Ownership and energy management in China's industrial firms

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Compared to other nations, energy is used less efficiently in China's industrial sector, which given its size has broad implications for global energy demand and the environment. Understanding the origins of this inefficiency is critical to identifying correctly the targets and potential impacts of future reform and energy policy initiatives. Using a new data set representing a cross section of industries in mainland China during a period of intensified pressure to reduce energy intensity (the Eleventh Five-Year Plan, 2006 to 2010) this analysis asks whether the dynamics of firm-level electricity demand differ systematically in state and non-state firms. The focus is on distinguishing the relative contribution of two channels that lead to energy savings: price and non-price drivers. Multiple specifications of an input demand function for electricity are estimated to quantify the impacts of prices of electricity, capital, and labor, the scale of output, firm ownership, and exogenous (non-price mediated) technological changes. Electricity price responses are found to differ significantly across ownership types. We find evidence that electricity use in private, stock-limited, and joint venture firms strongly responds to prices, while efficiency in state firms seems to be mediated instead through non-price channels, consistent with a stronger influence of regulatory mandates, state subsides, and performance evaluations. If differences across ownership types persist, further liberalization of electricity prices, as well as the implementation of market-based energy conservation or climate policies, may disproportionately burden non-state firms.

Keywords: energy efficiency, input demand function, ownership, China

1. Introduction

China's energy demand and emissions of carbon dioxide (CO_2) are the highest in the world, with industrial activity responsible for over 70% of national totals. Firms in China's industrial sector rely heavily on coal-fired electric power and direct coal use, with severe adverse impacts on the environment and human health (World Bank and China SEPA, 2007; Matus et al., 2012).[1] Many industries in China have high energy intensities relative to their counterparts abroad, consistent with observations of a broader productivity gap (Hsieh and Klenow, 2009). Raising efficiency and curbing emissions increases—across the economy as a whole and in the industrial sector in particular—rank among the nation's top energy policy priorities. Electricity price liberalization and emissions pricing are widely viewed as potentially effective policy approaches. There is a need to better understand the responses such initiatives galvanize within firms, as well as the broader consequences for economic development, competitiveness, and sustainability.

As part of a nationwide program that began in the late 1970s, the ownership structure of China's industrial enterprises has been in a state of transformation. Reforms changed the country's formerly ubiquitous state-owned enterprises through a combination of public offerings, internal restructuring, bankruptcy and reorganization, and other means, a process often referred to as *gaizhi* (改制 or "transforming the system"). Today's economic landscape is comprised of a mix of firm types that vary in form and relationship to the state. The extent to which the *gaizhi* process resulted in productivity gains is a topic of active investigation.[2] Shleifer and Vishny (1994) point out that such large-scale transformation is shaped as much by political priorities as by economic ones. Oi (2005) discusses the dynamics of this process in China, providing evidence it has been shaped by a desire to maintain employment, minimize government losses, and otherwise preserve social stability.

Against this backdrop, this analysis investigates the relationship between ownership—and the roles, pressures, and opportunities it implies—and the determinants of energy demand in China's industrial firms. Using a combination of descriptive statistics and econometric techniques, this study probes the neoclassical assumption that firms respond uniformly to changes in energy prices and polices. The results provide evidence that state and non-state firms respond differently. Specifically, the results suggest non-state firms exhibit a significant response through the price channel, while state firms show no significant price response and react much more strongly through non-price channels. Understanding these responses is important in explaining the persistence of inefficiencies in China's industry, and correctly inferring the impact of potential reform and policy initiatives.

[1] This calculation includes both direct emissions and indirect emissions associated with the production of electricity and heat.

[2] The magnitude of total factor productivity gains as a result of the *gaizhi* process is being investigated in recent work by Hsieh and Zheng (2013). This analysis suggests that by 2007 the labor productivity gap between state and non-state firms had narrowed but the capital productivity gap persisted. Previous work by Hsieh and Klenow (2009) suggested a large productivity gaps with advanced countries.

