminum	Mt	0.65	0.9
Iron alloy	Mt	4	7.4
Calcium carbide	Mt	2	3.8
Coke	Mt	80	42
Cement	Mt	250	370
Glass	M weigh Cases	30	90
Pulp and paper	Mt	6.5	15
Alcohol	Mt	1.6	1
Monosodium glutamate	Mt	0.2	0.182
Citric acid	Mt	0.08	0.0475
Copper	Mt	-	0.8
Lead	Mt	-	1.3
Zinc	Mt	-	0.65
Leather	M standard piece	-	11
Textile printing and dying	M meter	-	5580
Chemical fiber	Mt	-	0.59
Lead-acid battery	G VAh	-	7.46

(Source: State Council 2007, MIIT 2011)

The enforcement is through administrative pressure and energy pricing. Depending on the local needs, however, the government maintains some flexibility in enforcing the capacity control and elimination, as reflected in the later research.

2.3 Policy features

Two important features in the design and implementation of the energy-saving policy in China are the use of multiple and mixed policy instruments, and the spatially based regulation. They are closely related to the research in the following chapters, and are explained here.

2.3.1 Multiple, mixed policy instruments

For industries, the national and provincial energy-intensity targets were fulfilled through mandatory, voluntary, financial and economic, and technology and information measures. They were sometimes mixed in implementation, and not easily differentiated.

A large part of the policy was enforced through administration and negotiation, which is usually neither completely mandatory nor completely voluntary. Close to the mandatory side were the elimination of certain production process, capacity control, and energy efficiency performance standard, all of which were specific to some industries and technologies. The target setting for energy saving at the provincial, municipal, and county levels were usually negotiated between the higher and lower level government, but without much flexibility. At the firm level, the top-1000 energy consuming firms were mandated to commit to energy saving, but the detailed amount of energy saving, calculation method, and energy conservation plan were negotiable. Other firms were mainly involved in a voluntary manner. Local specific policies might vary greatly in the degree of mandating.

Financial and economic instruments include fiscal policies, tax policies and energy pricing. The central government had allocated $41.8 billion CNY by 2008 to improve energy efficiency (Zhou et al. 2010). Enterprises making energy savings could acquire either reward according to the energy they saved (200-240 CNY/tce) or rebate as a portion of their energy saving investment. Energy service companies offering energy saving performance contract would get even higher reward during 12th FYP period. Enterprises making qualified investment in energy-saving projects and equipment can receive corporate income tax exemption for 3 years and a 60% reduction for additional 3 years (Zhou et al. 2010). These financial incentives were also designed to support the mandating and voluntary energy saving in the Top-1000 program, and the adoption of energy-efficiency technologies.

Tax rebates for exporters, which had long been used to encourage export, were reduced for those exporting energy-intensive products (State Council 2011). Differentiated energy pricing was enforced for energy-intensive industries and enterprises and facilities with higher than standard per product energy consumption, in order to encourage efficient ones and to phase out inefficient ones.

Technology and information instruments include formal ones such as the Ten Key Conservation Projects, which promoted the adoption of ten energy efficiency technologies, with the support of financial subsidies through the central, industry-specific list of recommended technologies, and energy audit, which was required for the firms in the Top-1000 program but promoted more widely. On the other hand, informal communication and recommendation was also widespread, because the local governments needed the energy saving efforts from firms under their jurisdiction to fulfill regional targets, and worked with those firms closely.

2.3.2 Spatially based regulation and variation in regulation stringency

The energy-saving policy has been implemented in a top-down manner, with each level government had its own energy intensity target that were needed to reach by 2010. Besides the target, local government was flexible in the policy implementation. Because the targets were designed in terms of percentage decline based on the former performance, huge difference in the intensity targets existed between regions. This encouraged the local government to interpret, design and implement energy-saving policies with different stringency levels, which also affected different industries to varying degrees across regions.

Figure 2.1 demonstrates the energy-intensity targets that were required to reach by 2010 for the provinces. The least stringent target (Ningxia province, in dark black) had an intensity level more than five times of the most stringent (Beijing, in white). A lower intensity level implies higher production standard and higher cost associated with marginal reduction in energy consumption. Therefore, provinces had to implement more serious regulations to fulfill targets with lower energy intensity level.

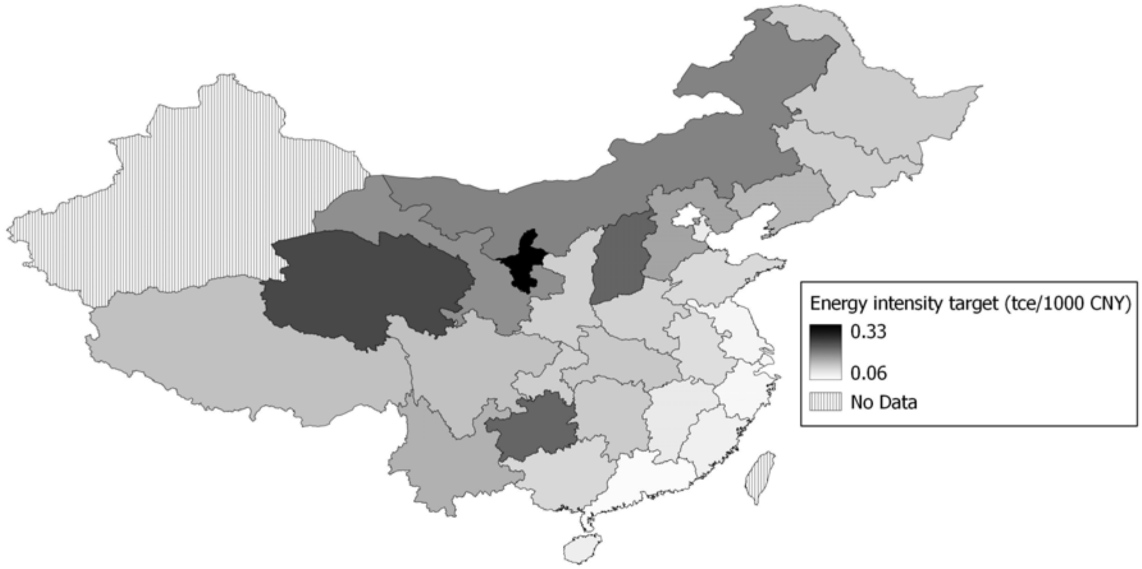

Figure 2.1 Energy intensity targets for province-equivalent administrations in 2010. (Data source: the NDRC)

In addition, the provincially differentiated regulation might also produce specific regulatory variation in some industries. Industries have different energy intensity levels, as shown in figure 2.2. While in general, energy intensive industries should be more stringently regulated compared to less intensive ones nation-wide, the same industry might be treated differently in different regions, because its contribution to the direction and magnitude of energy intensity change depends on both the industry's and the province's energy intensity levels. As a simple example, the industries on the left side of figure 2.2 had intensity level higher than all provinces, and might be regulated by most of the provinces; the industries on the right side had intensity level lower than all provinces, and were not likely regulated. But the industries in the middle had intensity level higher than the stringent provincial targets, and lower than the lax ones, and therefore were very likely regulated to different extents in different provinces.

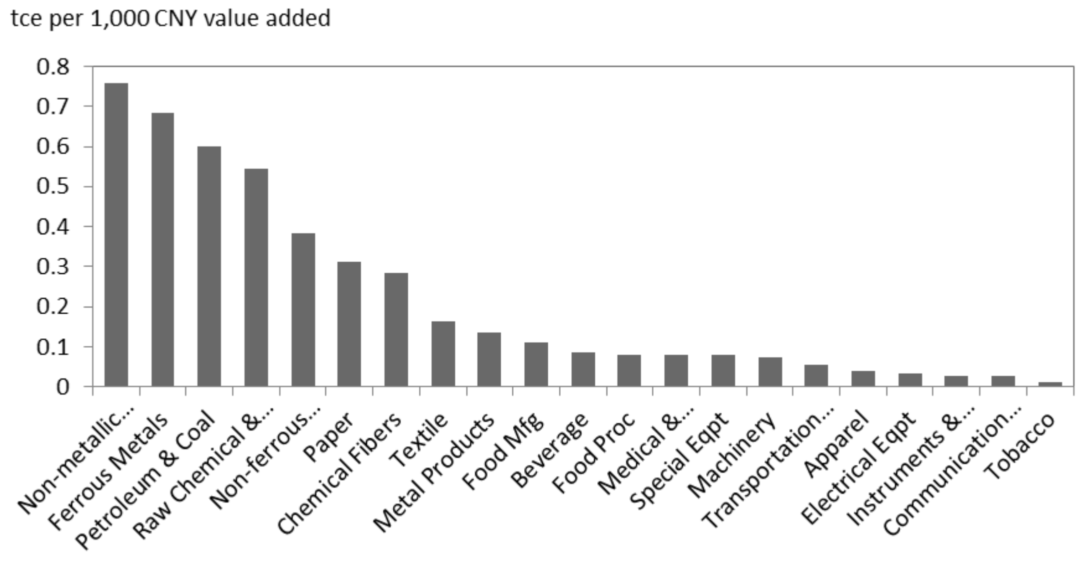

Figure 2.2 Energy intensity of manufacturing industries in 2005.
(Data source: China Industry Economy Statistical Yearbook, China Energy Statistical Yearbook)

Chapter 3 Motivations and contexts: Why do firms save energy?

Under the context of China's energy-saving policies introduced in the previous chapter, particularly the implementation of multiple, mixed policy instruments, this chapter explains why firms make energy-saving practices with regard to their own motivations. The general research question can be further specified into three related ones:

- What are the major motivations for firms to save energy?
- What are the major regulatory influences that induce firms to save energy?
- How do firms respond to the identified regulatory influences according to their motivations?

In answering these questions, an explanatory framework for firm energy saving is built up and refined, contingent to the context in China, based on interviews in 20 industrial firms and within and between case analyses. The framework not only explains industrial energy saving in China, but also identifies important policy instruments and institutional agents that influence the process. It on the one hand helps predict firm behaviors under different policy instruments and varying governance, and on the other hand directs the policy making to more effective ways of reducing industrial energy use.

This chapter is organized as follows. By reviewing two strands of relevant literature, the next section proposes a preliminary explanatory framework for firms' energy saving. Section two introduces the design of research method and the selection of cases. The findings are analyzed and reported in the following section with regard to the three research questions above. Discussions and policy implications are summarized in the last section.

3.1 Preliminary explanations

Two strands of research contribute to a better understanding of firms' energy-saving decisions, one from the environmental economics literature and the other from the management literature. This section reviews them respectively, and then tailors the findings into the Chinese context for a preliminary explanatory framework for firms' energy saving.

3.1.1 Energy efficiency gap and investment barriers

Industrial firms reduce energy consumption and improve energy efficiency generally through management – energy audit, energy information system, training, and housekeeping – and technical change – from replacing the whole production line to smaller ones like variable speed drives and energy-efficient lighting. From an economics perspective, profit-maximizing firms should exploit all the energy-efficient investments with a positive net present value. In reality, however, it is frequently asserted that some energy-efficiency technologies, even if cost-effective, are not fully employed in firms. This phenomenon is termed "energy paradox", or "energy efficiency gap".

Environmental economists explain the perception of such a gap between real efficiency level and social optimum level based on market failure and behavioral barriers (Gillingham et al. 2009; Jaffe et al. 2004). Sources of market failure include inadequate information, environmental externalities, broader innovation and adoption externalities, liquidity constraints in capital markets, and issues related to energy supply pricing and security. Behavioral issues include irreversibility and uncertainty in investment choice, bounded rationality, and heterogeneity in energy users.

In general, these issues have all been considered as barriers that cause slow diffusion of energy-saving technologies. Therefore, relevant here is the identification of the various barriers in the practical contexts, usually by surveys. Table 3.1 collects the top factors identified from these surveys. Following Weber (1997), they are grouped as institutional, economic, organizational, and behavioral ones. The former two are more related to the market failures and potential policies to correct externalities, while the latter two are more related to the behavioral aspects. It should be noted that the factors are grouped mainly for the ease of demonstration. They are more interdependent and not easy to separate in the real context.

It can be observed that there is not a consistent set of determinants for firms' energy saving identified across the survey studies. The inconsistency may reflect the different research-specific focuses and research designs of the individual researchers. Theory-based models or frameworks are usually not used. Therefore, the identified determinants are just aggregated together by each study. They may serve for their own, specific research objectives and as good indications for future research. But they do not enable a coherent understanding of how the external and internal factors determine firms' energy saving, whether for each research setting specifically or generally across studies. More consistent with the environmental economics perspective is the empirical studies about technology adoption and diffusion. These studies are reviewed in the next chapter because of their closer connections with the second research question.

Table 3.1 List of determinants for firms' energy saving.

	De Groot et al. (2001)	Rohdin &Tholl-ander (2006)	Rohdin et al. (2007)	Tholl-ander et al. (2007)	Sardi-anou (2008)	Schl-eich (2009)	Hasan-beigi et al. (2010)	Tholl-ander & Ottosson (2010)	Liu et al. (2012)
country	NLD	SWE	SWE	SWE	GRC	DEU	THA	SWE	CHN
institutional									
access to capital			×	×	×				
information		×			×	×			
incentive							×		
economic									
capital depreciation	×								
energy intensity	×							×	
cost		×			×				
risk		×	×				×		
time		×							
payback					×		×		
industry					×	×			
competitive position	×								
organizational									
priority	×			×		×	×		
environment profile				×					
long-term strategy		×	×	×				×	
size	×							×	
ownership			×						
split incentives		×				×		×	
behavioral									
ambition		×	×	×			×		
skill						×			×
competitors' performance									×

Note: NLD – the Netherlands, SWE – Sweden, GRC – Greece, DEU – Germany, THA – Thailand, CHN – China.

3.1.2 Corporate environmental strategies

The strand of literature in management, focusing on corporate responsiveness, behavior, and strategy on environmental and ecological issues, tends to go further beyond the assumption of fixed interest in profit maximization and the consideration of pollution as externalities and market failures in economic studies. Conceptually, environmental and conservation behaviors are incorporated in the concept of competitive advantage in two ways. One is Porter's dynamic view of competitiveness and argument for properly designed environmental regulations, which promote firms to adopt environmental strategies and innovations that lower costs and differentiate products to gain competitiveness (Porter and Van der Linde 1995; Esty and Porter 1998). The other incorporates the constraints imposed by the biophysical environment into the resource-based view of the firm, which not only considers firms' positions in their industries as Porter's view, but also firms' internal capabilities to transfer resources into competitiveness that are not easily imitated by competitors (Hart 1995).

Hart (1995) further summarize three interconnected capabilities of firms' environmental strategy – pollution prevention, product stewardship, and sustainable development – that may bring competitive advantage through lower costs, preempting competitors, and improving future positions. Based on the resource-based view of the firm, empirical studies confirm a positive link between environmental behavior and economic performance, especially in high-growth industries (Russo and Fouts 1997); proactive environmental strategies build up firms' unique capabilities for competitiveness (Sharma and Vredenburg 1998); capabilities for process innovation and implementation help transfer environmental management into cost advantage (Christmann 2000). Other internal characteristics that associate with environmental behaviors include managerial perceptions of stakeholder importance (Henriques and Sadorsky 1999), their interpretation of environmental issues and discretionary slack (Sharma 2000), and their environmental concerns (Naffziger et al. 2003).

Later research tends to link institutional context with firms' internal motivations, strategies, and organizations to explain environmental behaviors, and is more informative to this dissertation research. Bansal and Roth (2000) establish an abstract model to explain corporate ecological responsiveness, with three major motivations – competitiveness, legitimation, and environmental responsibility – triggered by three major contextual factors – issue salience, industry field cohesion and individual concern. Delmas and Toffel propose (2004) and empirically confirm (2008) corporate environmental strategies as a result of both external pressure from different stakeholders – customers, regulators, legislators, communities, environmental activists – on different corporate departments, and different departments' influence on managers' decisions. Williamson et al. (2006) find, on the other hand, that environmental behavior in small and medium-sized manufacturing firms are driven by regulation and business performance in cost reduction and efficiency, but less by wider stakeholders. Child and Tsai (2005) find a dynamic, bidirectional interaction accommodating corporate environmental strategies with regulatory constraints, rather than unidirectional compliance. The interaction is identified between institutional agents and multinational chemical corporations, which usually have larger bargaining power and more proactive position than local firms. Pulver (2007) explains divergent responses in the oil industry toward climate change as a result of oil companies' different perceptions of profit opportunities, which are in turn influenced by scientific networks and policy fields in which the companies were embedded.

3.1.3 Chinese context and a preliminary framework for energy saving in firms

Studies in the Chinese context stress on specific external and internal factors that complement the literature above to build up a preliminary explanatory framework for energy savings in firms. Particularly, Eichhorst and Bongardt (2009) interview three firms in Nanjing, one of the four cities in Jiangsu province where interviewed firms in this research locate, and identified major drivers for firms to enter into voluntary agreements of energy saving. The drivers include achieving parent company targets, enhancing relationship with local government, improving reputation, and reducing costs. In comparison to the cases in the Netherlands and Germany, the negotiation of voluntary agreements is found to be government-oriented with weak involvement of industry associations (Eichhorst and Bongardt 2009), which echoes the findings by Hu (2007) in two iron and steel firms in Shandong province. Liu (2009) surveys firms in a few cities in Jiangsu and neighboring provinces and finds government regulation, markets, and community and NGOs as important external pressures leading to environmental behaviors of firms. Zhang et al. (2008) survey firms in a county of Jiangsu and identify that the pressures from supply chain and customers and larger firm sizes makes firms more active in environmental management. On a similar topic, Shi et al. (2008) find three major barriers for firms to practice cleaner production in China – lack of economic incentive policies, lax environmental enforcement, and high initial cost.

In terms of broader environmental policy enforcement and firm responses, Dasgupta et al. (2001) find that inspections better improve polluters' environmental performance than pollution charges; on the other hand, Wang and Wheeler (2005) find progressive financial penalties, combined with self-reporting and few options for contesting regulatory decisions have significant deterrent effect on pollution. Christmann and Taylor (2001) find firms with multinational ownership, multinational customers, and export to developed counties have better self-regulation and environmental performance; Wang and Jin (2007) find that collectively or community owned firms also have better environmental performances in water pollution discharges than state-owned or private-owned firms.

Figure 3.1 summarizes the reviewed literature and proposes a preliminary framework, which helps develop the research design and analysis of firms' energy saving. A firm makes an energy-saving decision under three contexts: national governance, local governance and community, and industrial environment. The three external contexts and the firm's capabilities combined affect the firm's motivations, which in turn determine its energy-saving decisions. In fact, the three contexts are interdependent, and all the three policy instruments are applied by national and local governments jointly or simultaneously. A simple disaggregation of the three contexts, however, helps to direct the research focus to the interface between external influences and a firm's internal response that is marked in thick dashed lines.

The national government influences a firm through its enforcement of energy-saving rewards, tax break, technology mandates, and performance standard. Local governments, while having their own commitment to the national government for a certain level of energy saving, negotiate with a firm for an energy-saving agreement and keep track of the firm's implementation. Industrial characters, such as average growth and competitors' strategies, also affect a firm's decisions as the previous literature indicates. Finally, a firm's internal features, such as ownership and size, may affect its capabilities, such as innovation and bargaining power, which jointly with external influences determine its motivation and decision for energy saving.

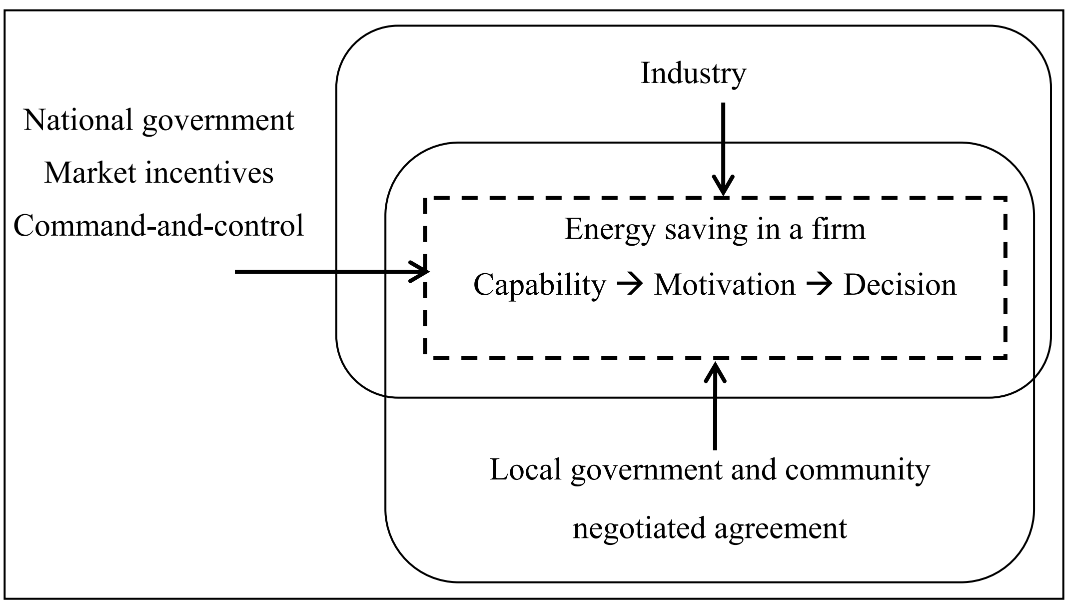

Figure 3.1 Preliminary framework of firms' energy saving decisions.

3.2 Research Methods

The research objective is to develop contingent, structural explanations of firms' energy savings in the Chinese regulatory context. Case study is the favored method here, for three reasons. First, theories and empirical evidence exist and are accommodated into this research, which means starting from scratch based on grounded theory is not needed. On the other hand, the summarized explanatory framework in figure 3.1 is relatively general, and does not readily provide specific propositions to be tested by more structured and quantified methods. Second, the variation of the focused issue – firm energy-saving behaviors – is not an easily observable and measurable, and needs detailed, individual investigations. Third, the internal and external factors that affect firm decisions are large in quantity, and some of them are difficult to observe and measure directly. Moreover, it is sometimes not easy to discern internal and contextual factors – for example, to distinguish a firm's own willingness from its response to the local government's pressure in making energy savings.

3.2.1 Research design and strategy

This research applies a multiple-case design, combining within-case identification and process-tracing to establish detailed explanations, and cross-case comparison to refine and generalize the within-case findings – testing the main findings, excluding plausible alternative explanations, identifying extra factors, and making syntheses. Either analysis, if used alone, is not sufficient: a single-case analysis is susceptible to selection bias and may lack external validity; cross-case comparison relying solely on co-variation may lead to inferential errors and lack internal validity.

A studied case is a single firm, or more precisely the firm's energy-saving behaviors in the context of national, provincial, local, and industrial influences. A firm may have made multiple energy-saving decisions, and each of these decisions and the whole processes that can be separately identified is considered a subunit of analysis, which adds opportunities for extensive analysis and enhances the insights into a single case.

The first two research questions – major motivations for firms to save energy, and major regulatory influences – are specified into alternative propositions to be tested to find the relative importance of different motivations and influences across cases. Supplementing, grouping, or disaggregating the motivations and influences are applied when needed. Following previous research (for example Bansal and Roth 2000), the major candidates of motivations are competitiveness, legitimation, and social responsibility. Competitiveness captures firms' objective to increase or maintain profits through efforts that also reduce energy consumptions, represented as pursue of higher profits, lower costs, and larger market share. Legitimation captures firms' objective to follow regulations and norms for long-term survival through efforts that also reduce energy consumptions, indicated by an intention to survive, lessen risks, and maintain license and government permission. Social responsibility captures the social obligations and values represented by individuals or organizations, such as individual satisfaction, and employee morale. While the three motivations are all significant in previous research, a stronger motivation for legitimation and competitiveness may be expected. Strong motivation for legitimation is reflected by the previous research of firm ecological responsiveness, and the context in China with ambitious energy-saving regulations. Competitiveness follows the reasoning of profit-maximization in energy-saving investment.

The regulatory influences are generally classified according to the instruments used as incentive-based ones – tax breaks, electricity pricing, investment rewards, subsidies, and loans – mandatory regulations – technology mandates, performance standards, and direct governance – and voluntary ones – energy-saving agreements. The sources of influences are also identified, as from a local or the central government. Greater influences may be expected from voluntary agreements (Bjørner and Jensen 2002), especially absolute reduction agreements (Sugino and Arimura 2011), and from investment assistance.

The third question – firms' responses to regulatory influences according to their motivations – is addressed by developing and testing alternative descriptive explanations for each case, and when possible, descriptions for each subunit of energy-saving decision within a firm, with reference to the framework in figure 3.1. The already identified motivations and influences are used in the descriptions, while other relevant factors, such as firms' capabilities, are identified in the description process. These alternative, plausible explanations are then tested and excluded across cases to derive a general explanatory framework that on the one hand explains the different cases, and on the other hand links to the literature and concepts.

Testing alternative propositions and explanations are different in their way of using multiple cases. For the former, multiple cases are used as literal replications, so that they share a same set of key motivations and key influences. For the latter, multiple cases are used as theoretical replications, so that they are explained in the same framework, but vary in their specific explanations, because of their distinctive contextual and internal features.

3.2.2 Case selection and description

The selection of cases is conducted to intentionally introduce variations in the key factors that may affect firms' energy savings, i.e. a theoretical sampling. This design is especially important because a single firm is not likely exposed to much variance in the recent five to six years, i.e. since the energy-saving policy was enforced. The key factors in which variations exist are local contexts that may have different pressure from local governments and communities, industrial contexts that may have different industrial dynamics and different regulations from the national policy, and firms' own features that may influence their capabilities, such as their sizes and ownerships.

The research focuses on a single province, Jiangsu. This guarantees that the national policy is uniformly interpreted from the provincial level to the city level, whereas there is still enough variance between cities in terms of their own energy-saving targets, enforcement, and development levels. Four cities are selected – Xuzhou, Nanjing, Zhenjiang, and Suzhou, all with a strong industrial economy. Table 3.2 lists the energy-intensity level, previous reduction, future target required by the provincial government, industrial share, and per capita GDP for the four cities, which helps to illustrate the local contexts. Xuzhou has the highest energy intensity, the least reduction, the lowest future target, and the lowest per capita GDP. Therefore, the regulation and pressure on energy saving in Xuzhou is lower than the other three.

The other three cities are considered with higher regulatory pressure, but for different reasons. Although Nanjing has a relatively high energy intensity level, it made the largest percentage reduction during 2006-2010. More importantly, it has already designed a detailed energy-saving plan according to its own target of 50% energy-intensity reduction, and negotiated with individual firms for their individual targets for 2015, while the other three cities have not. Zhenjiang's regulatory pressure is considered high simply because it has the lowest energy intensity and a very high share of industrial economy, and is relatively more difficult to make the same percent of reduction in energy intensity. Suzhou has the highest per capita GDP, and has relatively less incentives to protect the local industries from energy-saving regulations. It should be noted that except for Xuzhou, which is clearly different from the other three and still in rapid industrialization, the relative stringency of regulations is not directly discernible without detailed investigations.

Table 3.2 List of case locations.

City	Xuzhou	Nanjing	Zhenjiang	Suzhou
energy intensity in 2010 (tce/1,000 CNY) [a]	0.1123	0.1065	0.0779	0.0824
energy intensity reduction 2006-2010 [a]	19.68 %	21.71 %	20.50 %	20.98 %
energy intensity reduction in 2011 [a]	3.68%	3.71%	3.79%	3.93%
intensity reduction target 2011-2015 [a]	18.0%	19.0% [1]	18.0%	19.0%
GDP/capita in 2009 (1,000 CNY) [b]	27.51	55.29	54.73	83.70
industrial share of GDP in 2009[2, b]	52.3%	45.6%	58.2%	58.7%

Note: 1. While these targets are assigned by the provincial government, Nanjing has its own target of 50% reduction in energy intensity; 2. The share includes mining, manufacturing, utility, and construction industries. Source: a. Jiangsu economic and information technology commission; b. Statistical yearbook of Jiangsu 2010.

Four industries are included in the analysis: cement, iron and steel, paper, and chemical industries. Except that they are all energy-intensive industries, they feature different national-level regulations and industrial dynamics. Table 3.3 summarizes some of the relevant features and regulations. Both cement industry and steel industry have experienced serious overcapacity, with detailed requirements to eliminate facilities by specified technology and capacity standards, and stringent control of a capacity limit in a given region. The regulation for overcapacity in cement industry stays more serious after 2010, especially in Jiangsu. In addition, cement industry is highly regional-based, relying on local supply and demand, and is highly homogenous in terms of the technology used. This makes the regulation in cement industry reasonably justified, and can be strategically enforced toward the small and energy-intensive firms. The regulation in steel industry is similar, but there is relatively less pressure, because less closure is mandated after 2010, especially in Jiangsu, and the market is larger in geographical scope.

Table 3.3 List of case industries.

Industry	Cement[1]	Steel[2]	Paper[3]	Chemical[4]
National				
production in 2005 (million ton)	1070	350	32.0	-
production in 2010 (million ton)	1880	630	92.7	-
capacity closure 2006-2010 (million ton)	340	195[b]	10	-
planned closure 2011-2015 (million ton)	250	96[b]	10	-
reduction of energy consumption per product weight 2006-2010	12%[a]	12.8%[c]	18%	-
reduction target of energy consumption per product weight 2010-2015	-	4%[c]	22%	-
energy intensity reduction 2006-2010	-	-	-	35.8%[d]
energy intensity reduction target 2011-2015	-	18%	-	20%[d]
CO_2 emission intensity reduction target 2011-2015	17%	18%	-	17%[d]
Jiangsu				
capacity closure 2006-2010 (thousand ton) [5]	33500	11622[b]	503	-
planned closure 2011-2015 (thousand ton) [6]	15000	20[b]	300	-
Industry heterogeneity	low	low/middle	middle	high

Note: a. Only for cement clinker. b. Combined capacity for iron production and steel production. c. Only key firms for statistical purpose are included. d. Combined reduction in the petrochemical industry and chemical industry. Source: 1. Cement industry development plan during the 12th five-year; 2. Iron and steel industry development plan during the 12th five-year; 3. Pulp and paper industry development plan during the 12th five-year; 4. Petrochemical and chemical industry development plan during the 12th five-year; 5. Jiangsu energy-saving plan during the 12th five-year; 6. Jiangsu's planned closure of industrial outdated capacity during the 12th five-year.

Paper industry has capacity closure requirements for some specific facilities, but it is a relatively heterogeneous industry with no explicit requirements for regional capacity limit. The regulatory pressure has been long enforced, mainly toward small, high-polluting firms from an environmental perspective. Finally, the chemical industry is a highly heterogeneous industry. While several specific processes in it are highly regulated and experience overcapacity, such as the Chloral-alkali process, most others, especially those with high technology, high profit, and foreign investment, are not similarly regulated as the other three industries.

Besides location and industry, ownership and size are explicitly taken into consideration in case selection. After some initial screening, 20 cases are selected, shown in table 3.4. The names of the firms are coded to preserve anonymity. The composition is relatively well-balanced in cement and steel industries: they both include firms under low and high regulations; cement industry includes firms with all ownership types and a critical case that is subject to closure; steel industry includes firms in all locations and the two main types of technology – the long process using blast furnace to produce iron from iron ore and basic oxygen furnace to produce steel, and the short process using electric arc furnace to produce steel directly from scrap. The lack of foreign ownership reflects the common situation in the steel industry. Therefore, cases in the two industries are more useful to develop explanations of energy savings that are relevant to the spatial contexts and firm capabilities, while cases in the other two industries can be used to test the findings and strength the explanations related to industrial dynamics. Also included in table 3.4 are: the number employee a firm has, reflecting its size; whether the firm is a branch company managed by a headquarter along with other similar branches; the firm’s age since its initial operation and; the number of interviewees and how the interview was recorded;

the number of units of analysis, i.e. energy saving decisions, that can be separately identified in a case.

Table 3.4 List of cases studied.

Code	Industry	Location	Ownership	Employee	Branch	Age	Record	Units
C1[a]	Cement	Xuzhou	state	800	yes	9	1 audio	2
C2 [b]	Cement	Xuzhou	private	300	no	30	1 audio	3
C3	Cement	Nanjing	private	250	no	30	1 audio	2
C4	Cement	Nanjing	foreign	300	yes	1	2 notes	1
C5 [b]	Cement	Zhenjiang	private	500	no	7	3 audios	2
C6 [a]	Cement	Zhenjiang	foreign	800	yes	15	2 audios	2
S1 [b]	Steel	Xuzhou	private	2000	no	1	2 notes	3
S2 [a]	Steel	Nanjing	private	5500	no	50	2 audios	4
S3 [b]	Steel	Zhenjiang	private	400	no	9	2 notes	4
S4 [a]	Steel	Suzhou	state	4000	no	50	2 audios	4
P1 [b]	Paper	Xuzhou	private	500	no	30	1 audio	1
P2 [b]	Paper	Zhenjiang	state	1400	no	60	1 audio	1
P3 [a]	Paper	Zhenjiang	foreign	5600	yes	15	1 note	1
P4	Paper	Suzhou	foreign	300	yes	14	2 audios	7
P5 [b]	Paper	Suzhou	foreign	550	yes	16	1 note	4
Ch1[b]	Chemical	Nanjing	foreign	20	yes	6	1 audio	1
Ch2[a]	Chemical	Zhenjiang	state	4300	no	50	1 audio	7
Ch3[b]	Chemical	Zhenjiang	state	1700	no	60	1 note	3
Ch4[b]	Chemical	Zhenjiang	private	700	no	30	1 audio	2
Ch5[b]	Chemical	Zhenjiang	private	400	no	5	1 audio	2

Note: a. Top-1000 and Top-10000 energy-consuming enterprises; b. Top-10000 energy-consuming enterprises.

3.2.3 Data collection

The main data source is firm interviews, conducted in February, 2012. One to three interviewees were selected in each firm, according to their knowledge about the firm's decision making about energy savings. They were usually the top managers, managers in charge of production, directors of energy management, or directors of environment and safety. An interview was usually conducted for around one hour in the interviewee's office, with some occasions in the firm's conference room. In 14 out of 20 firms, the interviews were allowed to be audio-recorded. In the other cases, detailed notes were taken. All the interviews were conducted in Mandarin Chinese, and transcribed in Chinese for accuracy, which may otherwise be comprised in translation.

In an interview, the interviewee was first asked to briefly introduce the firm, and its position in the industry, relative to its direct competitors. Next, the interviewee was asked to introduce the energy-saving, material conservation, and pollution control efforts the firm has made, and the time for each effort. Material conservation and pollution control were explicitly inquired too because initial discussions with some firm managers, government officials, and researchers in China revealed that these efforts are related to energy savings and are good reference for within-case comparison. Particularly, energy saving and emission reduction are phrased together in the 11th five-year plan for the national economy and social development. The interviewee was then encouraged to describe in detail the process of each practice sequentially, the reasons for the practice, and specific criteria in making decisions. The main focus was on energy-saving practices. If all energy and environmental investments in the firm followed a same decision-making procedure, the interviewee would be asked to specify the procedure. Special attention was given to the firm's interaction with government agencies. Finally, the interviewee was encouraged to comment on the general practice and performance of the industry, the practices the firm should do but did not, and the barriers to the adoption.

Firm interviews were accompanied by interviews and informal discussions with staff in local and provincial governments and government-based institutions involved in enforcing energy-saving policies, i.e. the economic and information technology commissions, development and reform commissions, environmental protection bureaus, and energy-saving supervision centers. The information helps to understand the provincial and local governments' interpretation of higher level policies and their own policy enforcement, and to confirm the reliability of some information collected from firm interviews.

In addition, the company websites, news, and company reports of the studied cases and their industries were collected. They provided background information prior to an interview, complemented information collected from interviews and helped confirm the reliability of interview responses.

3.2.4 Data analysis

As explained above, the general strategy for identifying major motivations and influences in firms' energy saving is through testing competing propositions, and that for explaining firms' responses to regulatory influences according to their motivations is through developing and testing rival case explanations, with reference to the preliminary framework in figure 3.1. To assist the analysis, especially to test alternative propositions and rival explanations, all the interview transcripts are input to the qualitative analysis software NVivo. The Chinese transcripts are directly coded into concepts in English, to avoid inaccuracy introduced in translation.

Different motivations are first coded. The coding starts from more descriptive concepts, such as lowering costs, rather than directly using more abstract, theoretical concepts, such as competitiveness. If too many concepts are identified, similar ones are aggregated by employing a new set of concepts at a more abstract level. The coding starts from cement firms, and then steel firms, because they have more balanced composition. The process stops with two to four motivations. The relative importance of each motivation is also identified, according to their appearance in one case and across cases. A similar procedure applies to identifying policy influences.

The other contextual and internal factors are coded and maintained at a relatively disaggregate level at first. Combined with identified specific motivations and policy influences, they compose contingent descriptive explanations for each case. Alternative analytic explanations are generalized from the detailed descriptive explanations based on more abstract concepts. The explanations are eliminated, adapted, or strengthened when applied to other cases. This is an iterative process, and stops only when a robust explanatory framework emerges, whose variations accommodate all the cases.

3.3 Findings

3.3.1 Firms' motivations for energy savings

The findings for energy-saving motivations are shown first, in table 3.5. Competitiveness is the most important motivation for energy saving, and drives all firms in most of their energy-saving practices. This reflects the fact that reducing energy consumption, compared to other environmental behaviors, is more closely related to production processes and operational cost, and the nature of energy-saving investment as a profit maximization decision even in the current context of ambitious policies in China. In spite of this, following regulations and norms to ensure long-term survival is still very important – 14 firms are also motivated by legitimation in half of the identified energy-saving decisions. In comparison, although social responsibility is an important motivation for corporate ecological responsiveness, it has minor, if any, influence in firm energy-saving decisions.

Table 3.5 List of energy-saving motivations.

Motivation	Units	Firms	Case examples
Competitiveness	48	20	
• operational profitability	44	19	
➢ lower cost	33	18	C1-6, S1-4, P2-4, Ch1-5
➢ short payback period	18	10	C1, S1, S3, P3-5, Ch2-5
➢ efficiency improvement	5	4	C5, C6, P5, Ch2
➢ market-based incentives	4	4	C4, S2, S3, P5
➢ stable energy supply	4	4	C1, C6, S1, Ch2
• market position	9	6	
➢ environmental image	4	3	S3, Ch4, Ch5
➢ learn from leading firms	3	3	S2, P1, Ch5
➢ product quality	2	1	Ch3
• market share	3	3	C2, S2, Ch3
Legitimation	28	14	
• compliance with regional governance	16	10	
➢ energy-saving agreement	9	5	C1, C4, S2, S4, Ch2
➢ environmental requirement	4	4	S3, S4, P4, Ch3
➢ survival against government interest	4	2	C3, S2
• compliance with mandatory policies	12	8	
➢ expected capacity elimination	6	6	C2, S2, S3, P1, P2, Ch2
➢ technology mandate	2	2	C2, S2
➢ performance standard	2	2	C2, S4
➢ capacity closure	1	1	S4
➢ environmental standard	1	1	Ch3
• compliance within organization	3	3	C4, C6, P5
• employee working condition	1	1	P4
Social responsibility	3	3	
• response to national policy encouragement	2	2	C1, C6
• as a role model	1	1	C1
• environmental responsibility	1	1	P3
Total	56	20	

Competitiveness. The main reason for increased competitiveness through energy saving is that the operational profitability is improved. This is straightforward because most of the interviewed firms are energy-intensive with large shares of energy in production costs. The major energy-saving practices for them are based on mature technologies with quick payback, such as variable-frequency drive and waste heat to power. Interviewees from all but one firms explained their energy-saving efforts as a way to reduce costs or to improve the efficiency of the whole production systems; many of them justified the investments according to the payback periods, which are usually within three years, with a few under one year; benefits from policy incentives – tax breaks, rewards, and loans – sometimes make the decisions even easier because of shorter payback period and investment assistance.

A particular benefit to firms' operation is stable energy supply, especially electricity. This is because local governments used electricity quota and scheduled blackout for industrial firms in order to respond to shortages of electricity supply and guarantee residential use, especially in the summer, and sometimes to curb local industrial energy use at the same time. The blackouts are costly to firms' production (Fisher-Vanden et al. 2012). By reducing consumption and using waste heat for self-generation of power, firms can reduce the chance of being interrupted by intermittent restriction on electricity supply. One firm also considered the secure supply of coal in the future as a reason for energy saving.

Besides the operational cost-benefit rationalization, firms also invest in energy efficiency to improve their position in the industries. Without violation of any environmental standard or requirement from the government, S3, Ch4, and Ch5 made energy-saving efforts mainly or partly because the efforts might improve their facilities' appearance and environmental image. S2, P1, and Ch5 kept track of the energy-efficiency performance or adopted energy-saving technologies of the leading firms in their industries because they wanted to be more competitive. Ch3 tried to improve product quality and reduce energy use through technological changes. Additionally, some firms adopted large, new facilities to replace their old, small facilities or to merge other small firms, which were claimed partly for increasing output and improving energy efficiency.

Legitimation. The most common form of legitimation is to comply with regional governance – to fulfill the energy-saving agreements that firms negotiated with local and provincial governments, and to fulfill requirements of local governments on emission reduction beyond national standards. Firms may not face immediate difficulty in survival once they fail to meet the energy-saving or environmental protection targets, but they may incur more administrative pressure and be more difficult to sustain in longer terms under local jurisdiction. As extreme cases, interviewees from two firms expressed that they would not survive with their small-scale facilities or large energy consumption under the local governance, because of conflicting interests of the local government in local development and energy-saving performance.

Similar to the response to local governance, firms' compliance with command-and-control regulations sometimes make them reduce energy consumption. The most influential one is industrial policies that mandate the elimination of certain production technologies and facilities below certain capacity levels. By following the elimination standards, firms substitute new, more efficient capitals for old less efficient ones. But only one firm eliminated its facility that was strictly below the standard, while the other six replaced their old capitals in advance according to their expectation of future elimination and local interpretations of the policies. Firms also reduced energy consumption by using required energy-saving technologies and following technology-based energy-efficiency requirements and pollution-emission requirements.

In addition, three branches of foreign corporations, C4, C6, and P5, made some of their energy-saving decisions following headquarters' requirements. One branch of a foreign corporation – P4 – invested in a technical change because it also improved the working condition.

Social Responsibility. Only few firms have energy-saving practices that are not directly associated with motivations for competitiveness or legitimation, but rather with their social obligations and values. Interviewees from two firms indicated that the national policy context of energy saving encouraged their decisions. They include a branch of a state-owned cement corporation, C1, and a branch of foreign cement corporation, C6. The interviewee of C1 also indicated that as state-owned, they should be a role model in their industry. P3 considered energy-saving efforts as a strategy to climate change mitigation and environmental protection, and pioneered in measuring firm-level carbon footprint.

Table 3.6 lists the number of case firms and units of energy-saving efforts by three major motivations and different case features. While competitiveness is widely held in all firms and drives most of the efforts, legitimation is more of a concern in cement and steel industries, which may reflect higher regulation in the two industries with overcapacity. State-owned firms are also more associated with legitimation concern. There is a close relationship between the local government and state-owned firms –the local government relies more on state-owned firms for policy implementation, and in exchange these firms can enjoy more local protection (Lu and Tao 2009). More importantly, the top managers of state-owned firms, unlike their counterparts in private or foreign firms, have direct incentives to follow policies, because they are administered by the government.

Firms in Zhenjiang have less motivation for legitimation, mainly because it has a higher composition of chemical and paper firms, which are less regulated. The association between motivations and organizations are less obvious, except that only branch firms within corporations considered social responsibility.

Table 3.6 Number of firms and units by motivation and case feature.

Case classification	Competitiveness	Legitimation	Social responsibility	Total
Industry				
• cement	6(11)	5(9)	2(2)	6(12)
• steel	4(12)	3(9)	0	4(15)
• paper	5(12)	4(5)	1(1)	5(14)
• chemical	5(13)	2(5)	0	5(15)
Location				
• Xuzhou	4(9)	3(6)	1(1)	4(9)
• Nanjing	4(7)	3(6)	0	4(8)
• Zhenjiang	9(20)	5(9)	2(2)	9(24)
• Suzhou	3(12)	3(7)	0	3(15)
Ownership				
• state-owned	5(14)	5(12)	1(1)	5(17)
• private	9(21)	5(11)	0	9(23)
• foreign	6(13)	4(5)	2(2)	6(16)
Organization				
• independent	13(33)	9(21)	0	13(38)
• branch	7(15)	5(7)	3(3)	7(18)

Note: in parentheses are the numbers of energy-saving efforts and outside parentheses are the numbers of firms in each category.

3.3.2 Policy contexts for firm energy saving

To understand firms' motivations and decisions for energy savings, it is helpful to scrutinize of the policy contexts that associate with firms' energy savings.

Unlike the direct motivations for energy saving, a policy context may sometimes link with energy-saving efforts only loosely. For example, an interviewee might consider all their energy-saving investments are driven by a cost-benefit rationalization, but admit that without the investments they cannot fulfill the negotiated energy-saving targets. In this case, the firm's motivation for energy saving is solely competitiveness, but the voluntary agreement program is still considered in the policy context. Therefore, while some policy influences and motivations overlap, additional policy influences may be identified in some situation. If a policy mentioned by an interviewee does not affect any energy-saving decisions, however, it is not considered. A common example reflected in the interviews is that quite a few firms enjoyed investment subsidies and rewards as free-riders, and commented that they would not change their decisions even without those benefits.

The policies and regulations associated with firms' energy savings are organized according to the policy instruments used, as mandatory, financial, and voluntary ones in Table 3.7. The three types of instruments mainly associate the capital structure change, investment, and overall energy saving respectively, as explained below. For each policy, only the number of firms it applies is given, because a firm sometimes faces the same policy context, particularly the voluntary program, in multiple decisions, and an interviewee might not repeat the context in each energy-saving effort.

Mandatory Regulations. The firms' energy-saving decisions were more frequently influenced by mandatory regulations, followed by voluntary approaches, and less by financial incentives. This is different from the experience in other countries, indicating a distinctive policy context in China for industrial energy saving.

Table 3.7 List of policies associated with firms' energy saving practices.