2. Motivation

2.1 Impact of China's reform program on the industrial sector

To form hypotheses about the relationship between ownership and energy management in China one must first understand how industrial enterprise ownership and its significance have evolved since reforms began. In agriculture, substantial productivity gains have been attributed to the introduction of the household responsibility system, which related payments to individual effort (McMillan et al., 1989). Similarly, in China's industrial sector, reforms helped to link productivity to profit, starting with the introduction of a contracting system that rewarded managers a share of profits if the firm met targets for sales, profitability, rates of investment, and so on (Garnaut et al., 2006). Past research has found these measures to be effective in raising firm productivity (Gordon and Li, 1995). Reforms also gradually resulted in the introduction of harder budget constraints and reduction in excess workforce (Montinola et al., 1995; Cao et al., 2003). While by many measures private sector activity has picked up since the late 1990s, indicators can be misleading because even in many nominally private (e.g. stock-limited) firms, state equity ownership or oversight can be substantial (Oi, 2005; Huang, 2008).[3]

Along with the transformation of internal incentive structures, the agricultural sector experience suggests that reforms—particularly, the departure from quotas and fixed product prices—played an important role in productivity increases (McMillan et al., 1989). Liberalization of prices in factor and product markets in the industrial sector has been slower and arguably more uneven. While today most prices of intermediate and final goods are market determined, factor input prices are more complicated. Electricity prices have long been managed by the government, and pricing regimes for primary fuels vary in the extent of liberalization (Lam, 2004). Scholars have documented various ways in which the government supports firms, for instance, through subsidies to support R&D, promote exports, encourage investment, or reduce the cost of inputs, including energy, with large state firms among the most prominent and favored recipients (Lin and Jiang, 2011; Liu and Li, 2011; Haley and Haley, 2013).

The decades of reform and opening have also seen changes in the role of the private sector. An important early impetus for privatization was to absolve state enterprises of debt, particularly in small cities (Oi, 2005). State policy announced in 1995 to hold on to large enterprises but restructure small ones (*zhuada fangxiao* 抓大放小) effectively led to the privatization of firms owned by local governments, many of which were performing poorly (Oi, 2005). Today, China's state-owned enterprises are significantly larger in size than other enterprises. It is widely understood that these enterprises can access financing at lower interest rates, and have access to funding sources that are unavailable to non-state firms.

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[3] Previous scholarship describes the uneven development of private enterprise during the reform period. Rural private enterprise is found to play a strong role in poverty reduction and economic growth during the 1980s (Oi, 2005; Huang, 2008). Policy shifts during the 1990s supported state sector growth while the private sector assumed a lesser role (Huang, 2008).

2.2 Energy management trends in China and other transition economies

In parallel with ongoing reforms and the process of *gaizhi*, energy intensity in China has consistently fallen since the beginning of the reform period in 1978, with the exception of a short-lived increase in the mid-2000s.[4] China's national policy targets reductions in energy intensity to manage rising fossil energy use and its adverse environmental impacts. A large body of scholarship has focused on explaining the reductions in national energy intensity over different periods since 1978 (Lin and Polenske, 1995; Garbaccio et al., 1999; Fisher-Vanden et al., 2004; Fisher-Vanden et al., 2006; Crompton and Wu, 2005; Liao et al., 2007; Ma and Stern, 2008; Ma et al., 2009). Energy intensity masks the influences of economic structural change and underlying energy efficiency, effects that scholars have tried to disentangle (see for example Sinton and Levine, 1994; Zhang, 2003).

The energy intensity of China's industries is high relative to other world regions, as shown in Figure 1.[5] Inefficiencies in the production and delivery of electricity and heat contribute significantly to China's higher energy intensity. Inefficient use of energy and other inputs has been well documented during the existence of the Soviet Union and other centrally-planned economies (Cooper and Schipper, 1992; Cornillie and Fankhauser, 2004). Post-transition economies realized reductions in energy intensity in parallel with changes in the structure of their economies. While the decline in China's energy intensity since 1978 no doubt mirrors a similar process underway in China, the link between elements of reforms and energy intensity reduction has been less well studied.