Policy	Firms	Examples
Mandatory regulations	14	
• capacity control	10	
➢ outdated capacity elimination	8	C2, C3, S2, S3, S4, P1, P2, Ch2
➢ local capacity limit	3	C4, C5, S2
• environmental regulations	5	
➢ local request	5	C3, S2, S3, P4, Ch3
➢ national standard	1	Ch3
• technology mandate	4	C2, S2, S3, P2
• energy-efficiency performance standard	3	C2, S2, S4
• local electricity quota and rolling blackout	3	C1, C6, S1
Financial incentives	8	
• energy savings performance contract	5	C4, S4, P4, Ch2, Ch4
• tax break for resource conservation	3	C4, S2, Ch2
• subsidy for energy-saving investments	3	S2, S4, P5
• reward for energy savings	1	S3
• loan	1	S2
• tradable permit	1	P4
Voluntary and informal approaches	11	
• energy-saving agreement	9	
➢ local influence	8	C1, C4, S2, S4, P4, P5, Ch1, Ch2
➢ provincial influence	4	C1, S4, P3, Ch2
• government-firm communication	4	C5, S2, Ch1, Ch2
• national policy background	3	C1, C6, S2

Most mandatory regulations specify the exact technologies to be used or not allowed, usually with large capital replacement, investment, and energy-efficiency improvement. The most common influence in firms' energy saving is that regulates the production capacity and capital structure in industries with overcapacity, which is usually strictly specified with little flexibility to firms. Eight firms reduced their energy consumption by capital replacement, because their old capitals were listed or expected to be listed in the national or local catalog of capacity elimination. Three firms made ambitious energy-saving efforts and plans, in hope that their new capital investment could be approved under strict regulation of local capacity limit.

While the central government set elimination standards for certain production processes and restricted the regional capacities, the local governments were the impetus to the capital replacement. By replacing small, old capitals with large, new ones more actively than the policy mandates, the local governments can enjoy more tax revenues and fulfill energy-saving targets more easily, because firms with larger facilities usually have higher profit and energy efficiency. Firms respond to the national policy and local interpretations in advance in order to survive or stay legitimate. Otherwise, they may be at risk of being replaced by other large firms sooner or later, or finally eliminated according to the policy.

Because of the local governments' flexibility in policy enforcement, firms face varying regulatory stringency depending on the demand of local governance. For example, S4 managed to replace its small furnaces listed in the national elimination catalog with a furnace right above the required minimum capacity without the risk of being shut down, because it provides its by-products – furnace gas and coke oven gas – to about 100, 000 households for residential use. In comparison, S2, with larger scale capital, faced greater pressure of survival, because it had no such indispensable function to the local area, and drove up the local energy intensity, causing difficulty for the local government to meet its energy-saving target. Another example is C3, which managed to survive while hundreds of similar small-scale cement firms were closed in Jiangsu province, by maintaining its energy efficiency and environmental performance at high levels, and pioneering in the use of industrial wastes as almost all of its feedstock. However, it no long enjoyed tax breaks for resource conservation after 2009, and was required to suspend its clinker production, partly because its energy efficiency, environmental performance and resource conservation practice had been more popular in cement industry.

Closely related to the capital and capacity regulations are technology mandates and energy-efficiency performance standard. C2, S2, S3, and P2 were mandated to use certain energy-saving technologies, and C2, S2, and S4 had to meet the national-level standards for cement and iron and steel industries, in terms of energy consumption per unit product and energy consumptions in the main production processes. All these firms also experienced capital replacement because of two reasons: first, their facilities were old and inefficient, below the performance standard and within the existing or expected elimination list; second, capital replacement needs to be approved, usually by provincial or national government, which is a chance for the administrative agencies or local government that can help in the approval process to propose additional energy-saving and environmental protection requirements for the firms to follow.

Environmental control also gives firms not much flexibility in their approach to comply, and specifies the reduction of certain pollutants. Because some pollutants were emitted from power generation or other energy-intensive processes, five firms managed to reduce their energy consumption by replacing their capitals with newer ones, or removing the whole power generation facilities. Except Ch3, which stated that one of its energy-saving efforts were made for the compliance with national standard, the other technical changes for environmental protection in the five firms were all considered by the interviewees as responses to local governments' requirements beyond national standards. The final regulation is local sporadic control for electricity supply, which although not mainly intended for energy saving, affected C1, C6, and S1 in their energy-saving decision.

Financial Incentives. Financial incentives are mainly designed to assist energy-saving investments and thereby improve firms' competitiveness, with more flexibility for firms than mandatory ones. The most common market instrument are energy savings performance contracts (ESPC), which facilitated five firms and were considered by even more interviewees. Through ESPC, a contract is reached between a firm and an energy service company (ESC), which usually pays for an energy-saving investment, guarantees certain amount of energy savings, and shares the benefit of saved energy consumption with the firm for certain years, or is paid back by the firm through the energy-saving benefit or other ways. Because ESCs have been enjoying generous tax breaks and investment subsidies, they have been developing rapidly and seeking customers – firms' with energy-saving potentials – actively. Three benefits of ESPC to firms' energy savings are identified in the interviews. First, it provides a financing solution for firms that are not capable of investing in energy-saving projects, especially those requiring great investment (S4, Ch2). Second, it makes firms more willing to invest in the energy-saving projects whose payback period is uncertain or long (P4). Third, it informs firms about their energy-saving potentials, which are otherwise not apparent sometimes (Ch4).

Alternatively, firms can also acquire subsidies for their energy-saving investments or rewards according to the amount of energy saved directly from national, provincial, and city governments. While many firms enjoyed the policy benefits, the two policies in fact only influenced the decision-making in S2, S3, S4, and P5. For S3 and P5, the subsidies and rewards were made for small energy-saving investments in variable-speed drive and energy-saving lighting, which were already cost-efficient and made more attractive; For S2 and S4, the energy-saving subsidies were considered by the directors in charge of energy saving or environmental protection as a way to demonstrate the performance of their own departments and make contribution to the firms. The two incentives for investment are not as effective as ESPC, because firms need to apply in advance especially for national subsidies, finance the projects by themselves, and receive subsidies or rewards later, even after a period of operation and an audit of energy-saving performance. Therefore, firms need to have financing capabilities and accurate estimation for potential energy savings.

Another market incentive for energy saving comes from the fact that some energy-saving projects, for example the reuse of waste heat, are also qualified for tax breaks for resource conservation. C4, S2, and Ch2 all invested in some energy-saving projects that also reuse industrial wastes and are qualified for tax breaks. Rather than one-time subsidies or rewards, firms enjoy repeated policy benefits from tax breaks, which is more attractive to firms as stated by the interviewee in Ch2.

Along with these policy benefits, there is also tradable allowance for carbon dioxide emission implemented by the Suzhou city government for the local firms. The tradable allowance was considered by the interviewees to affect the substitution of energy source in P4, which is also the only firm identified to respond to energy-saving regulation through output reduction.

Voluntary Programs. Voluntary programs usually give firms the greatest flexibility in selecting energy-saving approaches, and associate with firms' legitimacy under local jurisdiction. Many firms experienced some informal communication and negotiation with the government for energy saving, and nine of them considered that the energy-saving targets and agreements negotiated with the government influenced their decisions. While the formal contracts or agreements were usually reached by firms and local governments, four firms in the Top-1000 program with large energy consumption experienced some influence from the provincial government. Three of the four firms and five other firms experienced influence from the local governments, which in turn need firms' energy savings to help fulfill their regional targets.

Besides the explicitly negotiated targets and agreements, four firms were influenced by informal communication with the local governments in their energy savings. On the one hand, local governments have some specific and sporadic demand for energy saving or environmental protection, because for example, a previous regulatory plan is not as effective as expected. On the other hand, firms would like to establish better relationship with the government in exchange for the support from the government for their development, or at least to know the regulatory trend to act in advance and preempt disruptions to their operation. Therefore, firms will take government demand and perspective from informal and personal communication into consideration for energy saving, and even propose energy-saving plans actively to the government, as the interviewee in C5 stated. The whole national policy background of energy saving also encouraged firms, and associate with firms' motivation for social responsibility.

Similar to table 3.6, the number of case firms by three major policy instruments and case features are listed in table 3.8. The cement and steel firms not only were more motivated by legitimation as indicated in table 3.6, they in fact experienced more mandatory regulations. With lower regulatory pressure and lower energy efficiency, firms in Xuzhou experienced few financial incentives and voluntary programs. The two policy instruments can be more flexibly implemented by the local government, and were therefore more employed in Nanjing and Suzhou with higher regulatory pressure. Domestic, independent firms associated more with the mandatory regulations, while foreign branches associated more with voluntary requirements. This may reflect newer capital and higher energy efficiency in foreign branches.

Table 3.8 The number of firms by policy context and case feature.

Case classification	Mandatory	Financial	Voluntary	Total
Industry				
• cement	6	1	4	6
• steel	4	3	2	4
• paper	3	2	3	5
• chemical	2	2	2	5
Location				
• Xuzhou	4	0	1	4
• Nanjing	3	2	3	4
• Zhenjiang	6	3	4	9
• Suzhou	2	3	3	3
Ownership				
• state-owned	5	2	3	5
• private	7	3	2	9
• foreign	3	3	6	6
Organization				
• independent	11	5	4	13
• branch	4	3	7	7

3.3.3 An explanatory framework for firm energy saving in China

The previous subsections present the motivations and policy context that associate with firms' energy-saving efforts. By linking motivations with policy context, as well as firms' internal capabilities and external industry dynamics, this subsection provides an explanatory framework for firms' energy savings in China. Specific explanations for energy saving are established for each firm, which are then generalized for each industry, and further generalized across industries and refined through iterative cross-case comparisons. The internal capabilities identified include energy-saving information, technology, financing ability, land, and government relation. The external industry dynamics include mainly the cohesion of an industry and the production capacity level.

The general finding is that there are two sets of energy-saving behaviors in firms – one related to main capital replacement and one not. They associate with distinctive internal motivations, capabilities, and decisions of the firms, as well as industry and policy context and local governance externally. The two sets of behaviors may exist in one firm because of its capital vintage, which may be subject to different policy context. The relationship between industry and policy context, local governance, and firm motivation, capability, and decision is illustrated in figure 3.2. The main motivations and decisions are in thicker frames, and the main influences are in thicker arcs, differentiated from regular arcs showing less important influences.

The first set of energy-saving behavior, circled by the dashed line at the upper right corner, is motivated by increasing operational profitability or achieving the negotiated energy-saving target of a firm, and often both. The final strategy is usually the investment in energy-saving technologies. Financing, technology, and information capabilities support the motivation, and determine the technology choice. The most important capability is financing ability. While less financing ability does not seem to influence firms' motivation for competitiveness or target fulfillment, it sometimes makes a firm give up certain energy-saving investment. For example, P4, Ch2 and Ch3 all had concern for installing some energy-saving technologies due to their poor business performance in recent years and lack of funds, although they all knew the technologies were cost-effective. Technology capabilities – previous technology basis (C3, Ch2), employees' previous experience in other firms (C4, S1, Ch5), and research collaborations (C5, S3, Ch3) – all make firms more confident about and advantageous in using certain energy-saving technologies. Environmental management systems (S2, P3), cleaner production audit (C5, P5), and informal personal communications (C1, P4) assist firms to identify energy-saving potentials and find certain solutions.

The industrial dynamics and voluntary policy are important contexts that affect firms' motivations. Both cement (C1, C3, C5) and steel (S1, S2) firms were concerned with overcapacity and low profit in the industries. Generally, firms in the two industries were keener to employ energy-saving technologies to lower their cost, and invested in projects with longer payback period, compared to most of the firms in paper and chemical industries, which experienced less competition. For the cement industry, local electricity quota and rolling blackouts and national investment plan in infrastructure changed the supply-demand structure and greatly increased the average industrial profit since 2010, and no major energy-saving practices were made in 2010 and 2011, as identified in the interviews. Even within paper and chemical industries, firms with more competition in their subsectors or with less profit in recent years (P4, Ch2, and Ch3) were identified with more energy-saving efforts and more motivations to lower cost through energy saving.

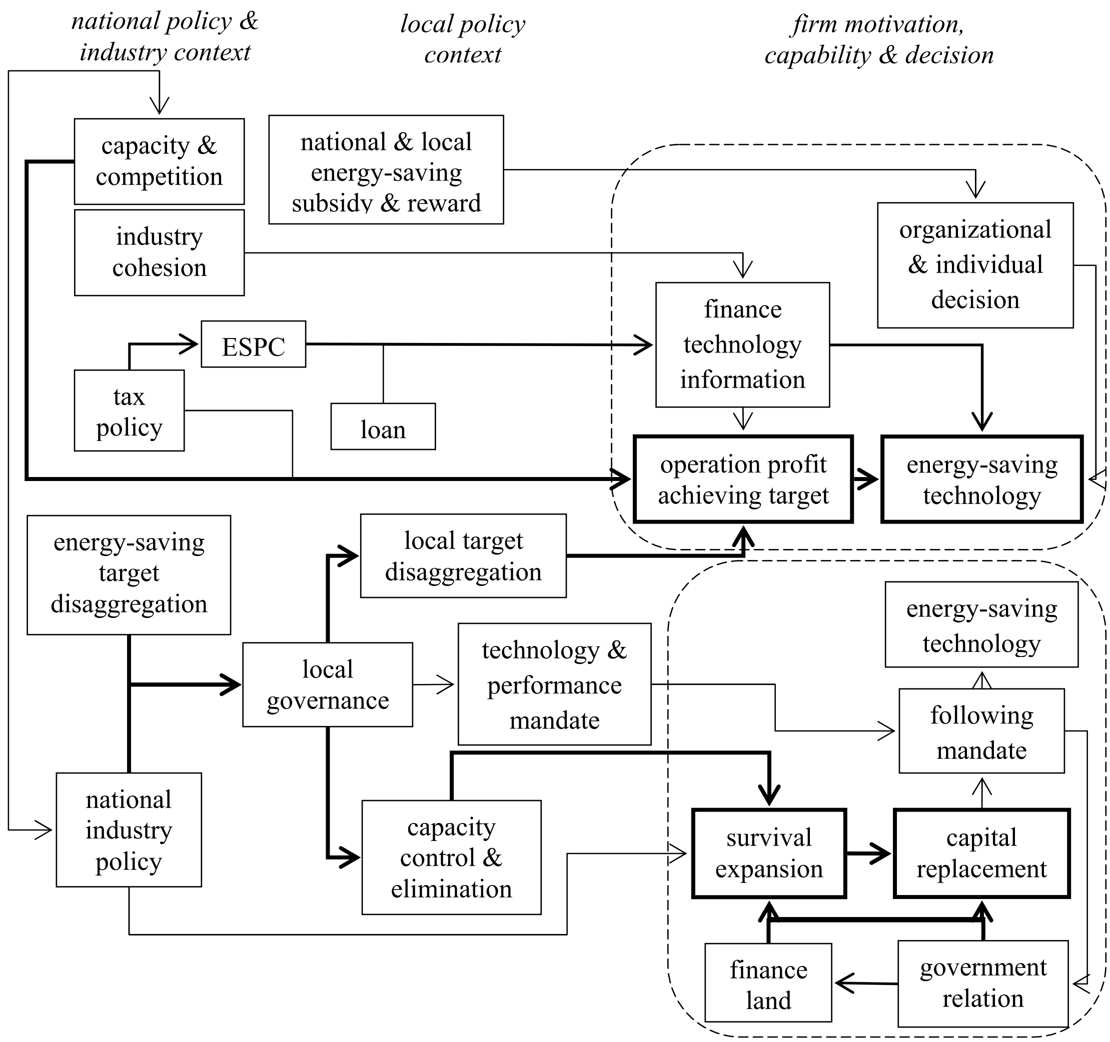

Figure 3.2 An explanatory framework for firm energy saving in China.

Negotiated energy-saving targets are important, particular for firms in Suzhou with reduction target in absolute amount, firms in the Top-1000 program with more pressure from both provincial and local governments, and firms in Nanjing, which had announced an ambitious target for 2011-2015 and negotiated with firms. All the other firms had no concern about fulfilling their targets or agreements.

Besides the voluntary agreement, multiple financial incentives are also associated with the first set of energy-saving behavior. A direct influence on firms' motivation is from tax breaks for resource conservation, but because only a few energy-saving technologies are qualified for tax breaks, the policy effect on energy saving is not as significant as its effect on firms' resource conservation efforts.

More policy influence is indirect, by strengthening firms' capabilities. The most helpful policy to date is the ESPC, which is especially important for firms lacking of other funding opportunities and used in both large and small projects. In this sense, loans can be also helpful, but it is not mentioned much by the interviewees. Energy-saving rewards and investment subsidies, on the other hand, have only minor influence, by motivating certain employees and departments as their contribution to the firms (S2, P5), and by shortening an already short payback period (S3, P5).

Indirect influence also comes from the industrial context. Firms in more cohesive industries – those with intense and dense formal or informal networks, similar technologies, and frequent flow of employees between firms – are more likely to learn from each other in energy-saving practice. While interviewees in cement, steel, and paper all implicitly indicated that they were in a cohesive field, it was especially the case for cement firms – most interviewees reported the energy-efficiency performance of neighboring firms and even firms in other regions with the same technology.

The second set of energy-saving behavior, circled by the dashed line at the lower right corner of figure 3.2, is motivated by the need to survive or develop, which requires the replacement of old, small capitals with large, new ones of the main production processes. Such motivations and decisions are jointly influenced by external regulatory context and internal firm capabilities. Externally, in cement and steel industries with lots of redundant capacity, there is strict national regulation that mandates the elimination of certain technologies under certain capacities, and prevents the capacity in a region from increasing. Because of the regional capacity limit, local governments usually follow a more stringent elimination plan, especially in exchange for new firms, which usually bring more tax revenues and less energy consumption compared to a few small, old firms. Therefore, firms in the two industries are more likely under the pressure of elimination. In comparison, the paper industry mandates the elimination of certain technologies, but has no regional capacity control, and the chemical industry eliminates even fewer technologies. Firms in these two industries have less concern for survival and less constraint for expansion. However, local government demand for environmental quality sometimes also leads to specific capacity elimination or relocation request, which influences not only cement and steel firms, but also paper and chemical firms.

Internally, the motivation for expansion or survival is determined by a firm's financing capability, land, and government relation. As the interviewee stated, C2 managed to expand with the closure of 19 other cement firms in the same area, because they had land, mine, and the support of the local government. In comparison, C3 had no financing ability to invest in larger production capacity, and tried to survive with a new kiln with a similar capacity but not in the elimination list, which was suspended finally. S4 had no concern about survival with its small furnace just above the elimination level, even under high energy-saving regulation in Suzhou, because of its important function to the local governance by supplying waste furnace gas and coke oven gas for residential use. S2, without such function, avoided relocation only after long-term communication with the local government and commitment for greater efforts in energy saving and environmental protection.

While the firms replace old capitals with new ones to survive or develop, the construction of the new capitals usually need to be approved by national or provincial government. In exchange for a smooth approval of new capitals, firms (C2, S2, S3, P2) usually have to use additional energy-saving technologies or achieve an energy-efficiency level mandated by the local or provincial government. In a similar manner, C5 actively proposed to the local government new energy-saving and environmental protection plans in hope of having its suspended expansion plan approved. Therefore, the second set of energy-saving behavior finally leads to the employment of some energy-saving technologies like in the first set, but under a purely mandatory context. Financial incentives and voluntary programs have little, if any, influence in the decision-making process.

3.4 Discussion and implications

Based on the research findings above, this section discusses more broadly the current policy mechanisms and impact, as well as future policy directions, with references to an economics perspective of the energy efficiency gap.

3.4.1 Current policy impact

The current policy in China that effectively affects firm energy saving is a combination of mandatory and voluntary instruments, and particularly the regulation on capacity and capital structure and energy-saving agreements. Combined they effectively influenced the energy-saving decision of most of the firms in the energy-intensive industries interviewed, according to their capital structure.

Three issues are relevant to this policy framework and worth noting. First, because the local government has great flexibility and interests in interpreting the two kinds of policies in their own ways, this may cause a significant spatial disparity in energy-saving regulations, according to local development stages and energy-saving targets. Such a disparity may lead to industry relocation and concerns for regional sustainability and long-term energy saving, which is further discussed in chapter five. Second, the greater flexibility in local governance may make firms uncertain about future policies and market conditions, and are less likely to make energy-saving investment. An example is that the production of C3 was suspended by the local government only three years after it replaced its major capital, in exchange for the opening of a larger cement firm under the context of local capacity control. Third, while the two main policy instruments complement each other in general, there is also a conflicting effect. The capacity control and local governance in electricity supply greatly reduce the output and change the market dynamics, which in turn cause the existing firms to enjoy less competition and less likely to make energy-saving investment to improve competitiveness.

The incentive-based policies are relatively less effective to date. A major reason is that it was not designed in an efficient way. While a large amount of budget has been allocated to subsidies and rewards for energy-saving investments, it does not help the firms with financing difficulties but rather has been frequently enjoyed by free riders who would have invested anyway. In addition, electricity pricing was designed according to specific technology and capacity, and should be effective in discouraging the use of inefficient facilities. But the design of electricity pricing overlaps with that of capacity control and capital elimination, and has been overshadowed by the latter – only one interviewee mentioned the policy in a situation that did not influence the firm's energy-saving decision. The free-rider problem and the overlapping policy programs that make part of the policies ineffective, however, are common rather than exceptions in energy-saving regulations. Examples are the insignificant effect of investment subsidies on energy consumption in Denmark (Bjørner and Jensen 2002), and the relative targets of voluntary action in Japan, whose effect has been overshadowed by the "Law Concerning the Rational Use of Energy" (Sugino and Arimura 2011).

3.4.2 Implications

The major motivation for firm energy saving in the current policy context is competitiveness, which suggests a space for both market-based and investment-focused incentives. Empirical evidence shows the adoption of energy-efficiency technologies is more sensitive to the cost of the equipment than to the expected cost of energy (Jaffe et al. 2004). This may justify the use of investment incentives, and, as an effective financing approach, ESPC has been proved helpful for firms to make energy-saving investment. On the other hand, however, investment incentives encourage excess entry and exacerbate the issue of overcapacity, which is now addressed by capacity control regulations. An introduction of market-based policies and the transition from energy-intensity targets to targets in absolute amount of energy consumption may help mitigate the problem. Market-based policies may also be effective in accelerating the shift to more efficient capitals (Ruth and Amato 2002), which is now addressed by capacity control and capital elimination regulations.

Important capabilities are also identified as associated with the adoption of energy-saving technologies, including those that improve information and technology. Firms are more likely to adopt the technologies that have been used by other firms and are more certain in energy-saving performance. Therefore, research, development and demonstration programs may be valuable in the current context.

While an explanatory framework for firm energy saving contingent to the Chinese context has been established in this chapter, understanding the energy efficiency gap, and particularly the decision of energy-saving investment, is still important. Firms are heterogeneous and employ different discount rate in energy-saving decisions – while some interviewed firms invested in projects with payback longer than three years, some other firms, especially foreign branches, only considered investments with shorter than one year payback, implying a discount rate over 100%. An extremely high discount rate may be partially adjusted by policies that fix the market failure, but may also partially associate with some features in firms that cannot be easily changed. Hence, the next chapter continues in line with the reasoning by examining empirically what firm features associate with more energy-intensity improvement, using firm-level data.

Chapter 4 Firm characteristics and energy efficiency improvement

The previous chapter explains why industrial firms choose to invest in energy savings. However, the questions of what determines the extent of firm energy-saving investments across firms, and particularly the contribution of internal and external factors of firms to their energy saving efforts remain unanswered. By matching annual firm level data from the Chinese industrial enterprise database with the outcome of the Top-1000 energy-consuming enterprise program, this chapter addresses empirically the question of what factors correlate with higher energy efficiency improvement in these large energy-consuming firms.

This chapter is an extension from and complement to the previous chapter in two aspects. First, it examines empirically the contribution of the contextual factors that influence firm energy savings that were identified in the previous chapter, such as regulatory pressure and industrial competition. Second, it explores firm characteristics that associate with behavioral and organizational heterogeneity among firms, which may influence their energy-saving investments and, particularly the implicit discount rate used in these investments.

Because the major energy efficiency improvement in firms is through technological change, the research has implications for the literature of technology adoption. By focusing on the firms in the Top-1000 program, which have similar access to information, subsidies, and other policy benefits, it is more likely for the research to examine whether and to what extent there are behavioral and organizational barriers to the adoption of energy efficient technologies in firms.

The results of these internal and external factors combined help evaluate the policy design in encouraging firms' energy saving investment, particularly for the Top-1000 program and its successor the Top-10,000 program, and generally for information and voluntary programs focusing on large industrial firms. The significance and magnitude of the effect of these factors on firm energy savings also help identify appropriate incentives in policy making.

The remainder of the chapter is organized as follows. The next section reviews the literature of the determinants for technology adoption and performance in energy saving and environmental protection that relates to this research. The subsequent two sections introduce the data used and empirical approach, respectively. The results are shown in section 4.4. The chapter ends in section 4.5 with discussion and policy implications.

4.1 Technology adoption and improvement in energy savings

There is a huge body of literature covering technological change related to energy and environmental issues. Because this chapter concerns the factors that affect the adoption and improvement of energy efficiency at the firm level, the review of the literature focuses on empirical research in firms, and excludes the research at an aggregate level and based on simulations. Depending on the interested outcome, the reviewed studies can be classified as ones concerning the improvement in energy demand and intensity, ones concerning technology adoption, and ones concerning program participation, which is considered a proxy for investment decisions

(DeCanio and Watkins 1998). The literature reviewed in this section guides the data collection and empirical approach discussed in the following to sections.

4.1.1 Improvement in energy demand and intensity

Change in energy demand or intensity level depends on the investments in energy conservation and efficiency improvement, capacity utilization and production levels, and fuel mix and products composition. Because energy is a factor of production, the empirical research usually starts from a production function or cost function, although not always in an explicit and strict way. While the main focus is energy price elasticity in the literature, the energy demand elasticity of other factors is sometimes examined, too.

Based on energy surveys covering 3762 Danish industrial firms and different functional forms, Bjorner and Jensen (2002) estimate the price and policy effects on energy demand; they find that both energy tax and energy agreements reduce energy consumption, price elasticity is smaller in magnitude for energy-intensive firms, and higher value added associates with more energy demand. With the same data source, Arnberg and Bjorner (2007) find that both electricity and other energy are complements with capital, and smaller own price elasticity estimates compared to the results based on cross-section data. Linn (2008) differentiates the energy intensity of entrants and that of incumbents based on the putty-clay investment model (Atkeson and Kehoe 1999), and estimates that a 10% increase in the energy price reduces the relative energy intensity of entrants by 1%. Firm features are explicitly examined in Fisher-Vanden et al. (2004). They investigate a sample of 874 large and medium-sized industrial enterprises in China during 1997-1999 with detailed energy use by type, and find that research and development expenditures, foreign and collectively ownership, and some industrial and regional contexts contribute to lower energy intensity.

More firm features are examined for their association with environmental performance, because the estimation is usually not restricted to the form from a production function or cost function. For example, based on survey data of 236 Mexican firms, Dasgupta et al. (2000) find environmental management, training, large size, higher education, inspections, and publicly traded firms associate with higher environmental performance. In general, firm characteristics, such as size, ownership, human capital, and productivity, and external factors, such as community pressure, capital markets, consumers, and regulators, are commonly empirically examined influences (Blackman 2010). While more firm characteristics are identified in the environmental literature, their implication for this research is limited, because environmental performance, unlike energy-saving efforts, usually does not bring private benefits to firms directly.

4.1.2 The adoption of energy-saving technologies

Some literature considers the decision and extent of the adoption of energy-saving technologies directly, without a measure of the outcome of the adoption in terms the change in energy demand and intensity.

Without explicitly linking to the individual firm characteristics, Anderson and Newell (2004) find the hurdle rates of 50-100%, or a one to two-year payback cutoff, for the adoption of energy-efficient technologies in small and medium-size firms that accepted free energy audits and recommendations by the US Department of Energy's Industrial Assessment Centers program; plant size is found of no measureable effect on the adoption decision, which contradicts to the results of other research.

Sugino and Arimura (2011) examine the factors influencing the energy-saving investment decisions and investment expenditures of 146 large Japanese firms over 8 years. While their main conclusion is that firms with voluntary agreements for absolute energy conservation are more likely to invest in energy efficiency, they also find positive association of the number of employees, and no significant association of liquidity constraint and R&D with the investments.

Arvanitis and Ley (2013) also examine the decision and extent of the adoption of energy-saving technologies, or in their words inter-firm diffusion and intra-firm diffusion, in 2,324 Swiss firms for the year 2008. They find significant differences between inter-firm and intra-firm diffusion with respect to associated firm characteristics: inter-firm diffusion is associated with high gross investment intensity, presence of R&D activities, large firm size, domestic ownership, high competitive pressure, more external experience of the technology, intrinsic motivation to adopt energy-saving technology; intra-firm diffusion is less associated with large firm size, domestic ownership, and competitive pressure, and more with external experience and intrinsic motivation. The energy intensity level of a firm is of minor, if any, relevance to the diffusions or investments.

4.1.3 Program participation

Firms' decision to join energy-efficiency programs is thought of as a signal of firms' willingness to undertake energy-saving investments (DeCanio and Watkins 1998). This is useful in empirical research because program participation is more easily observable than investments. Decanio and Watkins (1998) examine firms' decision to join the US Environmental Protection Agency (EPA)'s Green Lights program, which offers technical support to the participants and requires them to make all the lighting upgrades that meet a clear profitability test; they find that firms with more employees, more earnings per share, more previous growth in industry earnings, less expected future earnings growth, less insider control, and some industrial and regional specific contexts are more likely to join the program.

More literature concerns firms' involvement in environmental programs and certificates. For example, Arora and Cason (1996) find that firms with more employees, more consumer contact and R&D intensity are more likely to join the US EPA 33/50 program and commit voluntary reduction in key toxic chemicals. Nakamura et al. (2001) find the Japanese firms with larger sizes, younger employees, more export, less debt, and managerial value toward the environment are more likely to obtain ISO 14001 certification.

4.2 Data

There are multiple data sources used in the empirical analysis performed below. These data sources are introduced individually here according to the variables extracted from them.

4.2.1 The performance of top-1000 energy consuming enterprises

The national development and reform commission (NDRC), as the main institution in charge of the Top-1000 program, collected and announced in 2009, 2010, and 2011 the energy-saving performance of all the participating firms from the program start year 2006 up to the year before the announcement. The last announcement in 2011 is for the performance of all the firms throughout the entire program period of 2006-2010. The announcement includes the initially negotiated energy-saving target as well as fulfilled cumulative energy savings to 2008, 2009, and 2010 for each firm. These data are used to measure the energy saving efforts in firms. The direct measure of absolute amount of energy consumption for individual firms, however, is not available.

How the data of initial targets and cumulative energy savings were produced needs some explanations, because they are relevant to the decision of the empirical approach below. While negotiation existed between provincial government and firms within their jurisdiction for each firm's energy conservation agreement, the preliminary energy-saving targets were set by the NDRC for each firm according to the firm's industrial sector and technology level, due to a time constraint (Price et al. 2010). The target and an energy conservation plan to fulfill the target with annual progress were negotiated by the firm and the local government where the firm located. A firm could choose from one of the two methods to calculate its energy saving, either by energy consumption per unit product or energy consumption per unit total output, and stick to the method through 2010. Most of the firms chose the latter because it is easier to reach, for example, through the adjustment of the composition of the products. The annual energy saving according to per unit output is measured as the change of energy consumption per output multiplied by current output, i.e.

$$\Delta E_t = \left(\frac{E_{t-1}}{Y_{t-1}} - \frac{E_t}{Y_t}\right) \times Y_t \;, \qquad (4\text{-}1a)$$

where ΔE_t is the energy saving in year t, E is the total energy consumption, and Y is the total output measured in monetary terms. The annual energy saving according to energy consumption per unit product is measured as

$$\Delta E_t = \sum_{i}^{n} \left(\frac{E_{i,t-1}}{Q_{i,t-1}} - \frac{E_{i,t}}{Q_{i,t}}\right) \times Q_{i,t} \quad , \qquad (4\text{-}1b)$$

where $Q_{i,t}$ is the amount of product i produced in year t, usually measured in weight or quantity. The cumulative energy saving in a firm is the sum of its annual energy saving, measured in either way, since 2006.

While initially there were 1,008 firms involved in the program, firms dropped out over time because of mandatory closure, bankruptcy, mergers, or major changes in production and energy use. By the year 2010, 881 firms remained in the program. They are from nine two-digit industrial sectors: iron and steel, chemicals, electric power, petroleum and petrochemical, construction materials (or nonmetal mineral products according to the standard Chinese industrial classification), nonferrous metals, coal mining, paper, and textiles.

4.2.2 Chinese industrial enterprise database

The main data set for the characteristics of individual firms comes from the Chinese Industrial Enterprise Database, which is an annual survey of industrial firms conducted by the National Bureau of Statistics of China (NBS). It covers all the state-owned industrial firms and non-state-owned industrial firms with annual sales of five million CNY or more. While the survey itself may be consistent with a comprehensive coverage across years, the variables included in the released annual sample vary.

For each firm, its basic information – name, location, industry classification, telephone number, ownership, initial registration time, and number of employees – financial information –assets, liabilities, sales, and profit – and production information – total output, new product, and export – are covered every year. Unique firm identity code and industry value added are provided in most of the years. Other useful information, such as R&D expenditure, employee education expenditure, and employee composition, is provided in only one or several years.

Matching the firms in the database across years and with those listed by the top-1000 program is not straightforward, because of the inconsistency in the data collection process. Two entries are matched if they share exactly the same name and identity code. When small discrepancy exists in the name, a match is established based on the same telephone number, on the condition that the two entries are in the same location, industry sector, and with the similar number of employees. An internet search is used for the confirmation of some potential matches – with similar name, location, and industry classification, but different identity code – to see whether a reform and re-registration happened, which changed the name and identity code of a firm.

Even with extensive search and matching efforts, a large share of observations is missing after the matching process. The main reason is systematic omission in the release of the Chinese Industrial Enterprise Database for recent years. For example, the 2010 data does not include firms in four provincial equivalent jurisdictions, Beijing, Tianjin, Hebei, and Shanxi; the 2009 data is a subsample with about 25% random omissions; the 2008 data does not include firms in the nonferrous metal industry. Beyond the missing observations, only two of the 881 firms that completed the program are not included due to the inconsistency between the NDRC announcements. Finally, the matching produces a panel data set for 2007-2010 with 481 firms. Figure 4.1 shows the number of firms that completed the program, and that are included in the research by industrial sectors. Because the missing observation is mainly made by the NBS and not related to the operation of the Top-1000 program administered by NDRC, it may not cause bias in the estimation, although caution is needed for the interpretation of the estimation results.

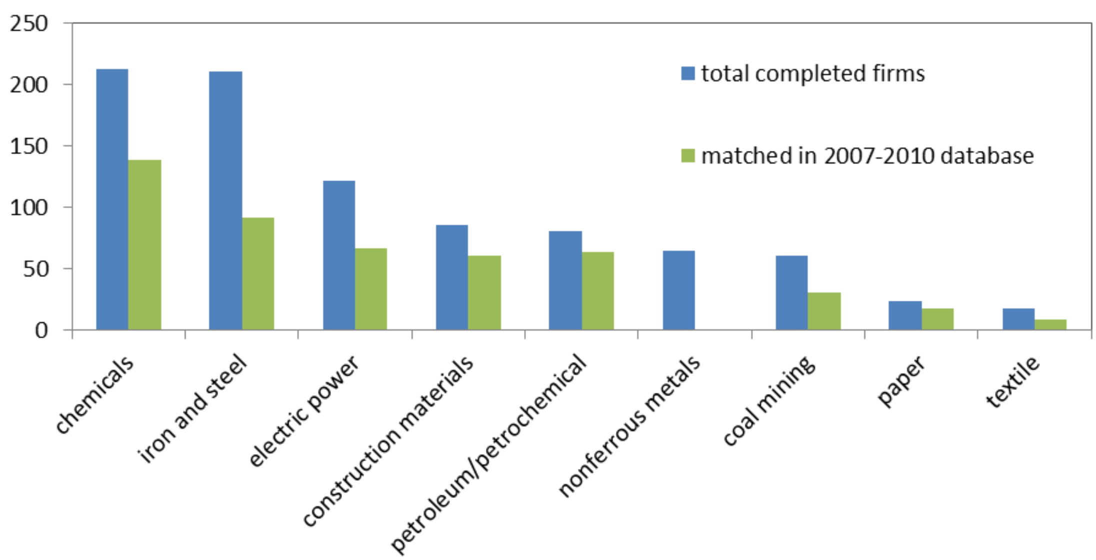

Figure 4.1 Numbers of firms that completed the Top-1000 program and those matched in database by industries.

4.2.3 Regional and industrial context factors

Regional and industrial context, as indicated in the previous chapter, may affect the motivation and capability of firms to save energy and make investments. In addition, some variables are not available at the firm level, and can only be measured by aggregate proxies, such as electricity prices and knowledge spillovers. The data source includes China Statistical Yearbooks, China Industry Economy Statistical Yearbooks, and China Energy Statistical Yearbooks made by the NBS, the State Electricity Regulatory Commission (SERC), and the NDRC.

Regional context is mainly reflected here by policy influences and regional endowment, such as general regulation pressure, development level, knowledge spillovers, electricity price, and electricity supply. Regulatory pressure directly comes from the provincial energy-saving targets that need to be fulfilled by 2010, in terms of both absolute energy-intensity levels and percentage declines, which are reported by the NDRC. In addition, more developed regions may be less dependent on local energy-intensive industries, and consider the environment with a higher value, both of which motivate the local government to regulate industrial energy saving more stringently. Variables concerning local development, such as per capita GDP and fiscal expenditures, can be found in the China Statistical Yearbooks for provinces, and in the China City Statistical Yearbooks for cities. Fiscal expenditures also reflect the capability for the local government to provide subsidies and rewards. Besides the direct impact, more involved firms within a province may foster the spread of information between them and the regulatory agency. While the detailed social network structure among the firms is not available, the number of firms within a province may be a proxy for such knowledge spillovers.

There are six major regional electricity grids in China, each covering several provinces, and electricity supply and price data are available at the provincial level. Provincial electricity production and consumption data is recorded in the China Energy Statistical Yearbooks. The ratio of electricity consumption relative to consumption in a province reflects the scarcity of electricity supply, and the likelihood of local electricity quota and rolling blackout that influence firms. Provincial weighted electricity price after 2007 can be calculated from the annual Supervising Reports of Electricity Pricing by the SERC, by combining of the provincial weighted average sales prices and provincial surcharges.

Industrial context generally concerns the competition within an industry. Competition is measured by the average profit rate and the percentage of loss-making firms, which can be calculated from the China Industry Economy Statistical Yearbooks. In addition, a more homogeneous industry may also face greater competition, because firms are less likely to improve competitiveness through differentiation. Such homogeneity is measured by the relative standard deviation of profit rates and outputs of the involved firms within the same sector. The petroleum and petrochemical industries are in fact two industrial sectors, but because they are closely interdependent and treated as one industry by the NDRC, the industrial variables used are the aggregate of the values of the two industries.

4.3 Empirical approach

Because the NDRC only reported the initial energy-saving targets and cumulative energy saving from 2006 to 2008, 2009, and 2010 for each firm, the absolute energy consumption or intensity data for each firm is not available. Based on the available data, this section first discusses decomposition of reported firm energy savings into ones related to energy conservation and efficiency investments, ones related to expansion and embodied technological change, and ones related to change in product composition. Given an appropriate decomposition and control for energy intensity change due to expansion and product composition change, the estimation of determinants for energy efficiency investments is then discussed, incorporating both firm and contextual factors, and both time-variant and time-invariant factors.

4.3.1 Decomposition of energy saving in firms

The energy savings in year 2009 and 2010 for each firm are readily available as the differences in cumulative energy savings between 2009 and 2008, and between 2010 and 2009. Because most firms chose to calculate their energy savings according to energy consumption per unit output for the whole firm, the calculated energy savings are determined by a combination of three processes. The first is energy efficiency investments for the existing capital or capital turnovers that maintain the same production capacity, which reduce energy consumption per unit product, and make real energy conservations. The second is expansions and inclusion of new production capacities that produces the main products with higher energy efficiency through embodied technological change, or directs the additional capital to the production of less energy-intensive products. The third, as a particular case of expansions, is the development of new products.

For simplicity, assume that without prices change, a firm has one process A in year *t-1*, i.e. $E_{t-1}= E_A$, $Y_{t-1}= Y_A$; in the next year *t*, the firm simultaneously invests in energy efficiency for process A, adds an additional process B for the same product, and produces a new product in process C, i.e. $E_t= E_A` + E_B + E_C= E_A` + E_B + E_t^{new}$, $Y_t= Y_A + Y_B + Y_C = Y_A + Y_B + Y_t^{new}$. Given the calculation for annual energy saving in equation 4-1a,

$$\Delta E_t = \frac{E_{t-1}}{Y_{t-1}} \times Y_t - E_t = E_A + E_A \times \frac{Y_B}{Y_A} + E_A \times \frac{Y_C}{Y_A} - E_A^{`} - E_B - E_C \quad ,$$

re-arranging the right hand side, dividing both sides by Y_{t-1}, and denoting *E/Y* as *EI* gives

$$\frac{\Delta E_t}{Y_{t-1}} = \frac{E_A - E_A^{`}}{Y_{t-1}} + \frac{Y_B}{Y_{t-1}} \times \left(\frac{E_A}{Y_A} - \frac{E_B}{Y_B}\right) + \frac{Y_C}{Y_{t-1}} \times \left(\frac{E_A}{Y_A} - \frac{E_C}{Y_C}\right)$$

$$= \left(EI_A - EI_A^{`}\right) + \frac{Y_t - Y_{t-1} - Y_t^{new}}{Y_{t-1}} \times (EI_A - EI_B) + \frac{Y_t^{new}}{Y_{t-1}} \times (EI_A - EI_{new}) \, , \quad (4\text{-}2)$$

where on the right hand side of the second equal sign, the first term represents the decrease in energy intensity in the old process, the second term represents embodied energy intensity improvement in the new capital relative to the old one, and the third term represents energy intensity decrease in the new products. The decomposition is valid because the method to calculate annual energy saving, approved by the NDRC, uses the energy intensity level for an entire firm in the previous year as the basis.

Such decomposition is not a perfect separation and representation of different sources of energy consumption change in firms. For example, while higher capacity utilization usually associates with lower energy loss and higher energy efficiency, its effect is not captured separately but by the first or the second term on the right side of equation 4-2, depending on whether the utilization rate decreases or increases. Also, change in products composition, if not involving new products, is captured by the first or second term. The latter example may be less of a concern, because the direction of energy-intensity effect of product composition change is likely similar to that of new product development, given that is the effect of new product development is measurable. To at least partially take into account the effect of capacity utilization, the estimation differentiates a decrease in output from an increase, i.e.

$$\frac{\Delta E_{j,t}}{Y_{j,t-1}} = \alpha + \beta \times \frac{Y_{j,t} - Y_{j,t-1} - Y_{j,t}^{new}}{Y_{j,t-1}} \times D_{j,t} + \gamma \times \frac{Y_{j,t}^{new}}{Y_{t-1}}$$
$$+\theta \times \frac{Y_{j,t} - Y_{j,t-1} - Y_{j,t}^{new}}{Y_{j,t-1}} \times \left(1 - D_{j,t}\right) + \varepsilon_{j,t} \quad , \quad (4\text{-}3)$$

where $D_{j,t}$ is a dummy variable with value one if firm j has an expansion in year t, i.e. its output, after excluding new product output, is greater than the output in the previous year; α, β, γ, and θ are respectively energy-intensity deceases in the original process, in the expanded process, in the process of new products, and in the original process when the capacity utilization rate is lower. A descriptive statistics for the used variables is in table 4.1.

Table 4.1 Summary statistics for energy saving decomposition.

Variable	Unit	Obs.	Mean	Std. Dev.	Min	Max
intensity decrease ($\Delta E_t / Y_{t-1}$)	kg coal equivalent /thousand CNY	962	21.64	94.49	-141.3	2083
expansion rate ($\Delta Y_t / Y_{t-1}$)	-	962	0.2698	5.998	-1	109.64
new product increase (Y_t^{new} / Y_{t-1})	-	962	0.1156	1.539	0	46.62
expansion dummy (D_t)	-	962	0.3690	0.4828	0	1

4.3.2 Decisions on energy-efficiency investment

Assume that the intensity decrease in the old capacities, i.e. the first term on the right hand side of equation 4-2, is driven by energy efficiency investments. Such investments are determined by the available technologies *K*, financial capabilities *F*, a payback cut-off *T*, and some random disturbance ε, all specific to a firm j, i.e.

$$\frac{E_{j,A} - E^{`}_{j,A}}{Y_{j,t-1}} = f\left(K_{j,t-1}, F_{j,t-1}, T_{j,t-1}\right) + \varepsilon_{j,t} \quad , \tag{4-4}$$

where for simplicity one year lag between the decision and investment outcome is assumed. Here a payback cutoff, rather than a hurdle rate or implicit discount rate, is used to be consistent with the response from case study interviews, but the selection between the two does not influence the general reasoning that follows.

Available technologies and their specific payback to a firm are determined by the firm's detailed production process, capital vintage structure, fuel mix, and energy prices. While the first three are not observable for individual firms, they can be generally captured by the firm-specific fixed effect and industry-specific fixed effect terms. Because only electricity price is available, coal and petroleum prices are not controlled for. This may not be much of a problem, because these prices vary much less across regions compared to the electricity price, and usually depend only on transportation cost. The variation of technology availability caused by the awareness of energy-saving technologies in general and specifically for a firm's own industrial sector is assumed to be trivial, because all the firms had been involved in the Top-1000 program, and were subjected energy audits; key staff in each firm attended training workshops, made energy-conservation plans, and worked closely with the local administrative agencies.