2.3 Firm performance, energy management, and the role of ownership

Focusing on energy provides an opportunity to probe the relationship between firm ownership and input use efficiency, which connects to a broader literature on determinants of firm performance. Scholars have long puzzled over why firm performance varies so widely, even within industries operating in the same national or regional market (Bloom et al., 2011). While much of this literature has focused on output-oriented measures of performance (e.g., profit), input-oriented measures such as capital, labor, or resource productivity are also of interest. Studying firms captures decisions at the most granular unit for which system-wide reporting is available. "[T]he pursuit of greater resource productivity" has been identified by Porter and Linde (1995) as an example of adaptive action firms may take to enhance performance. In energy, previous research suggests that firm characteristics matter in energy management decisions such as energy efficiency investments (DeCanio and Watkins, 1998). Insights from firm-level studies can also illuminate the role of competing theories in explaining market outcomes, for example, between perspectives emphasizing the dominance of institutions through the environment of laws, rules, and norms, and those emphasizing the importance of bargaining between institutions

[4] Energy intensity at the national level is calculated as the sum of all energy used by firms and households divided by the value of real economic output.

[5] This figure includes both direct primary energy use and direct electricity and heat use by industry, expressed in comparable energy units (tons of coal equivalent).

and organizations, with organizational influence affected by access to financial, technical, or other resources (Child and Tsai, 2005).

Previous research has pointed to ownership as a decisive factor in firm performance (Bloom et al., 2011). This observation has been particularly salient in the case of emerging markets in which some productive assets are closely managed by the state (Child and Tsai, 2005). A wide range of factors affects the dynamics of firm performance and energy management, complicating attribution. In the case of China, previous research has also named other important factors: access to financing, access to technology (Zhu and Geng, 2013; Fisher-Vanden, 2006), lack of motivation (Liu, 2012), lack of awareness of energy saving strategies (Kostka et al., 2011; Kuo et al., 2012), and firm size (Zhang et al., 2008). It is possible that ownership influences energy management through its impact on one or more of these factors.

In China there is abundant evidence of channels by which ownership matters. Peng and Luo (2000) related organizational performance to a firm's interpersonal ties with top executives at other firms and to government officials, noting that these ties were more numerous in the case of state-owned firms. Child and Tsai (2005) reaffirmed this observation, and also noted that in China multinationals (MNCs) are viewed as having superior environmental control technology, relative to state-owned firms. Based on Wang et al. (2003), Lin (2013) includes dummies for state and collectively-owned firms when assessing the effectiveness of environmental monitoring. Wang et al. (2003) notes that firms from the private sector have less bargaining power than state-owned enterprises when it comes to environmental regulation, while interviews with managers in the chemical industry in Child and Tsai (2005) revealed a view of private and Hong Kong/Macau/Taiwan enterprises as less environmentally responsible than state-owned enterprises in mainland China. Fisher-Vanden et al. (2004) used multivariate regression to consider the differential impact of factors on energy intensity outcomes in China from 1997 to 1999 and identified ownership as one of the important influences. However, in many of these studies, ownership is included as a dummy variable without detailed investigation of the connection between ownership and energy management decisions.

2.4 Contribution of this study

This study contributes to broader understanding of the relationship between ownership and factor input use efficiency, focusing on the case of electricity demand by industrial enterprises in China. Its central question is: Does ownership influence firm electricity demand responses, and if so, through what mechanism(s)? Importantly, answering this question first requires establishing the facts and context. In particular, I describe firm ownership types in terms of shareholding structure, industry composition, energy footprint, energy intensity, factor input prices, and other characteristics. Then multivariate regression—including pooled ordinary least squares and within estimators (fixed and random effects)—is used to investigate a relationship between firm ownership and patterns of electricity demand. Taken together, the descriptive and regression analysis provides initial insights into the mechanisms by which ownership influences electricity demand.

3. Setting and Data

3.1 China's Eleventh Five-Year Plan

The survey used in this study includes annual observations from 2005 to 2009, which substantially overlaps with China's Eleventh Five-Year Plan (FYP) (2006 to 2010). The Eleventh FYP included unprecedented emphasis on energy intensity reduction (in response to concerns that the longstanding decline in national energy intensity was reversing), setting an target of 20% reduction in energy intensity by 2010 relative to 2005. Responsibility for meeting the target was disaggregated at the provincial level, and ranged from 12% in Qinghai to 30% in Jilin, with most provinces facing the national target of 20% (Gov.cn, 2006).[6] In the early part of the Eleventh FYP, the program was still being established and observed progress toward the national goal was slower at the beginning compared to the end of the period. Consistent with the energy intensity target, the Ministry of Industry and Information Technology and the National Development and Reform Commission launched the 1,000 Enterprises Energy Conservation Program (effective in 2006), which targeted many of the large energy users for process and technology upgrading, and provided access to funds to support energy efficiency investments.