Financial capability depends internally on a firm's current asset relative to current liability, often referred to as current ratio, and its profit rate. Generally, high current ratio and high profit rate make a firm more favored by a creditor, and more likely to get loans. Externally, government provides subsidies and rewards to support technology innovation and diffusion, which may help firms in investments. This is measured by fiscal expenditure on science and technology, environmental protection and energy saving per industrial output relative to the total industrial output for a province.

The main focus here is the payback cutoff explicitly or implicitly used by firms, which is assumed to be influenced by both firm characteristics and contextual factors.

Firm characteristics include time-variant ones such as export rate, the number of employees, and profit rate, and ones that treated time-invariant due to their variance or availability, such as ownership, age, reform and re-registration, and expenditures in R&D, in employee education, and in advertisement. While profit rate is discussed above as a factor influencing financing capability, it may also affect a firm implicit discount rate. As suggested by the case study research in chapter 3, firms with lower profit may have stronger motivation to use energy-saving investments to lower production cost. Whether a reform and re-registration happened in a firm during its participation in the Top-1000 program is a dummy variable, acquired by comparing the firm's ownership type in 2006 and 2010, and checking whether the firm's starting date in 2010 data is after than 2005. The expenditure variables should vary annually, but can only get for the year 2007, and are assumed relatively the same in the following years.

Provincial targets – in terms of absolute energy intensity in 2010 and percentage decline – may affect firms' technology adoption, because the local governments were likely to make additional pressure for the firms to help with the regional targets over time. Similarly, firms in provinces with higher per capita GDP and electricity scarcity are assumed to adopt longer payback cutoff, or lower discount rate. While the general awareness of technology is assumed irrelevant above, learning-by-using and knowledge spillovers – measured by the number of Top-1000 firms in a province – may reduce a firm's uncertainty about a technology, and therefore lower discount rate and increase energy saving.

Industrial competition and homogeneity – the average profit rate, share of loss-making firms, and distributions of profit rate and output – may also make firms use a longer payback cutoff to lower operational costs and improve competitiveness.

The estimation first introduces time-variant factors into equation 4-3 for flexible estimation, leading to

$$\frac{\Delta E_{j,t}}{Y_{j,t-1}} = f\begin{pmatrix} CR_{j,t-1}, PR_{j,t-1}, NE_{j,t-1}, ER_{j,t-1}, \\ AP_{s,t-1}, SL_{s,t-1}, DP_{s,t-1}, DO_{s,t-1}, \\ EP_{r,t-1}, ES_{r,t-1}, EX_{r,t}, GDP_{r,t-1} \end{pmatrix} + \sum \gamma \frac{\Delta Y_{j,t}}{Y_{t-1}} + \alpha_j + u_r + v_s + \varepsilon_{j,t}, \quad (4\text{-}5)$$

where the second term aggregates the control for output growth, new product development, and capacity utilization; j indicates a firm, including its current ratio CR, profit rate PR, number of employees NE, and export rate ER; s indicates an industrial sector and its contextual factors, including average profit rate AP, share of loss-making firms SL, relative standard deviation of profit rate DP, and relative standard deviation of output DO; r indicates a region and its contextual factors, including electricity price *EP*, electricity scarcity *ES*, relevant fiscal expenditure rate *EX*, and GDP per capita. One year lag is used for all the variables except government expenditure, for which the same year value is used because subsidies and rewards were usually given only after the investments had been made, but their availability should have been confirmed by the firms before the investments were made.

Table 4.2 Summary statistics for variables of energy efficiency investments.

Variable	Unit	Obs.	Mean	Std. Dev.	Min	Max
Firm level						
profit rate	%	962	3.06	17.93	-198.9	203.7
current ratio	-	962	1.17	2.45	0.0190	59.18
employee	thousand	962	7.22	14.56	0.07	116.3
export rate	%	962	3.99	10.97	0	100
age in 2011	-	481	26.7	19.96	4	111
ownership	-	481	1.85	1.24	1	5
reform	-	481	0.11	0.31	0	1
education/output	%	481	0.086	0.242	0	2.51
R&D/output	%	481	0.770	3.078	0	41.86
advertisement/output	%	481	0.033	0.232	0	4.60
Industry level						
profit rate	%	16	6.70	3.85	1.71	16.34
% of loss-making firms	%	16	18.18	6.01	11.34	32.99
relative standard deviation of profit rate	-	16	1.24	0.416	0.873	2.13
relative standard deviation of output	-	16	6.08	6.06	0.855	21.54
Province level						
electricity price	CNY/mWh	52	526.1	106.4	309.6	750.3
electricity scarcity	-	52	0.747	1.00	0.175	5.567
per capita GDP	kCNY	52	25.12	12.49	9.90	68.07
relative fiscal expenditure	%	52	1.00	0.662	0.195	3.125
energy efficiency target*	kCNY/tce	26	8.76	3.69	0	14.99
percentage target*	%	26	18.42	4.41	0	22
involved firms	-	26	26.38	20.71	1	94

Note: For Xinjiang province both of the targets and its energy-saving performance were not announced. In estimation, the two targets for Xinjiang are treated as zeros or the minimum level in other provinces.

Two ways for estimation and specification of the disturbance terms are considered. One uses α_j to capture the firm-specific fixed effects. The results are expected to reflect firms' own decision making change in very short terms, i.e. between 2008 and 2009. Because the data set is a short panel with only two years observations and fixed effect terms consume a large portion of degrees of freedom, a mixed model is considered as an alternative to include α_j, u_r, and v_s first assumed as independent and identically distributed random variables across firms, provinces, and industries, and then to explore the potential clustered data structure at the individual, provincial and industrial levels in the regression analysis. After appropriate specification is reached, the time-invariant factors are then included.

4.4 Results

4.4.1 Intensity change in old capacity, new capacity, and new products

The results for estimation of equation 4-3 are shown in table 4.3. As discussed in 4.3.1, the three processes associated with energy intensity change all have significant effects on firm energy intensity change and are consistently and highly significantly measured in all specifications. There is no measurable effect of lower capacity utilization on energy intensity change, whether it is specified as a continuous rate or a dummy variable. Firm specific fixed effect and year specific fixed effect terms have minor, if any, influences on the estimation. This indicates the usefulness of energy intensity decomposition presented in 4-2 and 4-3, and not much unexplained variance clustered at the firm level.

The annual energy-intensity decrease in the old capacity, driven by energy-efficiency investments and capital turnovers, is about 16 kg coal equivalent per thousand CNY, or 16 kgce/kCNY, during 2008-2010. Whether and how capacity utilization is controlled for does not influence the estimates much. The result is very impressive – considering that a ton of raw coal in China is about 700-800 CNY in price and equals about 0.7 ton of coal equivalent, energy-efficiency improvement led to annual reduction in operational cost of at least 15 CNY every 1000 CNY output, or 1.5% increase in gross profit rate.

Table 4.3 Intensity decreases in old capacity, new capacity, and new products.

Intensity decrease	(1)	(2)	(3)	(4)	(5)
in old capacity (α)	16.60***	15.58***	15.57***	16.86***	15.48***
	(2.3504)	(2.717)	(3.168)	(3.364)	(1.767)
in new capacity (β)	16.15***	16.21***	16.21***	16.19***	16.22***
	(0.3940)	(0.5531)	(0.5541)	(0.5425)	(0.5374)
in new product (γ)	-9.399***	-9.060***	-9.060***	-9.075***	-9.058***
	(1.784)	(1.763)	(1.768)	(1.763)	(1.761)
due to utilization	6.036	0.5624	0.5675	-	-
decrease, rate (θ)	(8.510)	(11.44)	(11.47)		
due to utilization	-	-	-	-2.164	-
decrease, dummy (θ)				(4.480)	
firm fixed effects	no	yes	yes	yes	yes
year fixed effects	no	no	yes	no	no
N	962	962	962	962	962
adjusted R^2	0.6497	0.6692	0.6685	0.6694	0.6699

Notes: In parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The estimates for energy-intensity decrease in the new capacity are about the same as that in the old one, but with smaller standard errors. The result represents the energy-efficiency improvement embodied in the new capitals, due to technological change. Because the overall technological change is not likely influenced by the short term regulation in energy saving, its effect is more consistent throughout the firms. In comparison, because energy-intensity decrease in old capacity is a mix of technological change introduced by capital turnovers and adoption of energy-efficiency technologies, it varies more across firms.

Quite unexpectedly, energy intensity increases with the production of new products, reflected by the significant and negative sign. To see this closely, table 4.4 lists the estimated results when firms with new products and those without are separated. The energy intensity decreases in both old capacity and new capacity are much smaller in firms with new products. The estimates for annual energy intensity decrease in old capacity in firm without new products are similar to previous estimates, but the estimates for decrease in new capacity and capitals are twice as previously estimated. In firms with new products, the estimates for new capital are similar to previous estimation, and that for old capacity are much smaller and less significant. In addition, the variance of energy intensity decrease in the old capacity is much larger in firms with new products, when firm specific features are not controlled for.

Table 4.4 Intensity decreases in firms with and without new products.

Intensity decrease	no new products	no new products	no new products	with new products	with new products	with new products
in old capacity	12.94***	14.39***	11.06***	9.145*	5.244***	4.436*
(α)	(1.665)	(1.238)	(1.739)	(5.497)	(1.192)	(2.657)
in new capacity	33.84***	33.82***	34.37***	12.12***	15.71***	15.72***
(β)	(0.5807)	(0.7626)	(0.7833)	(0.4049)	(0.2234)	(0.2291)
in new product	-	-	-	-3.926***	-6.149***	-6.127***
(γ)				(1.199)	(0.5695)	(0.576)
due to utilization	-10.66	-	-23.69***	2.224	-	-2.516
decrease, rate (θ)	(7.431)		(8.7775)	(13.41)		(7.376)
firm fixed effects	no	yes	yes	no	yes	yes
N	743	743	743	219	219	219
adjusted R^2	0.8207	0.8438	0.8465	0.8242	0.9806	0.9804

Notes: In parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 4.5 further displays a dichotomy of firms' profiles with and without new product development. Although the dependent variable, annual energy intensity decrease relative to previous output, has very close values in the two kinds of firms, the firms with new product development are on average almost three times larger in output and six times larger in output growth even if new products and lower capacity utilization are not counted, and they fulfilled more than two times energy saving annually and in total according to the NDRC's calculation, compared to that in firms without new products. In addition, the percentage of firms with new products varies greatly across industries, from only one firm in electric power industry to half of the firms in iron and steel industry.

Table 4.5 Statistics for firms with and without new products.

	obs.	$\Delta E_t/Y_{t-1}$ (kgce/kCNY)	$\Delta Y_t/Y_{t-1}$	$\Delta Y_t/Y_{t-1} \times D_t$	Y_{t-1} (bCNY)	ΔE_t (ktce)	firms	ΔE_{total} (ktce)
no new product	743	21.79	0.083	0.219	5.88	27.4	356	147.9
with new product	219	21.14	0.902	1.21	14.9	66.4	125	316.4

The seemingly different results in table 4.4 and table 4.5 reflect different ways to fulfill energy saving in the two kinds of firms and the calculation method. Although the energy intensity decrease in new capitals is much larger than that in old capacity, its contribution to the calculated energy saving is scaled by the growth rate of output, as indicated by equation 4-2 and 4-3. The 743 observations without new products have an average annual output growth of 21.9%, which scales the intensity decrease in new capitals down to only half of the decrease in old capacity, even if the negative energy-efficiency effect of lower capacity utilization in old capacity is not considered. On the other hand, the 219 observations with new products have an average annual output growth of 121%, which scales the intensity decrease in new capitals up to four times larger than the decrease in old capacity, using the results based on fixed effect estimations. Much larger average output of firms with new products further makes the absolute amount of energy conservation in old capacity comparable to that in firms without new products, and makes the calculated energy saving in new capitals several times greater.

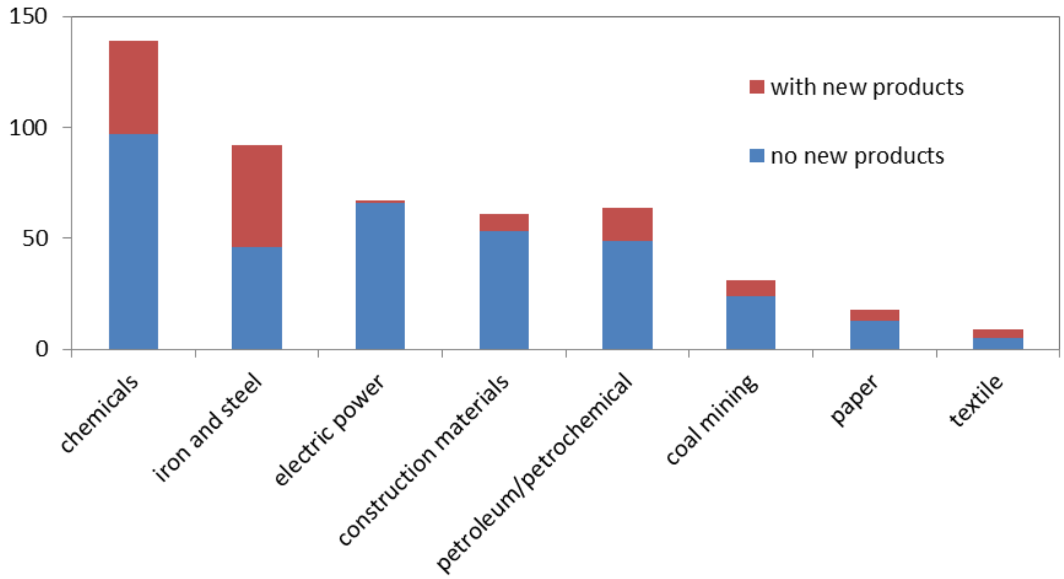

Figure 4.2 The number of firms with and without new products by industries.

The major energy saving method for firms without new product development is through energy-efficiency investments, and the method for firms with new products is through great expansion and moderate efficiency improvement in new capitals. There are two possible reasons for less energy-efficiency improvement in firms with new products. One is that energy saving and associated cost reduction and development of new products and associated market differentiation are alternative approaches for firms' motivation to improve competitiveness. The other is that the two are competing investment decisions that require substantial financial and technological capabilities. Additionally, there may also be a measurement issue that contributes the difference. The output growth is measured in monetary terms and may partially reflect better market condition for those firms with higher growth rate. If this is the case, the firms with new products face less competition pressure, and therefore are more willing to expand and less concerned with cost reduction in energy saving.

4.4.2 Determinants for energy-efficiency investments

The results above suggest that the firms with and without new products should be differentiated in the following estimation for factors influencing energy savings. The results of pooled OLS and fixed effects estimation, and that of mixed effects estimation are in table 4.6 and table 4.7, respectively. The fixed effect estimation is supposed to capture the short-term effect by focusing on variance within firms, while the pooled OLS estimation is supposed to capture the longer term effect by comparing between firms. The mixed effect estimation improves both estimations by taking care of the clustered data at different levels.

Particularly for firms without new products, the first mixed effect estimation shows that most of unexplained variability is at the industrial level and to a lesser extent at the provincial level, but not at the individual firm level. This echoes the close values of adjusted R^2 for the pooled and fixed effects estimations in table 4.6, and an F-test, which cannot reject the null hypothesis that all fixed effect terms are zeros. Including random coefficients for the new capacity term at the industry and provincial level further improves the mixed effect estimation. This reflects the fact that efficiency improvement in new capitals differ among industries and among provinces. On the other hand, for the firms with new products, the data is clustered at the firm level, for which fixed effects estimation is appropriate and does improve the estimation results. The results are therefore separately interpreted for firms without and with new products, with the former mainly based on the second specification of the mixed effects estimation, and the latter mainly based on fixed effects estimation.

Table 4.6 Factors for energy efficiency investments with pooled and fixed effect estimation.

Intensity decrease	all	no new products		with new products	
	pooled	pooled	FE	pooled	FE
profit rate	-0.324***	-0.409***	-0.211	-2.40***	-0.745***
	(0.117)	(0.079)	(0.186)	(0.245)	(0.254)
current ratio	-0.466	-0.775	0.077	0.060	-0.818
	(0.730)	(0.749)	(1.222)	(0.722)	(1.570)
employee	-0.159	-0.072	0.013	0.175	0.301
	(0.135)	(0.114)	(0.947)	(0.174)	(0.517)
export rate	-0.378**	-0.445***	0.533	-0.139	-0.283
	(0.173)	(0.127)	(0.540)	(0.265)	(0.386)
average profit rate	-2.131**	-1.974***	-10.94**	-0.660	-1.017
	(0.905)	(0.671)	(5.246)	(1.439)	(10.07)
% of loss-making	-1.351***	-0.819***	-6.194*	-2.375**	1.589
firms	(0.451)	(0.310)	(3.514)	(0.929)	(4.685)
relative standard	0.064	-0.008	0.585*	-0.904	-0.080
deviation, profit rate	(0.332)	(0.233)	(0.347)	(0.550)	(0.353)
relative standard	-10.34	-4.044	45.16	4.996	-53.88
deviation, output	(6.356)	(4.542)	(33.27)	(10.21)	(60.65)
electricity price	0.027	0.064***	0.100	-0.128	-0.338
	(0.037)	(0.025)	(0.157)	(0.079)	(0.221)
electricity scarcity	0.693	-5.012	-13.80	23.87*	-2.650
	(6.449)	(4.278)	(76.95)	(13.50)	(94.33)
relative fiscal	15.46***	16.02***	-0.194	-9.290	-20.34
expenditure	(5.801)	(4.030)	(24.74)	(10.76)	(31.51)
per capita GDP	-0.244	-0.481***	-3.156*	0.351	-3.093
	(0.228)	(0.165)	(1.668)	(0.418)	(2.351)
in new capacity	15.41***	33.65***	34.58***	8.745***	14.28***
	(0.4135)	(0.549)	(0.810)	(0.490)	(0.552)
in new product	-7.618***	-	-	9.898***	-1.321
	(1.408)			(1.758)	(1.825)
due to utilization	2.938	-13.86*	-29.85***	-10.08	-1.204
decrease, rate	(8.636)	(7.105)	(9.695)	(11.74)	(7.841)
firm fixed effects	no	no	yes	no	yes
N	960	742	742	218	218
adjusted R^2	0.6606	0.8420	0.8467	0.8771	0.9812

Notes: In parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

For firms without new products, higher profit and more export are associated with less energy saving in all estimations, with the only exception of fixed effects estimation, which only captures the difference within firms between 2008 and 2009. The result for profit rate is consistent with the finding in the case study research presented in the previous chapter, and the finding of Decanio and Watkins (1998) that firms with less expected future earnings growth are more likely to join the Green Lights program. It confirms that firms with less profit are more likely to adopt energy-efficiency investments with longer payback, so as to lower cost and improve competitiveness. The correlation between higher exports and lower energy saving does not follow the usual expectation of firms' environmental practice. For example, Nakamura et al. (2001) find that Japanese firms with more export are more likely to obtain ISO 14001 certification. The explanation may also link to the previous reasoning – more export is likely associated with more differentiated products and markets, tax rebates, and less pressure of competition, and therefore less motivation to lower the energy cost. The number of employee has no effect on energy saving, which is consistent Anderson and Newell (2004)'s finding of selective adoption from energy audits in small and medium-size firms, and differs from many other studies. This may result from explicit control for output and output growth in this estimation. Current ratio also has no measurable effect, indicating that firms' energy-efficiency investments are not significantly affected by liquidity constraints in current policy setting with financing support from the government and ESPC. Similarly, Japanese firms are also not subject to liquidity constraints (Sugino and Arimura 2011).

At the industry level, there is some evidence that lower average industry profit rate, like firms' own profit, also contributes to more energy saving. On the other hand, industries with more loss-making firms seem less likely to reduce energy consumption, which may suggest absolute loss, compared to lower profit, is a stronger damage to firms' financing ability and overshadows its effect on motivating

Table 4.7 Factors for energy efficiency investments with mixed-effect estimation.

Intensity decrease	all	no new products		with new products	
profit rate	-0.302***	-0.389**	-0.382***	-2.29***	-0.106
	(0.116)	(0.078)	(0.073)	(0.230)	(0.119)
current ratio	-0.506	-0.761	-0.958	-0.158	-0.086
	(0.717)	(0.729)	(0.676)	(0.762)	(0.270)
employee	-0.039	-0.023	-0.106	0.196	-0.045
	(0.144)	(0.119)	(0.110)	(0.230)	(0.068)
export rate	-0.310*	-0.392***	-0.242**	-0.108	-0.182*
	(0.177)	(0.130)	(0.123)	(0.300)	(0.102)
average profit rate	-2.167	-1.757*	-1.025	-1.763	-0.734
	(1.374)	(1.030)	(0.964)	(1.835)	(0.554)
% of loss-making	-1.137	-0.671	-0.322	-3.27***	-1.10***
firms	(0.740)	(0.554)	(0.517)	(1.189)	(0.362)
relative standard	0.158	0.0542	0.015	-0.722**	-0.110
deviation, profit rate	(0.327)	(0.230)	(0.220)	(0.345)	(0.198)
relative standard	-8.113	-2.256	-0.987	-7.079	3.23
deviation, output	(10.48)	(7.867)	(7.315)	(12.28)	(3.88)
electricity price	0.024	0.056**	0.043*	-0.081	-0.026
	(0.040)	(0.025)	(0.023)	(0.098)	(0.030)
electricity scarcity	-1.044	-5.723	-5.124	23.47	14.83***
	(6.84)	(4.254)	(3.920)	(17.53)	(5.23)
relative fiscal	16.03**	16.93***	16.83***	-5.149	-2.893
expenditure	(6.614)	(4.123)	(3.788)	(13.32)	(4.125)
per capita GDP	-0.223	-0.427**	-0.340**	0.310	-0.014
	(0.255)	(0.168)	(0.156)	(0.553)	(0.162)
in new capacity	15.80***	33.64***	23.76***	9.949***	8.423***
	(0.4071)	(0.534)	(8.84)	(0.475)	(2.386)
in new product	-7.412***	-	-	8.820***	1.019
	(1.387)			(1.585)	(3.597)
due to utilization	-1.843	-17.18**	-8.663	-3.552	-7.074
decrease, rate	(8.569)	(6.94)	(6.917)	(9.424)	(4.788)
firm level (α_j)	0.000	1.444	-	40.46	4.941
	(0.000)	(20.04)		(9.34)	(2.606)
province level (u_r)	11.29	3.689	0.000	0.069	-
	(3.923)	(3.011)	(0.000)	(0.280)	
industry level (v_s)	7.854	6.446	5.931	0.001	-
	(3.238)	(2.183)	(2.040)	(0.422)	
new capacity× α_j	-	-	-	-	4.292
					(1.594)
new capacity× u_r	-	-	38.63	-	-
			(8.91)		
new capacity× v_s	-	-	8.229	-	-
			(12.44)		
N	960	742	742	218	218
Log-likelihood	-5197	-3646	-3616	-1115	-924

Notes: For random effects, standard deviations are estimated. In parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

firms to improve competitiveness. The coefficients for the two factors measuring industry homogeneity are not significant.

Provincial context has stronger influence. As expected, higher electricity price and more fiscal expenditure on science and technology, environmental protection and energy saving both encourage more energy efficiency investments, suggesting that market and technology policies can be effective. GDP per capita is negatively correlated with energy saving, unlike the expectation. This result is robust in all estimations and may reflect the fact in more developed provinces with higher GDP per capita, firms had already used more advanced technologies and had less potential in energy conservation and efficiency improvement. In comparison, in firms with new products, where major energy saving is through expansion and embodied technology change in new capitals, energy intensity decrease is not associated with GDP per capita.

The coefficient for capacity utilization is negative in all specifications except the second mixed effects estimation. However, as specified in equation 4-3, decrease in capacity utilization is measured as negative output growth, suggesting that lower capacity utilization actually decreases energy intensity. This may reflect that the measurement mainly captures the process of outdated capacity closure, which suspended capacities that were most energy-intensive.

The energy intensity decrease in firms with new products is clearly different. The decrease is negatively associated with profit and the percentage of loss-making firms, like in the estimation for firms without new products. Electricity scarcity weakly correlates with energy intensity decrease. According to the estimated coefficients, these firms seem to be more sensitive to their profit rates when making energy saving investments, indicating they are more flexible in determining whether or not to invest in energy saving. There is no evidence of influences from other factors. The explanatory variables, however, do help correct the negative correlation between new products development and energy intensity decrease. This means that the negative impact of new product development on energy efficiency investment has been controlled for in the current specifications, and new product production is not intentionally directed to either energy saving or energy consuming.

With the mixed effects specifications, the time-invariant factors – firms' age, ownership, reform, and expenditures in R&D, in education, and in advertisements, and provincial regulations and knowledge spillovers – are also included. None of these factors show statistically significant effect on energy saving. However, their interaction term between ownership and the new capital for firms without new products, that between ownership and the new capital and between R&D and the new capital for firms with new products have significant coefficient. This indicates some effect of firm heterogeneity only on the choice of new capitals.

4.5 Discussion and implications

The energy efficiency gap and investment barriers have been explained as market failures and behavioral barriers (Gillingham et al. 2009; Jaffe et al. 2004). Market related barriers include incomplete information and uncompensated positive externalities in information diffusion, externalities in innovation and adoption, environmental externalities and energy pricing, and capital market constraints.

Behavioral barriers include the uncertainty and irreversibility in efficiency investment, biased investment estimation, and heterogeneity of energy users.

While increasing focus is now given to the behavioral barriers in energy efficiency investments, this research indicates no measurable evidence of these factors in correlation with energy intensity decrease in old production capacities of Chinese energy-intensive firms, even for commonly observed influences such as ownership and firm size. Limited association between firm feature and energy efficiency is found only in the selection of new capitals. On the one hand, this result is supported by the method to focus on energy intensity change, rather than absolute demand change, and to control for change in capital structure and product composition. On the other hand, this result relates to the research setting of the Top-1000 program, which combines information dissemination, voluntary agreement, monitoring, and financial support. These measures help remove market failures and behavioral barriers – such as lack of information and uncertainty – in adopting energy efficiency technologies. Because new capital investments are not subject to these policy measures, firms' heterogeneity in new capital investments still exists.

The factors that help explain most of firms' variance in energy intensity decrease are all economic ones. Particularly, the results support the observation of the case study research in the previous chapter and another research, showing that higher competitive pressure pushes firms to make more ambitious energy efficiency investments to reduce operational costs. Lower firm and industry-wide profits and lower export rate all associate with more energy intensity decrease. Corresponding with this, electricity price, measured at the province level, also positively associate energy intensity decrease. The significance of firms' rational behaviors in energy saving is again greatly due to the policy assistance, especially ESPC which helps firms acquire financing support for their investments more easily. However, there is likely a fine line between competitive pressure and absolute loss, which negatively affects the investments, probably because industries with more loss-making firms are less favored in the capital market and by the energy services companies.

Government expenditures do help firms in reducing energy intensity, unlike the previous chapter that suggests serious free-riders. The results reflect on the one hand the difference of two types of research design and sample selection, and on the other hand the limited effectiveness of financial policies in energy saving. Therefore, further research is needed to examine to what extent and under what conditions the financial policies are effective, and how efficient they are.

According the current calculation method for firm energy saving, which refers to the energy consumption per output at the firm level in the previous year as the basis, firms with greater expansion – usually indicated by the development of new products – fulfilled much more energy saving. However, these firms adopt new capitals with less efficiency improvement and conserve energy in their existing production capacity at a slower pace, compared to firms with less or no expansion, and take advantage of their higher growth rate and greater output in energy saving calculation. The fact suggests the need for more detailed energy audit and monitor, and energy saving targets designed in absolute terms, if energy conservation and GHG emission mitigation are the final policy targets.

Chapter 5 Spatially based regulation and industry location

The previous two chapters focus on firms' reduction in energy consumption under the current policy. Alternatively, firms may choose to relocate and avoid higher regulation. Based on a dataset of 20 two-digit manufacturing industries across 29 provinces during 2005-2010, the impact of the provincial energy-saving regulations on manufacturing location in general, and the differential impact across industrial sectors are examined.

This research departs from the existing literature in three important aspects. First, unlike the previous literature with dichotomy of policy stringency or inappropriate proxies for regulation, the energy-saving regulation stringency in China is predetermined by the policy targets, varies continuously across provinces, and interacts with industries in a complicated way according to an industry's energy intensity, as measured by energy consumption per unit of value added. Second, potential unobserved heterogeneity raised by spatially dependent data generating processes, such as the adaption of provincial governance according to neighboring provinces and spillovers of factors of production, may not be fully addressed by using fixed effects terms. This research explicitly tests for spatial autocorrelation in the data set. Third, previous research was usually based on a single policy measure. In contrast, this paper compares the spatial effect of electricity price with that of regulation on energy saving. It also compares different regulatory effects between industrial sectors nation-wide, complementing the main drivers of inter-provincial change in industry location. The efforts compose a more comprehensive understanding of the policy impacts of various manifestations of environmental regulation stringency on industrial location.

In addition to its contribution to the literature, the research provides a basis on which to evaluate energy-saving policies in China and to inform efforts at strengthening long-term energy saving and regional sustainability. The spatially based regulations are basically the same in 2011-2015 as in 2006-2010 of the research period, and may be extended to 2020 for the committed national target of CO_2 emission reduction. Studies show that Chinese industrial relocation in the early 1990s, especially the movement of energy-intensive industries into the east coast region where energy intensity is relatively low, helped save more energy, thanks to the region's endowment, preferential policies, and spatial interactions (Zhao and Yin 2011; Yu 2012). Policy-induced relocation of energy-intensive industries outside the region may decrease energy saving through other means. The relocation may also increase the consumption of other resources in high demand by the energy-intensive industries, like water, in other regions, and raise a threat to regional sustainability.

The remainder of the chapter is organized as follows. The first section briefly introduces the previous literature regarding the locational effect of environmental regulations. Section 2 and section 3 explain the use of data and estimation approach, respectively. The results for baseline estimation, spatial autocorrelation and spatial models, and those for dichotomous policy measures and nation-wide policy effects are reported in section 4 and section 5, respectively. The paper closes in section 6 with an interpretation of the results and implications.

5.1 Previous research

Whether industrial activities are sensitive to inter-jurisdictional differences in environmental regulation has long been a research focus. Domestically, this question concerns the economic costs of environmental regulations – the loss of productivity and jobs due to higher regulation, and the costs of relocating production and workers across regions. Internationally, understanding impacts of tougher regulation on industry is essential to the debate over competitiveness, emissions leakage, and trade liberalization. Regulation-induced displacement of production and associate pollution may be further encouraged under trade liberalization, which leads to a concern that firms undercutting environmental standards to maintain competitiveness (Cole et al. 2006; Kim and Wilson 1997; Konisky 2007). Alternative arguments exist, however, notably Porter's dynamic view of comparative advantage, suggesting that proper design of environmental regulations can encourage innovation and technological change, and thus enhance competitiveness (Porter and Van der Linde 1995).

Both lines of argument call for better institutional arrangements to control pollution, which requires clear understanding of the types and size of costs induced by various environmental regulations currently enforced.

The most extensively studied regulation is the county nonattainment designations under the Clean Air Act Amendments (CAAA) in the US. Its regulatory effect has been confirmed to be negative and significant on polluting firms' location in nonattainment counties (Henderson 1996; Becker and Henderson 2000; List et al. 2003), their growth (Greenstone 2002), employment (Walker 2011), productivity (Greenstone et al. 2012), and overall county manufacturing activity (Kahn 1997). The regulation caused US based multinational firms to increase their foreign production (Hanna 2010). The estimated cost of reallocating workforce is far below the estimated benefit, but is much larger than the transition assistance allocated under the regulation (Walker 2012).

The evidence of other regulatory effects is not comparably satisfactory. The main reasons, from the perspective of research design, are the use of indirect policy measures that cause endogeneity in regression models, and the lack of panel data to deal with unobserved heterogeneity. Unlike the county ambient attainment status, which is directly observed and predetermined for the research period, indirect proxies for environmental regulation are usually used in other research. The most popular proxies in studies about the US environmental regulation impacts on industry come in the form of adjusted pollution abatement costs and expenditure measures. However, these measures have been confirmed to be endogenously determined through jurisdictional interactions in adjusting regulations (Levinson and Taylor 2008) or reversely by industrial activities (Ederington and Minier 2003), and to have insignificant effect on industrial activities if treated exogenously (Levinson 1996; Becker 2011). Research about regulatory impacts on industry location in European countries often uses environmental indexes that are not directly associated with practical regulation levels, often uses single-period cross-sectional data, and shows inconsistent results (Cave and Blomquist 2008; Javorcik and Wei 2004; Mulatu et al. 2010).

5.2 Data

5.2.1 Data source

The main dataset for this research comes from the China Industry Economy Statistical Yearbooks, which report industry-aggregate characters in each province annually, such as the number of firms, employment, and payable value-added tax. Only the manufacturing sector are considered because they are less dependent on geographical proximity to natural resources or consumers, and thus are more footloose than the mining and utility sectors. The dataset covers consistently all state-owned firms, and non-state-owned firms with annual sales of five million CNY or more. These firms accounted for more than 95% of manufacturing value added in 2005. Out of the 30 two-digit manufacturing industries according to the national industry classification standard (GB/T 4754-2002), 21 are consistently reported by the Yearbooks at the provincial level annually. The other nine industries that are not reported and not available for this study accounted for only 9% of manufacturing value added in 2005. Because the year 2004 was an industry census year, whose more comprehensive survey coverage produced industrial statistics out of the track described by the data from the years before and after, only data of years after 2004 are used.

The dataset is sufficient for the study, with the 2005 and 2006 as base years, and 2007-2010 as years with provincially differentiated regulations. Other provincial characteristics, such as Gross Regional Productivity (GRP), fiscal revenue, and unemployment rate, come from the China Statistical Yearbooks. Industrial characteristics, such as share of ownership, investment, and export, come from the

China Statistical Yearbooks, China Industry Economy Statistical Yearbooks, and China Economic Census Yearbook 2004. Most energy-related data, such as industrial energy consumption and provincial electricity production and consumption, come from the China Energy Statistical Yearbooks.

5.2.2 Data selection

Both employment and value added or output can indicate industrial size industrial location change. Employment is used here because value added by industry has not been reported since 2007, and output may reflect changes in supply or demand markets that are not related to industry location.

Regulatory stringency of energy-saving policies is measured by the inverse of the 2010 energy-intensity target for each province, announced by the National Development and Reform Commission (NDRC) and maintained on its website. In this way, the policy measure is expressed as an energy-efficiency target – the value added per energy consumption required to be met. A higher value represents more stringent regulation, which includes extensive energy-saving requirements, high administrative pressure, strict capacity control and elimination, and even direct relocation request, as indicated by the case study research in chapter 3.

Provincial targets interact with industrial performance on energy intensity, measured accordingly as industrial energy consumption per value added so that higher energy intensity and higher targets lead to tougher industry-by-province regulation. Only 2005 data are used to construct industrial energy intensity for two reasons. First, the provincial policy targets were designed based on energy consumption in 2005, and provincial enforcement, beginning around 2006-2007, could only use 2005 industrial energy consumption as the latest reference. Later enforcement may still follow the initially differentiated approaches to different industries, because the industry-specific and firm-specific requirements may have already been designed. Second, value added data are no longer reported at the two-digit or lower industry levels after 2007, making calculation of energy intensity unavailable. Considering that the time span of analysis is short, and the differences among industries' energy intensities are large (figure 2.2), it is assumed that the relative regulation levels across industries were unchanged.

The regulations are not randomly assigned, and considering these factors that may correlate with provincial energy-saving targets are particularly important for estimating the locational effect of regulation. As a counterpart of current local regulations on energy saving, the data of provincial electricity prices and industrial performance on electricity consumption are collected (figure 5.1a), implying the locational effect of a potential market policy. Provincial electricity prices in 2007-2010 are the sum of the provincial weighted average sales prices and provincial surcharges, reported in the annual Supervising Reports of Electricity Pricing by the State Electricity Regulatory Commission. The 2006 price is calculated by subtracting from the 2007 prices the price increases in 2007, reported from the same source. The 2005 price is calculated by subtracting from the 2006 prices half of the provincial price adjustments announced by the NDRC. The price adjustments are weighted by half as the price differences between 2005 and 2006 under two observations: First, the adjustments were in effect since June 30, 2006, and the 2006 prices were the average of the prices before and after the adjustment, assuming the same amount of electricity consumption in the first and second halves in 2006. Second, no price adjustment has been found on the NDRC's 2005 announcement list, which suggests that the price in 2005 for a province might be the same as that in the first half of 2006.

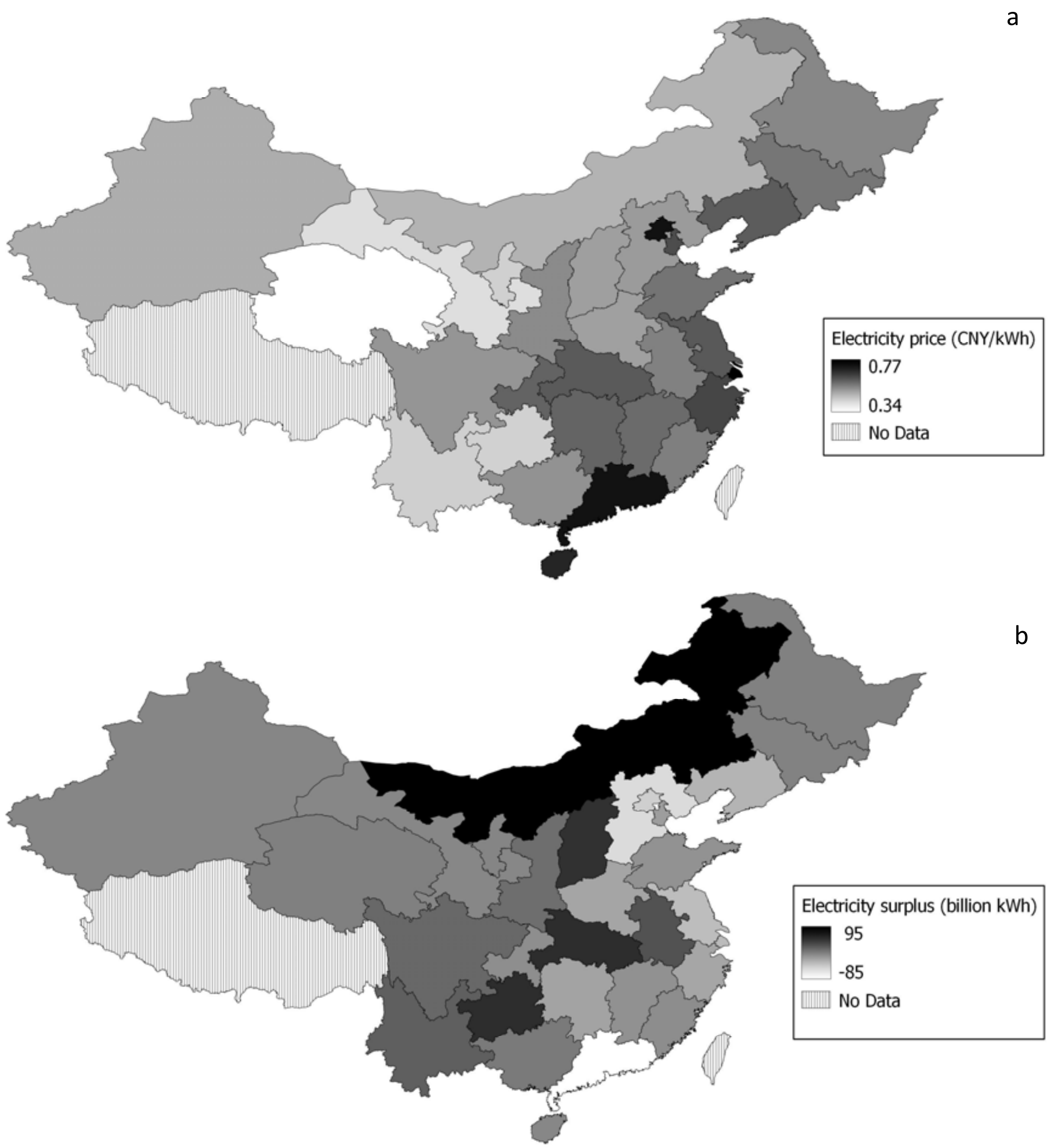

Figure 5.1 Spatial correlation of electricity price and energy endowment in 2010. Energy endowment is the difference between electricity production and consumption. (Data source: State Electricity Regulatory Commission's Annual Supervising Reports of Electricity Pricing; China Energy Statistical Yearbook).

Industrial electricity consumption is measured differently from their energy-intensity performance, namely as the ratio between annual electricity consumption and annual production cost. In this way, the interaction between provincial prices and industrial performance is a measure of electricity cost in industrial production cost for each industry in each province, and represents the industry's sensitivity to electricity pricing. Annual industrial electricity consumption comes from the China Energy Statistical Yearbooks, and the main business costs, reported by the China Industry Economy Statistical Yearbooks, are used as proxies for the annual industry production costs.

Similarly, provinces with lax targets and low electricity prices usually have more abundant energy endowments, which may also attract energy-intensive industries. This energy endowment is measured as electricity surplus, i.e. production minus consumption, for each province in general (figure 5.1b). The interaction term between provincial surplus and industrial energy intensity is used to measure industry-specific attractions in each province. Likewise, the development level of a province may correlate with both its energy-saving target and its economic structure, and is measured in per capita GRP.

Other individual-level and provincial-level covariates are also controlled, to at least increase estimation precision. Individual-level covariates include scale economies, measured as average employment per firm, and local protectionism, measured as the share of industry-specific payable value-added tax in provincial fiscal income. The former is a common determinant for industrial agglomeration, and the latter is a specific one in China (Lu and Tao 2009; Bai et al. 2004).

Other factors that are discussed in the industrial agglomeration literature, such as knowledge spillovers, are not considered at the individual level but at the provincial level, because including them at the individual level greatly reduces the number of observations, changes the sample structure systematically, and does not improve the estimation, as preliminary analysis have shown. These factors include market size, measured here by provincial GRP and population, economic prosperity, measured by GRP growth and unemployment rate, labor supply, measured by the number of vocational school graduates, labor cost, measured by manufacturing wage, knowledge spillovers, measured by the number of patents, transportation infrastructure, measured by total volume of freight traffic, and manufacturing investment.

5.2.3 Data description

Some adjustments are made for the sample before estimation. The tobacco industry is excluded because it is an extremely small sector compared to others, with no more than four firms in most provinces. Also, industries in Xinjiang province are excluded because the provincial policy target is not available, and industries in Tibet are excluded because the geographic feature prevents most of the industries from locating there. Out of the remaining 20 industries in 29 provinces, 13 provincial industrial units are not observed in all the six years of 2005-2010. Although observed in some years, they are excluded to create a balanced panel dataset, mainly for the spatial analysis. Analyses show this final adjustment does not affect the estimation results. The final sample includes 567 out of the 580 provincial industrial units observed in six years. Table 5.1 shows the descriptive statistics of the variables in the final sample.

Table 5.1 Summary statistics.

Variable	Unit	Obs.	Mean	Std. Dev.	Min	Max
industry by province						
employment	1,000 people	3402	105.5	205.7	0.2	3245
average firm size	1,000 people	3402	0.284	0.289	0.026	6.13
tax contribution	%	3402	1.78	2.43	0.001	24.55
provincial						
efficiency target	CNY/kgce	29	9.18	3.50	3.02	15.78
electricity price	CNY/kWh	174	0.457	0.095	0.259	0.711
energy surplus	billion kWh	174	-0.431	28.38	-85.2	96.33
per capita GRP	1,000 CNY	174	19.36	12.17	4.47	57.86
provincial GRP	trillion CNY	174	0.810	0.665	0.4844	3.30
population	million people	174	44.11	26.28	5.39	101.30
GRP growth	%	174	13.12	2.22	5.40	23.80
unemployment rate	%	174	3.81	0.64	1.3	6.5
vocational school graduates	1,000 people	174	139.9	100.9	5.804	466.9
manufacturing wage	1,000 CNY	174	17.91	5.02	11.03	39.00
patent granted	1,000 items	174	9.18	14.81	0.07	87.29
freight traffic	billion ton	174	0.736	0.494	0.0621	2.841
manufacturing investment	trillion CNY	174	0.129	0.143	0.0045	0.790
industrial						
industrial energy intensity	kgce/CNY	20	0.23	0.23	0.026	0.76
electricity consumed/cost	Wh/CNY	120	61.74	49.87	13.56	212.63
% of export shipments	%	120	17.39	16.49	1.659	68.14
% of loss-making firms	%	120	16.73	3.86	8.04	27.14
% private employment	%	120	29.69	9.67	8.32	50.59
% state employment	%	120	22.02	14.79	1.97	58.95
foreign investment, lag	billion CNY	120	52.32	53.86	4.85	280.4
Hong Kong, Taiwan, and Macao investment, lag	billion CNY	120	26.49	24.53	4.43	151.0

Notes: All the monetary variables are initially collected at current price, and deflated at 2005 price for description and estimation. The price deflator for each year is calculated as the ratio between GDP growth at current price and that at constant price, i.e. $p_t = (GDP_{t,current} / GDP_{2005, current}) / (GDP_{t, constant} / GDP_{2005, constant})$, all reported by the China Statistical Yearbook 2011 for consistency.

5.3 Empirical approach

5.3.1 Baseline specification

Employment is assumed to be negatively affected by regulatory stringency, which varies across provinces, across industries within each province, and through time. For the ease of estimation, it is first assumed that the incremental accumulation of policy impacts after initial enforcement is linear through time. This strong assumption is relaxed later. The effect of regulations – the enforcement of energy-efficiency targets – and their counterparts of electricity pricing, both generally on a province and specifically on an industry within the province, is then expressed as

$$Reg_{ipt} = \beta_1 T_p \times \tau + \beta_2 EI_i \times T_p \times \tau + \beta_3 \log(P_{pt}) + \beta_4 El_{it} \times \log(P_{pt}) + \varepsilon_{ipt} \quad , (5\text{-}1)$$

where T_p is province p's energy-efficiency target, P_{pt} is its electricity price in year t, EI_i is industry i's energy intensity in 2005, El_{it} is its electricity consumption per business cost in year t, ε_{ipt} is an individually and identically distributed disturbance term, and τ is zero in base years 2005 and 2006, one in year 2007, two in year 2008, and so forth. The policy enforcement is assumed to be effective from 2007 onward, because provincial targets were announced at the end of 2006, and the NDRC did not evaluate and audit provincial fulfillment of their targets until 2008 for the year 2007.