The Eleventh FYP coincided with coal price liberalization and the adjustment of managed electricity tariffs in part to reflect the higher costs of coal utilization. Over the survey period, electricity prices fluctuated modestly (plus or minus 10-15%) in response to state-led adjustments, while coal prices were liberalized over the same period, resulting in large and localized price increases after 2008 (see Figure A1). China also felt the effects of economic crisis in late 2008 and 2009, which prompted leaders to launch a massive stimulus program starting in 2009. The extent to which these events may be correlated with the effects of interest in this analysis is important to bear in mind.

3.2 Data set

The data set used in this analysis was generated from a survey conducted jointly by the Tsinghua Center for China in the World Economy (CCWE) and Chinese Academy of Social Sciences (CASS) in 2010. The sample was drawn from a larger pool of enterprises listed in the National Bureau of Statistics Industrial Enterprise Survey Database. The final survey included a representative sample of 1,000 randomly-selected firms that represent the regional distribution of economic activity, the weight of each province in the country's industrial output value, and other factors. After eliminating firms with incomplete data, 800 firms were included in the analysis. The sample of firms includes six provinces—Jiangsu, Shandong, Shanxi, Hebei, Jilin, and Sichuan—and includes annual observations from 2005 to 2009. Firms cover a wide range of industries, including the extractive industries, electricity, food and beverage, textiles, equipment, pulp and paper, chemicals, and communications. Ownership categories include state, collective, stock-limited, private, wholly foreign-owned enterprises (WFOEs), and joint ventures. Ownership types included in the survey are mapped to the ownership classification used by

[6] After the Eleventh FYP period, policymakers announced that a reduction of 19.1% had been achieved.

China's National Bureau of Statistics in Table A1. Firms answered quantitative and qualitative questionnaires that asked for financial information, energy demand information by product, and factors affecting firm technology choice. Firms in the sample are classified into eighteen industries grouped on the basis of two-digit industry code. The industry classification and change in primary energy and electricity intensity for each industry over the survey period is shown in Table 1.

Comparing the sample with nationally-reported statistics for firms above a certain size threshold on the basis of output shares,[7] the sample deviates from the national composition in several respects. In particular, the sample has larger shares of output from the Transport Machinery Equipment (13) industry, and to a lesser extent over-represents the coal and oil extractive industries (1). Comparing industrial structural changes in the sample and NBS data, the trends are broadly similar, with the exception of disproportionately large growth in the output of firms in the coal and oil extractive industry (1) included in our sample. This industry is omitted, along with the two other primary energy industries—(16) electricity and heat and (17) gas production and supply—from our sample in the later portion of this analysis focused on electricity, as these firms have no significant electricity use, produce a significantly more primary-energy intensive intermediate product relative to other industries, and therefore differ significantly in general patterns of capital, labor, and energy demand.

3.3 Defining ownership

Previous studies have documented the difficulty of classifying firms by ownership type in China (Huang, 2008), as well as the challenge of linking a particular ownership type with characteristic roles, behaviors, and incentives. As a more robust basis for classifying firms, we examine the shareholding structure of firms in the sample classified by ownership type (Table 2). Firms classified as state-owned on average are more than 90% owned by the state. Governance of firms classified as state-owned is divided among multiple levels of government (SASAC is the State-owned Assets Supervision and Administration Commission, a national authority, while province and city governments are also well represented). The share of non-state firms reporting to SASAC is much lower or (in the case of joint ventures) zero, while private firms do not report to national (SASAC) or provincial authorities at all—they are overseen at the city or county level, or do not answer to any authority. The proportion of firms reporting to city-level authorities is quite high for all categories. For collective, stock-limited, private, WFOE, and JV firms, the share reporting to No Authority is also quite large.