The natural log of employment is used to remove the highly skewed distribution. Similarly, the natural log for electricity price is used to readily allow for the interpretation of its regression coefficient as price elasticity. The same transformation is not applied to policy targets because the differences between provincial targets are much larger, and an elasticity interpretation is not convenient.

Like employment, the statistical distributions of other individual-level observations – employment, tax contribution, and average firm size – are considerably skewed with thick tails. They are transformed by taking the natural logarithm before entering into the estimation.

All these individual-level covariates and provincial-level factors enter into the estimation with one-year lag, to avoid potential simultaneity and to strengthen the causal inference on energy-saving regulations. As an exception, specifications with contemporary and lagged electricity data are both considered, because electricity price before 2005 is not available, which leads to one year less observations with lagged electricity data.

The preexisting industrial composition in each province is controlled by industry-by-province fixed effects terms. The national-level energy-saving policies and other domestic and foreign influences that have different impacts across industries but not provinces are controlled by industry-by-year fixed effects terms. The estimation is in the form of

$$\log(y_{ipt}) = Reg_{ipt} + X_{ipt-1}\gamma + X'_{pt-1}\gamma' + \mu_{ip} + \theta_{it} + \varepsilon_{ipt}\,, \qquad (5\text{-}2)$$

where y_{ipt} is the employment in industry i, province p, and year t, Reg_{ipt} is the effect of energy-efficiency target and electricity pricing specified before, X_{ipt-1} is the lagged individual-level covariates, X_{pt-1} is the lagged provincial-level covariates, μ_{ip} is the industry-by-province fixed effects, θ_{it} is the industry-by-year fixed effects, and ε_{ipt} is an individually and identically distributed disturbance term.

5.3.2 Spatial autocorrelation

The data sample may be spatially correlated and lead to inconsistent estimates, because of spatially-dependent data generation process, such as neighboring provincial governments competing with each other to attract investors, or unobserved spatial heterogeneity, such as spillovers of factors of production. Particularly relevant here is provincial governments monitoring the behavior of other provinces so as to balance their environmental regulation and economic growth.

A simple way to detect the spatial correlation in data is to map them geographically and observe the pattern directly. In this way, figure 2.1 shows the spatial autocorrelation of provincial energy-intensity targets. For more complicated data structure and tests of statistical significance, some measures are used, among which Moran's *I* is the most common one. Moran's *I* is a statistic structured as the Pearson product-moment correlation coefficient between one variable and its spatial lag, produced by multiplying with the variable a spatial weight matrix *W*:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\ (z_i - \bar{z})(z_j - \bar{z})}{\sum_{i=1}^{n}(z_i - \bar{z})^2}, \qquad (5\text{-}3)$$

where is z_i the observation of z in region i, is the average of z across regions, and W_{ij} is the element in the spatial weight matrix $\bar{z}$ W, denoting some spatial relationship from region j to region i. The value ranges from -1 – perfect dispersion – to +1 – perfect correlation. Spatial autocorrelation is indicated by a significant deviation from zero, the random dispersion.

A spatial weight matrix is usually constructed in a geometric way, for example based on contiguity of spatial units, or in a more theoretical formulation, for example based on a distance decline function. In research about China, Coughlin and

Segev (2000) and Yu and Wei (2003) both use contiguity-based weight matrices. Because Hainan province is an island with no neighbors, the former specify Hainan and Guangdong province as contiguous, and the latter combine the two as a single province, considering their geographic proximity and historical unity. Madariaga and Poncet (2007) construct the spatial weight matrix based on the inverse of squared distance, and Yu (2012) construct the matrix based on the inverse of distance.

Both contiguity-based and squared distance-based weight matrices are considered here, with Hainan province treated contiguous with Guangdong province. The former is expected to capture more small-scale spillovers and externalities among cities and counties along the border, and the latter is expected to capture more large-scale interactions and spillovers between provinces. The weight between province *i* and *j* is set to one if *i* and *j* are contiguous and to zero otherwise in the former, and is set to the inverse of their squared distance in the latter. The matrices built are then row-standardized so that all the weights between a province and all the others sum to one. Kronecker products of the weight matrices and corresponding identity matrices are used, to construct block matrices with dimensions of the numbers of one-year observations or total observations of the dataset, and one block containing weights for an industry in one year across provinces.

The core specification can be revised to measure the size of spatial dependence. One way is to explicitly add spatial lags of the dependent variable to the model, as a spatial autoregressive model:

$$y_{ipt} = \rho W y_{ipt} + Reg_{ipt} + X_{ipt-1}\gamma + X'_{pt-1}\gamma' + \mu_{ip} + \theta_{it} + \varepsilon_{ipt} \quad , \quad (5\text{-}4)$$

where W is the weight matrix, and ρ is the spatial autoregressive coefficient describing the strength of spatial dependence, with a value between -1 and 1. Alternatively, it can be assumed that spatial autocorrelation only exists in the error terms as a spatial error model. The previously specified fixed effects and disturbance terms are revised as:

$$\varepsilon_{ipt} = \lambda W \varepsilon_{ipt} + \mu_{ip} + \nu_{ipt} \quad , \qquad (5\text{-}5)$$

where λ is the spatial autocorrelation coefficient, μ_{ip} is the individual fixed effects, and ν_{ipt} is independently and identically distributed disturbance term over industry, province, and time.

5.4 Results

5.4.1 Baseline estimation

Table 5.2 reports the value of coefficients and associate standard errors obtained from estimating several variations of equation 5-2. The coefficient for the provincial target, industrial intensity, and time interaction term (β_2) is negative and significant under all specifications, indicating a deterrent effect of energy-saving regulations on energy-intensive industries. When preexisting provincial industrial compositions are controlled by industry-by-province fixed effects, as in columns 2 to 5, the coefficient is consistently estimated between -0.82 and -0.72%. It is the most significant among the three energy-related factors that affect industry location.

The coefficient for the cross-industry impact of provincial energy-efficiency target (β_1) is significant and positive under specifications with contemporary electricity data. The positive value is explained elsewhere (Mulatu et al. 2010) as forming a cut-off point with the interaction term, which usually has a negative value, so that for industrial pollution there is a neutral level above which industries are negatively affected and below which industries are positively affected. However, the decreasing magnitude and significance of the cross-industry coefficient when more variables are controlled, and especially when the regression is specified with lagged electricity data and only 2006 as base year (column 4) suggest that an alternative model specification is also relevant.

Regulatory impact on employment can be more accurately interpreted combining the cross-industry and industry-specific terms, based on the estimation of column 4. Taking an industry of high energy intensity of 0.7 kg coal equivalent/CNY (nonmetallic mineral products or ferrous metals industries), a regulatory difference of 7 CNY/kgce, i.e. two standard deviations of the energy-efficiency targets, causes an annual employment loss of 2.8% under high regulation relative to low regulation (exp((-0.0082×0.7+0.0017)×7)-100%, or (-0.82%×0.7+0.17%)×7 roughly, similarly afterwards), and 12% in four years. In contrast, an industry with low energy intensity of 0.05 kgce/ CNY would experience 0.9% relative gain in annual employment, and 3.7% in four years under high regulation. If the cut-off point argument stands, the ratio between the two coefficients suggests that industries with 2005 energy intensity above 0.21 kgce/CNY were negatively affected by high regulation. They include nonmetallic mineral products, ferrous metals, petroleum and coal processing, raw chemical material and chemical products, nonferrous metals, paper and paper products and chemical fibers industries.

Table 5.2 Regulatory effects on log employment, core specifications.

	(1)	(2)	(3)	(4)	(5)
province target × τ (β_1)	0.0041***	0.0049***	0.0032***	0.0017	
	(0.0014)	(0.0006)	(0.0009)	(0.0010)	
target×intensity × τ (β_2)	-0.0338***	-0.0073***	-0.0072***	-0.0082***	-0.0080***
	(0.0028)	(0.0009)	(0.0027)	(0.0029)	(0.0027)
log electricity price (β_3)	0.3352***	-0.0496	0.2441		
	(0.0897)	(0.1169)	(0.1684)		
log electricity price ×	-0.0004	0.0019***	-0.0014		
consumed electricity/cost (β_4)	(0.0004)	(0.0005)	(0.0013)		
log electricity price, lag (β_3)				0.1820	
				(0.2001)	
log electricity price ×				-0.0026*	-0.0029**
consumed electricity/cost				(0.0014)	(0.0014)
(β_4), lag					
energy surplus, lag	-0.0001	0.0011***	0.0003	0.0015***	
	(0.0007)	(0.0004)	(0.0004)	(0.0005)	
energy surplus ×intensity, lag	0.0050*	-0.0011	0.0003	0.0001	-0.0000
	(0.0019)	(0.0012)	(0.0012)	(0.0014)	(0.0013)
per capita GRP, lag	0.0368***	0.0096***	0.0099***	0.0077**	
	(0.0034)	(0.0030)	(0.0029)	(0.0034)	
log firm size, lag	0.0776***	0.1885***	0.1365***	0.1398***	0.2305***
	(0.0239)	(0.0183)	(0.0183)	(0.0207)	(0.0216)
log tax contribution, lag	0.6588***	0.1679***	0.1468***	0.1141***	0.0970***
	(0.0105)	(0.0090)	(0.0092)	(0.0101)	(0.0102)
GRP, lag	-0.1605	-0.2399***	-0.2607***	-0.2610***	
	(0.0984)	(0.0648)	(0.0634)	(0.0834)	
population, lag	0.0232***	0.0079**	0.0073**	0.0286***	
	(0.0017)	(0.0032)	(0.0031)	(0.0081)	
GRP growth, lag	0.0136**	0.0168***	0.0190***	0.0182***	
	(0.0064)	(0.0024)	(0.0024)	(0.0025)	
unemployment rate, lag	0.0805***	-0.0486***	-0.0466***	-0.0314	
	(0.0232)	(0.0152)	(0.0147)	(0.0196)	
vocational school graduates,	-0.0002	0.0015***	0.0014***	0.0010***	
lag	(0.0004)	(0.0002)	(0.0002)	(0.0002)	
manufacturing wage, lag	0.0051	-0.0012	-0.0172***	-0.0082	
	(0.0064)	(0.0037)	(0.0046)	(0.0055)	
patent, lag	0.0064***	0.0011	0.0016*	0.0008	
	(0.0021)	(0.0007)	(0.0007)	(0.0008)	
freight traffic, lag	0.3977***	0.0955***	0.1027***	0.0845***	
	(0.0517)	(0.0242)	(0.0229)	(0.0232)	
manufacturing investment,	-0.1308	0.3181***	0.2742**	0.7074***	
lag	(0.2241)	(0.1107)	(0.1094)	(0.1387)	
industry by province	no	yes	yes	yes	yes
industry by year	no	no	yes	yes	yes
province by year	no	no	no	no	yes
N	3402	3402	3402	2835	2835
adjusted R^2	0.7773	0.9885	0.9898	0.9911	0.9922

Notes: In parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The evidence of electricity pricing's deterrent impacts on industrial employment is not comparably strong – the interactive coefficient is only negative and significant when one year lag is used at 10% level. A cut-off point is 70 Wh/CNY of electricity consumption per unit of production cost, above which were only four industries in 2010 – nonferrous metals, nonmetallic mineral products, ferrous metals, and raw chemical material and chemical products industries. The list included additionally paper and paper products, chemical fibers, metal products, and textile industries in 2005. With the highest electricity consumption per unit of production cost data from nonferrous metals industry of 136 Wh/CNY in 2009 and 213 Wh/CNY in 2005, 1% increase in electricity price would lead to an employment decline in that industry of 0.17% in 2010 and 0.37% in 2006. In comparison, a recent study in the US at the state level shows the results for industry-wide effect of the same magnitude (Deschenes 2010); at county level, almost all industries are confirmed to be negatively affected by electricity prices, with the largest elasticity of -1.13, one magnitude higher (Kahn and Mansur 2010).

When lagged electricity data is used, there is strong evidence that manufacturing industries were attracted by provinces with more abundant energy supply. Provinces with electricity surplus two standard deviations higher (57 billion kWh) are associated with 8.6% more manufacturing employment. However, there is no evidence that the energy endowment is more attractive to energy-intensive industries. The effect of interaction between energy endowment and industries with higher electricity-intensity is also estimated with no significant influence on employment, but the estimation not listed here due to limited space.

5.4.2 Spatial autocorrelation and estimation

Moran's I is used as the test statistic for the dependent variables and corresponding p-values inferred from random permutations of the real data are listed in table 5.3. With either specification of the weight matrix, spatial correlation of industrial employment was strong throughout the research period. In contrast, the estimated residuals in the previous section specified by column 4 in table 5.2 do not have any autocorrelation, with the only exception of negative autocorrelation in 2006 at 10% significance using the contiguity weight matrix. This may suggest some small-scale industry relocation between neighboring provinces in 2006, which is not captured in the estimation, because 2006 is assumed as a base year with no spatially differentiated regulation.

Table 5.3 Moran's I of dependent variables and estimated residuals.

	Total	2005	2006	2007	2008	2009	2010
Contiguity-based W							
log employment	0.3396	0.3332	0.3349	0.3346	0.3393	0.3366	0.3375
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
residuals	-0.0174	-	-0.0555	0.0054	-0.0281	0.0329	-0.0085
	(0.885)		(0.964)	(0.385)	(0.823)	(0.112)	(0.568)
Distance-based W							
log employment	0.3472	0.3428	0.3409	0.3383	0.3456	0.3476	0.3489
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
residuals	-0.0000	-	-0.0216	0.0109	0.0117	0.0268	-0.0086
	(0.520)		(0.797)	(0.293)	(0.286)	(0.129)	(0.641)

Notes: In parentheses are p-values inferred as the rank of the Moran's I statistic of the real data relative to the reference distribution of the statistics, created from 999 random permutations of the real data. A high p-value larger than 0.95 suggests negative spatial autocorrelation at 10% significance level.

Table 5.4 Regulatory effects on log employment, spatial lag and spatial error models.

	(1)	(2)	(3)
province target × τ (β_1)	0.0020*	0.0017*	0.0017
	(0.0011)	(0.0009)	(0.0010)
target×intensity × τ (β_2)	-0.0090***	-0.0083***	-0.0082***
	(0.0029)	(0.0025)	(0.0029)
log electricity price, lag (β_3)	0.2462	0.1892	0.1820
	(0.2048)	(0.1774)	(0.2001)
log electricity price × consumed	-0.0030**	-0.0027**	-0.0026*
electricity /cost, lag (β_4)	(0.0014)	(0.0013)	(0.0014)
energy surplus, lag	0.0016***	0.0016***	0.0015***
	(0.0005)	(0.0005)	(0.0005)
energy surplus ×intensity, lag	0.0001	0.0001	0.0001
	(0.0014)	(0.0012)	(0.0014)
per capita GRP, lag	0.0050	0.0072**	0.0077**
	(0.0039)	(0.0031)	(0.0034)
log firm size, lag	0.1345***	0.1383***	0.1398***
	(0.0211)	(0.0185)	(0.0207)
log tax contribution, lag	0.1142***	0.1137***	0.1141***
	(0.0101)	(0.0090)	(0.0101)
GRP, lag	-0.2130**	-0.2548***	-0.2610***
	(0.00897)	(0.0746)	(0.0834)
population, lag	0.0261***	0.0272***	0.0286***
	(0.0083)	(0.0073)	(0.0081)
GRP growth, lag	0.0190***	0.0185***	0.0182***
	(0.0025)	(0.0022)	(0.0025)
unemployment rate, lag	-0.0340*	-0.0329*	-0.0314
	(0.0197)	(0.0176)	(0.0196)
vocational school graduates, lag	0.0010***	0.0010***	0.0010***
	(0.0002)	(0.0002)	(0.0002)
manufacturing wage, lag	-0.0086	-0.0084*	-0.0082
	(0.0054)	(0.0049)	(0.0055)
patent, lag	0.0008	0.0008	0.0008
	(0.0008)	(0.0007)	(0.0008)
freight traffic, lag	0.0818***	0.0840***	0.0845***
	(0.0239)	(0.0212)	(0.0232)
manufacturing investment, lag	0.6546***	0.6943***	0.7074***
	(0.1433)	(0.1239)	(0.1387)
ρ	-0.1455		
	(0.0987)		
λ		-0.0389	
σ_v^2	0.0166	0.0199	0.0209
N	2835	2835	2835

Notes: In parentheses are standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Industry by province fixed effects and industry by year fixed effects terms are included.

Following the Moran's *I* statistics, the contiguity spatial weight matrix is used. The estimation follows the initial generalized moments estimator of Kapoor et al.

(2007) , and the generalization of Mutl and Pfaffermayr (2011) for within-estimators and spatial autoregressive models. The extensions for the specification of column 4 in table 5.2 with spatial lag and spatial autocorrelation are listed in column 1 and 2 of table 5.4, respectively. Column 3 shows the original estimation without spatial consideration. As suggested by Moran's *I* statistics, there is very little, if any, spatial dependence identified. The spatial coefficients are insignificant and small. Including spatial terms leaves little less variance unexplained, and makes the estimation for the three energy-related factors in larger magnitude, but the change is very little compared to the baseline estimation. In general, there is no evidence for the strategic interaction between provincial governments in energy-saving regulations.

5.5 Qualitative measures of regulation

An extension from the estimation of equation 5-2 is considered in this section, based on dichotomous measures of regulatory stringency. With the dichotomous measures of regulations and industries, also considered in this section is nation-wide effect of energy-saving regulations with a triple-difference estimation framework.

5.5.1 Estimation sensitivity to qualitative measures of regulation

The analyses above use the absolute value of provincial energy-efficiency targets (value added per energy consumption), and industrial energy intensity (energy consumption per value added), to measure the provincial regulatory stringency and the differentiation of regulation in specific industries, respectively. These results pertain to the impact of the performance-based energy-saving regulations in China. Alternatively, it is useful to consider alternative, dichotomous measures of regulations and industries, as high/low regulation, and energy-intensive/less intensive industry. By doing so, the magnitude and trend of regulatory effect is more transparent and comparable with other research, and the sensitivity of the results to measures of regulation and industry can be tested.

Pooling industries into groups is relatively easy, because there are sharp discontinuities in the distribution industrial energy intensity according to the 2005 data. Four industries have intensity levels above 0.54 kgce/CNY, i.e. above the cut-off point suggested by the regression with base year 2005 and contemporaneous electricity data. Another three have intensity levels below 0.40 but above 0.28 kgce/CNY – i.e. above the cut-off point suggested by the regression with base year 2006 and lagged electricity data. The other 13 industries include three with intensity levels between 0.11 and 0.17 kgce/CNY, and nine with intensity levels under 0.09 kgce/CNY. Therefore, the energy-intensive group can be set safely to include only the top four industries, and then expanded by including one industry at a time sequentially according to their intensity levels, to explore the change of cross-industry and industry-specific effects of regulation. The nine industries with lowest intensity levels can be safely left out of the energy-intensive group throughout the analysis.

Provincial energy-intensity targets change more continuously. Therefore, the demarcation between high and low regulation explored ranges from 0.08 CNY/kgce to 0.16 CNY/kgce, i.e. from seven provinces in the high regulation group and the other 22 in the low regulation group to 22 in the high regulation group. Provinces are similarly added to the high-regulation group one at a time.

Figure 5.2a and 5.2b show the annual general high-regulation effect on employment across industries and additional effect specifically on energy-intensive industries, respectively. Except using high-regulation and energy-intensive dummies for provinces and industries instead of energy-efficiency targets and industrial energy intensity, the rest of the regression specification follow that in column 4 of table 5.2. One point corresponds to one combination of demarcations for high regulation and for energy-intensive industries.

The general high-regulation impacts across industries change from negative to positive when more provinces with laxer regulations are considered highly regulated (figure 5.2a). At the same time, the additional effects on energy-intensive industries change from little below zero to significantly negative (figure 5.2b). The general trends are far from smooth, indicating that the effective regulation level in each province is not linearly correlated with its energy-efficiency target specified in previous regressions. Some provinces with laxer targets actually experience more induced employment loss and contribute more to the pooled regulatory impact than some provinces with more stringent targets. With different specifications of energy-intensive industries, the trends of general effects are parallel (figure 5.2a), while the trends of specific effects are crossing each other (figure 5.2b). They suggest that each province has different effective regulations on different industries, which are not shared nation-wide.

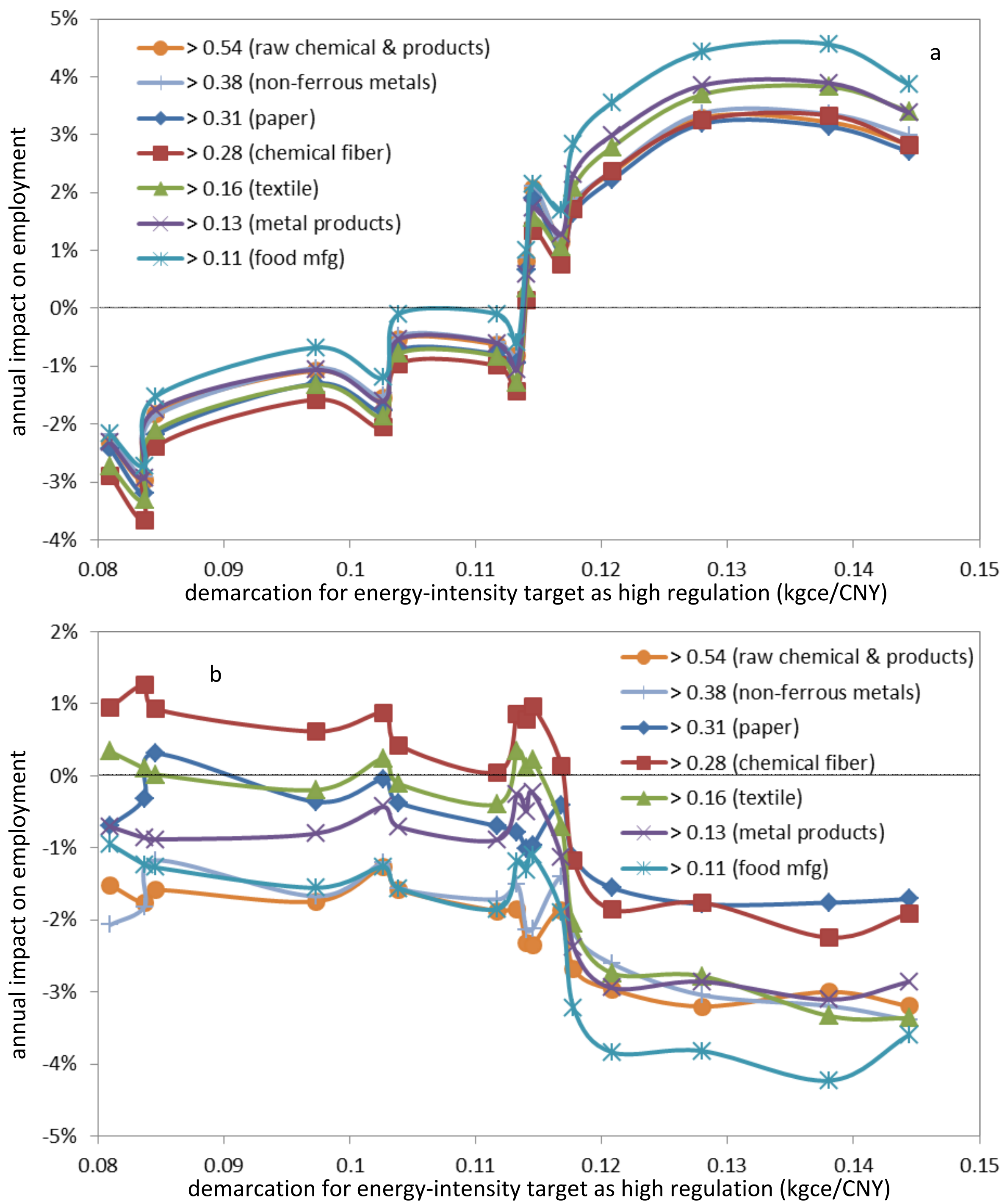

Figure 5.2 Sensitivity of regulatory effects to classifying industries and provinces. More industries and provinces are sequentially included into the high categories: (a) cross-industry regulatory impact, (b) additional impact specifically on energy-intensive industries.

The general cross-industry high-regulation effects in figure 5.2a capture the differences between high-regulation associated change in industries other than energy-intensive ones and low-regulation associated change over all industries. The additional effects in figure 5.2b capture the differences between high-regulation associated changes in energy-intensive industries and other industries. Therefore, the large negative general effects and small negative or insignificant specific effects on the left-hand sides of the figures suggest that in a few provinces with extremely high regulation, the regulatory effects are dispersed evenly to most manufacturing industries. The insignificant general effects and significant negative specific effects under some specifications of industries in the middle of the figures suggest that provinces with moderate energy-efficiency targets regulate only some of their industries stringently. The positive general effects and negative specific effects on the right-hand side simply suggest that the high-regulation group is specified too broadly, so that the two types of effects captured are mainly industry-specific effects relative to the average. The previous estimation results with numerical measures correspond to somewhere in the middle of the figures with small, positive general effects, and negative industry-specific effects in larger magnitude.

5.5.2 Nation-wide effect on energy intensive industries

The previous subsection demonstrates that the direction and magnitude of cross-industry and industry-specific effects of high regulations depend on the specifications of high-regulation provinces and energy-intensive industries. Following the observation, this subsection continues with the dichotomous measures of provinces and industries, and applies a triple-difference estimation framework. Such estimation not only helps identify cross-industry and industry-specific effects between highly and lowly regulated regions, and thereby spatial relocation of industries, but also helps identify regulatory effect on energy-intensive industries throughout the country. The latter is driven by local regulations shared by all provinces and national-level regulations on specific industries, and may lead to industrial relocation outside China and carbon leakage in other countries.

Assume that provinces with lax energy-saving targets only regulate energy-intensive industries to fulfill their targets, so that other industries can be considered as a control group with no regulation. Energy-intensive industries in these provinces experience a treatment denoted as $d_i = 1$, which consists of both national-level regulations for these industries, and local regulations for these industries averaged over provinces with lax targets. In provinces with stringent targets, industries that are not energy-intensive experience a treatment denoted as $d_p = 1$. The energy-intensive industries experience a treatment denoted as $d_{pi} = 1$, which can be decomposed into a provincial treatment $d_p = 1$ like other industries in the same provinces, an industrial treatment $d_i = 1$ like the same industries in other provinces, and an additional treatment denoted as $d_i\, d_p = 1$, because the impact of d_{pi} not necessarily equals the sum of provincial treatment due to tougher targets and industrial treatment shared by all provinces. With control variables omitted only for simple display, the regulatory effects on industrial employment can be represented as

$$y_{ipt} = \alpha_t + d_p\beta_{1t} + d_i\beta_{2t} + d_i d_p\beta_{3t} + \varepsilon_{ipt} \quad , \qquad (5\text{-}5)$$

where α_t is the change of control group through year, and β_{1t}, β_{2t}, and β_{3t} are the year-specific effect sizes of provincial, industrial, and additional treatments. Because the data are pooled into groups with sufficient observations for each group, the treatments can be estimated for each year specifically. The results can also help test the linear accumulation of regulatory effects assumed previously.

Individual-level and provincial-level controls used in previous regressions are all kept. Instead of using industry-by-year fixed effects terms, industrial characters are explicitly incorporated for estimating the industrial treatment, especially those that may correlate with industrial energy intensity and energy-saving regulations. They include electricity consumption per production cost, ownership structure measured as percentage of employment in state-owned firms and percentage of employment in private firms, dependence on international market measured as export rate, general industrial business performance measured as percentage of loss-making firms, and foreign investment measured as capital input from foreign countries and capital input from Hong Kong, Macao, and Taiwan. The investment sources are differentiated following previous evidence about the association between environmental regulation and investment from ethnically Chinese sources (Dean et al. 2009). In addition, year fixed effects are included.

With a reference to the results from the previous section, only the provinces with extremely stringent regulations of energy-intensity targets below 0.084 kgce/CNY are included in the high-regulation group. There are eight provincial equivalents – Beijing, Guangdong, Shanghai, Zhejiang, Jiangsu, Fujian, Hainan, and Tianjin – accounting for about 40% of the GDP of the whole research area. Five provinces with targets between 0.084 and 0.11 kgce/CNY are removed, so that the low-regulation group is more distinctive from the high-regulation group, and comparably accounts for about 40% of the GDP. The distinction between the two groups also features the high regulation in the east coastal region, and the low regulation in other regions, especially the west. The energy-intensive group is more broadly defined to include industries with energy intensity above 0.13 kgce/CNY. They include nonmetallic mineral, ferrous metals, petroleum, raw chemical, nonferrous metals, paper, chemical fibers, textile, and metal products industries, accounting for 47% of the 2005 value-added of the all studied industries. The two industrial groups also feature the distinction between heavy industries – those with large demand for natural resources and material processing – and light industries.

Figure 5.3a-c show the high-regulation effect (β_{1t}), cross-province effect on energy-intensive industries (β_{2t}), and additional effect on energy-intensive industries under high regulation (β_{3t}) in 2006-2010. High regulation is associated with 11% loss in employment in all manufacturing industries relative to low regulation. Energy-intensive industries suffer 21% of employment loss nation-wide compared to other industries. There is no significant additional effect on energy-intensive industries under high regulation – their regulation-associated employment loss is 21% relative to other industries in the same provinces, and amounts to approximately 11% relative to the same industries in other provinces.

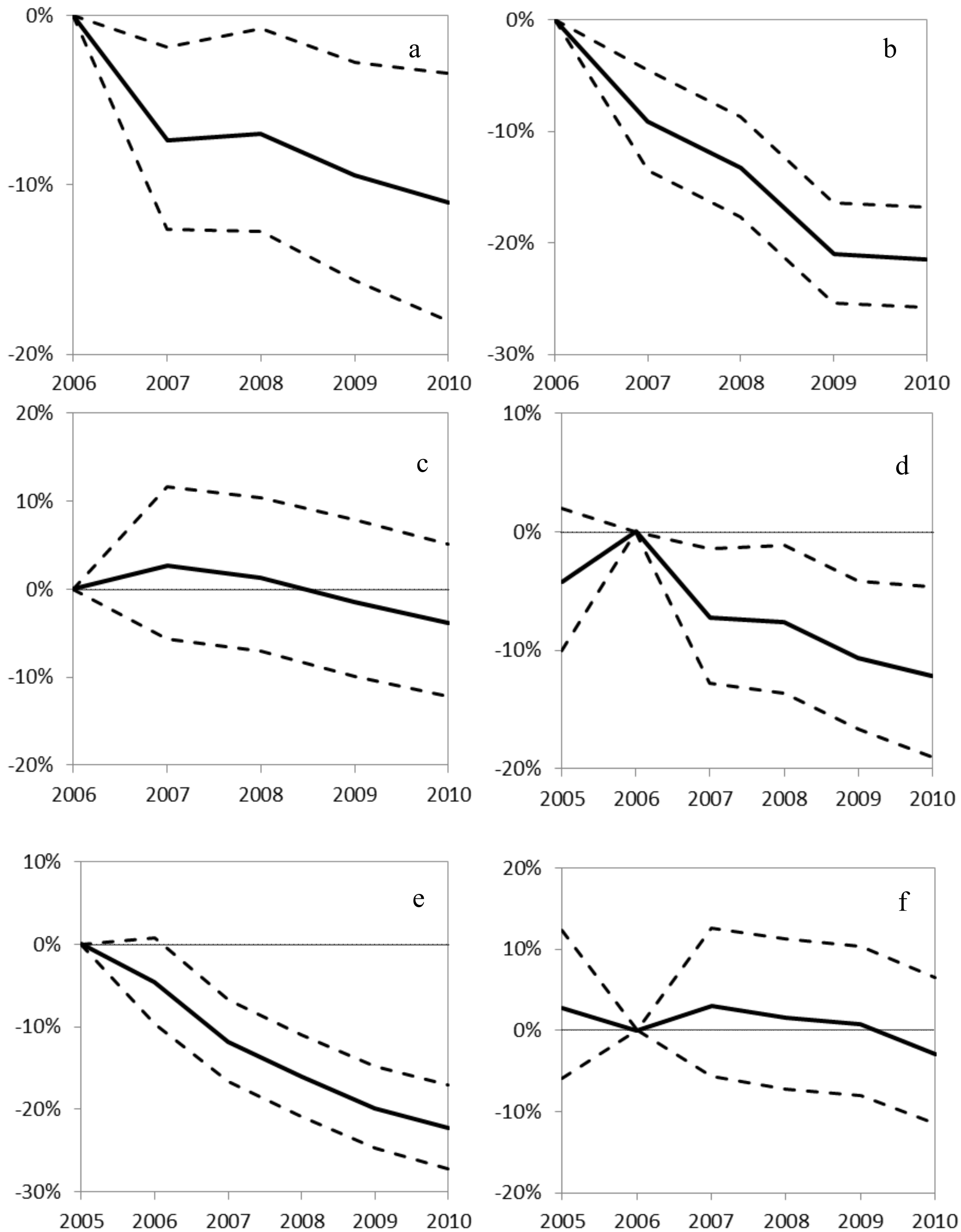

Figure 5.3 Regulation-associated change in employment with qualitative measures. (a) high-regulation impact across industries, (b) cross-province impact on energy-intensive industries, (c) additional interactive impact on energy-intensive industries under high-regulation, with base year 2006 and lagged electricity data; (d) high-regulatory impact across industries, (e) cross-province impact on energy-intensive industries, (f) additional interactive impact on energy-intensive industries under high-regulation, with base year 2005 and contemporary electricity data. Dashed lines represent 95% confidence intervals.

Because the national-level regulation, which is assumed to affect energy-intensive industries nation-wide, started from late 2005, the 2005 data is included to estimate the industrial treatment during 2005 and 2006, by using contemporaneous electricity data. The estimations for high-regulation effect, industrial effect, and additional interaction effect, shown in figure 5.3d-f, are -12%, -22%, and insignificant, respectively. The counterfactual effect of high regulation during 2005-2006 – regulation associated employment change before the regulation was enforced – is positive and insignificant (figure 5.3d). Such a counterfactual result suggests a real causal relationship between high regulation and employment loss, rather than a correlation between regulation and employment loss in a reversed causal channel or through other variables. However, the positive associate between regulation and employment before 2006 may suggest an underestimation of the regulation-induced employment loss.

The regulation-induced employment losses did not increase in a linear way as previous specified. Rather, both provincial and industrial employment declines occurred mostly in 2007 and 2009, and were moderate or even trivial in other years. The pattern may suggest that regulating agencies and industrial firms adapted their efforts according to previous performance in the process of fulfilling the performance-based energy-saving targets.

5.6 Discussion and implication

Results above demonstrate that during 2006-2010 energy-saving regulations in China had significant, negative impact on the location of manufacturing. In provinces with high efficiency (low intensity) targets, most industries were affected; in provinces with lower targets, only a subset of energy-intensive industries was comparably affected. The provinces with higher targets and 40% of national GDP lost 11% of manufacturing employment due to their tougher regulations relative to the provinces with lower targets and 40% of GDP. Nine energy-intensive industries lost 21% employment relative to other industries nation-wide. Energy-intensive industries under high regulation experienced roughly the linear combination of the two impacts. In comparison, the regulation difference in the US CAAA, which mandate polluting firms to adopt "lowest achievable emission rates" technology in nonattainment counties, caused 10% employment loss in four years and a maximum 15% loss in eight years, in polluting industries in nonattainment counties relative to the same industries in attainment counties (Walker 2011).

Electricity price also had a deterrent effect on a few industries with high electricity demand in production, but its estimated impact is less significant compared to the energy-saving regulation, and is in smaller magnitude compared to the effect in the US. This is because unlike direct regulations that control industry scale, higher electricity price also leads to input substitutions, which partially mitigate the regulatory effect. Abundant energy endowment, on the other hand, was a more significant factor for the location of all manufacturing industries, and its estimated impact is similar to that of energy-saving regulations. It is important to note that there is a spatial nexus of the three factors in China – stringent regulations, high electricity price, and short of energy in the east coastal provinces, and lax regulations, low electricity price, and abundant energy supply in the west provinces, with few exceptions.

The estimation may still understate the magnitude of regulatory impacts on employment loss. The unit of analysis in this research – two-digit industries in provinces – raises an aggregation bias. The two-digit industries are composed of less aggregated subsectors, and eventually plants, that are heterogeneous in their performance of energy consumption, and may face different costs of compliance. Similarly, provinces are composed of cities and counties, which have heterogeneous targets in 2010 even in the same province, based on their energy-intensity level in 2005 and their negotiation with a higher level government. While the research captures the change of employment across provinces and two-digit industries, the more subtle changes within provinces and within industries are not captured. The latter might bring more location change than the estimation between east and west.

In spite of the strong evidence of energy-related change of industry location, there is still no evidence of real employment loss in the provinces with high regulation, and associated transitional costs for reallocating production and labors. The main reason lies in the fast growth of the Chinese economy. Figure 5.4a shows the relative changes of the employment in the nine energy-intensive industries in the east and west. West provinces had essentially little employment increase before the spatially differentiated regulation was introduced at the end of 2006, but had more than 20% increases afterward. In the same period, east coastal provinces did not experience a real loss, but an increase at a slower pace – the employment increased almost by half during 2001-2006, and less than 20% afterward. When comparing the relative change of the whole manufacturing employment as in figure 5.4b, east provinces still maintained a higher increase relative to the west, although with a smaller difference. The trends suggest that the comparative advantage in the east – for example, agglomeration economies, scale economies, access to foreign investment and knowledge spillovers – have been fully compensated by the energy-saving regulations after 2006 in the energy-intensive industries, and partly compensated in other manufacturing industries.

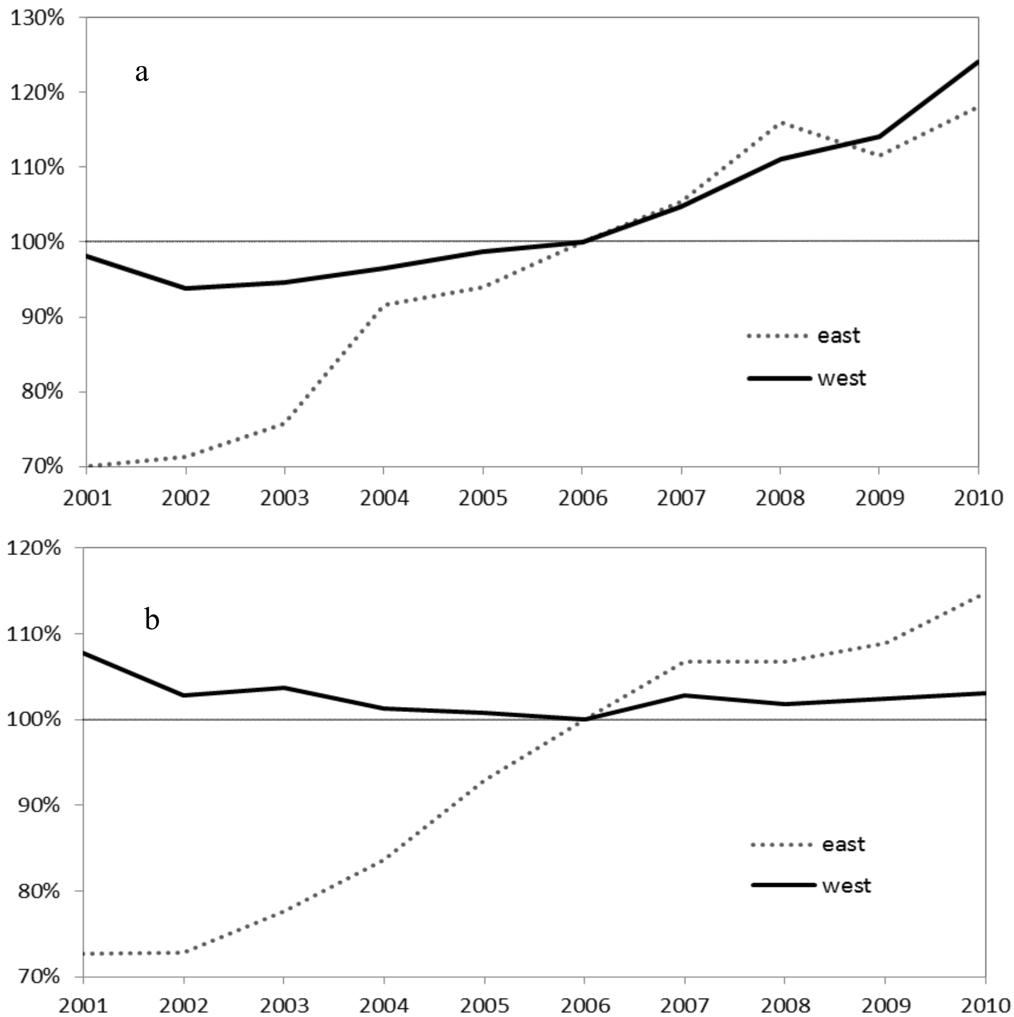

Figure 5.4 Employment change in the east and west provinces relative to 2006 level. (a) energy-intensive industries; (b) all manufacturing industries.

In the future, the location of energy-intensive industries between east and west may be further reversed, considering even more stringent energy-saving targets in the east after 2010. The central government enunciated another 16% reduction of energy intensity during 2011-2015, with similar provincial disaggregation, and committed 40-45% reduction of CO_2 emission per unit GDP by 2020 on the 2005 base. The continuation of spatially differentiated regulations may cause real relocation of employment and production from the east to the west, and transitional costs of reallocation the factors of production. In addition, research suggests high-regulation associated decline in productivity (Greenstone et al. 2012), which may make firms less competitive in the east coast, where the economy depends highly on export and competitiveness in the international market.

The regulatory implications on the environment and energy saving are of greater concern. Previous research indicate that the location of industries in the east region helped reduce energy intensity because of the substitution of other production factors for energy (Zhao and Yin 2011), better infrastructure, and spatial nexus (Yu 2012). The expanding energy-intensive industries in the west have less access to these factors of production, and less capability to reduce energy consumption in production. Particularly, the lax regulation in the west is more attractive to firms that are less willing to reduce their energy intensity in the east, which may be continuously less willing to make energy-saving efforts after the relocation. In addition to the energy consumption in production, the relocation of production capacities may increase the energy consumption in transportation, given that the major consumer market and other industries linked with the energy-intensive industries are in the populous east.

Because the energy-intensive industries are usually pollution-intensive with high demand for natural resources, there are also considerable environmental consequences associated with the location of energy-intensive industries in the west.

These potential consequences associated with energy-saving regulations direct future research to understand better the dynamic impacts of geographical distribution of industries on the demand for energy and natural resource and the environment, both globally and locally. By considering both policy-induced industry relocation and relocation associated environmental and economic consequences regionally and nationally, future policy making can better balance the national policy demand with local need, and set appropriate policy targets and assistance programs for technology and welfare support.

Chapter 6 Conclusion and implications

With growing policies related to climate change and GHG emissions, and commonly perceived large untapped potential for energy efficiency improvement, the choice of policy instruments to reduce the consumption of fossil fuels is a crucial research theme. Important considerations include the market and behavioral failures the policies may mitigate, policy effectiveness in practice, efficiency, as well as the distribution of policy impacts.

This dissertation focuses on the recent energy saving policies in China and its major impact on the industrial sector. The policy is featured by the use of multiple, mixed policy instruments and spatially differentiated enforcement. Firms' motivation and capabilities in the policy context are identified. The effectiveness and cost distribution of the policy and specific programs are explored.

The case study research shows that the major motivation for firms to reduce energy consumption is to increase competitiveness and particularly lower cost. Another important motivation is legitimation, within the current policy context of seriously implemented energy-saving agreements and regional capacity control and elimination. Compared to corporate environmental behaviors, energy saving is not likely motivated by social responsibility. The widespread motivation for competitiveness and cost reduction through energy saving is further reflected in the firm level empirical research. The empirical results show that firms with no opportunity to develop new products and less expansion realized significantly more energy saving within their existing production capacity, and adopted new capitals with more energy efficiency improvement, compared to firms that developed new products and greatly expanded their production. Those firms with less expansion also responded to the pressure of less individual profit, worse market, and higher electricity price by more reduction of energy intensity in production. These results suggest that the market-based policy, which has not yet been explicitly used in China, may be effective to firms by increasing their energy cost relative to other factors of production.

The evidence of the effect of financial incentives particularly for energy efficiency investments is complicated. Detailed case study research shows that firms did not consider subsidies and rewards as important for decisions about efficiency investments, and enjoyed the policy benefits as free-riders. On the other hand, broader scale empirical evidence shows that energy intensity decrease in firms is positively correlated with the regional fiscal expenditures on energy saving, environment, and technologies. Therefore, the incentives are very likely effective, but the extent of their cost effectiveness and general efficiency need to be further explored.

As identified in the case study research, energy-saving agreements and capacity elimination were major policy influences that associated with great energy saving efforts. The energy saving agreement was a key part of the Top-1000 program, which also provided information and technology support. The program was successful, not only because the policy target was overly fulfilled, but also because firms involved did not show significant behavioral heterogeneity in energy saving, as the literature usually suggested. While flexibility is permitted by the program, the method for calculating energy saving made firms with great expansion fulfill more calculated savings easily but in reality do not improve much of their efficiency level. This issue, however, will be mitigated by the recent introduction of absolute energy saving targets.

A greater problem is the regionally differentiation in the setting of policy targets and enforcement of energy saving agreements and capacity regulations. The regional disparity in regulation stringency has directed the industry growth to regions with laxer regulations. Considering that these regions usually also have better energy endowment and lower electricity price, the trend of industry location to these regions is significant. Such locational effect should be taken into account in the policy design, by providing technology and financial assistance to regions with industries moving in so as to maintain local sustainability and encourage continuous energy saving. Market-based policy may also help mitigate the unintended industry relocation, because the empirical evidence shows that industries were more sensitive to regulatory disparity than to electricity price.

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