For purposes of this study, a state-owned firm is defined as belonging to the "state" ownership classification, acknowledging the definition of state ownership is subject to some interpretation. This is because these firms likely have the strongest manifestations of the attributes of state ownership expected to affect input use efficiency. These attributes include

[7] In the China Statistical Yearbook the totals in *Table 14-2 Main Indicators of State-owned and Non-state-owned Industrial Enterprises above Designated Size by Industrial Sector* include non-state-owned industrial enterprises with annual revenue from principal business over 5 million Chinese yuan (CSY, 2009).

factors such as access to financial resources, including operating loans (*liudong zijin*) and subsidies for energy efficiency investments, stronger influence in the policy process, distinct labor and capital prices (discussed below), and with these advantages a sense of pressure and responsibility to uphold state policies.

3.4 Ownership and energy management

Summary statistics for the full sample and by ownership type are shown in Table 3. Interestingly, we find state firms are significantly older (at 26 years state firms are, on average, at least 14 years older than the average age of any other category) and have a larger output size than other firm types (on average by a factor of four in the case of WFOEs and by a factor of 31 in the case of sampled private firms). State firms also employ significantly more people (though the gap is smaller than in the case of output).

Ownership types also differ in their contribution to the total share of energy consumption (Table 4). State firms account for a significant fraction of electricity use, but a small share of total primary energy consumption. By contrast, stock-limited firms account for large shares of both electricity and primary energy consumption. Although they are more numerous, private firms account for modest fractions of consumed electricity (around 14%) and primary energy (around 19%). Energy consumption patterns in part reflect the fact that some ownership types are concentrated in particular industries (Figure 2). For instance, state-owned firms comprise over half of the enterprises engaged in (16) electric power and (17) gas production and supply.[8] State-firms are also well represented, albeit less so, in (1) coal, oil, and gas exploration, (2) metals and mining, (7) oil refining and nuclear fuel processing, (13) transportation equipment manufacturing, and (18) other industries and services. As shown in Table 5, state and collective firms show only modest reduction in primary energy intensity over the survey period relative to other ownership types, while the change in electricity use intensity is fairly similar across all categories.

We also find differences in the technology level and R&D emphasis among ownership types as well as by authority. For instance, state-owned firms, WFOEs, and joint ventures are over-represented in terms of their adoption of internationally-leading technology, while collective, stock-limited, and private firms are over-represented among firms with a low technology level. As shown in Figure 3, state firms and WFOEs are more likely to have nationally-leading technology (largest proportion of any category), while collective, stock-limited, private, and joint venture[9] firms tend to be most concentrated in the mid-level group. While many causal channels are possible, in the case of state firms, they are more likely to be larger and centrally managed, making these firms subject to national imperatives and programs that promote adoption of advanced technology.

Another measure of emphasis on technology is R&D expenditures as a percent of sales value (Figure 4). While differences may be explained by firm size and the overall industry

[8] These industries are excluded from the subsequent analysis given their unique role as providers of primary energy and energy carriers.
[9] No distinction is made between domestic and international joint venture firms in the data set.

composition of each ownership category, some interesting observations emerge. State-owned firms maintain the largest ratio. Firms in China have faced significant pressure to raise R&D intensity over the last two decades, so the high fraction could reflect increased investment or the reclassification of related activities to boost the R&D/sales ratio (Gao and Jefferson, 2007). The R&D/sales ratios are much lower for collective and private firms, which are also the smallest in terms of average size. R&D/sales ratios by authority reveal a more definitive relationship. Moving to ever more local levels of government is associated with a reduction in the ratio of R&D/sales. This trend is unsurprising for several reasons: 1) central policies have targeted increases in reported R&D intensity among firms under their direct control, 2) firms at the local level may be engaged in adapting existing products to local conditions rather than innovating on them, and 3) it may be more difficult for smaller firms to afford large, risky R&D investments.

3.5 Ownership and policy pressure

The qualitative survey responses provide evidence that policy pressures on firms to save energy and reduce emissions also differ by ownership type, as shown in Table 6. When asked to list the top reasons for engaging in emissions reduction, the proportion of state-owned firms expressing leadership performance evaluation as a top reason for emissions reduction activities was almost 20% for state-owned firms, but not a concern for private, WFOE, or JV firms. However, there are some commonalities—laws and regulations seem to be important to a similar percentage of firms in each category. Interestingly, state-owned firms and WFOEs expressed less concern about meeting industry standards (perhaps in part because they are already technological leaders, according to the analysis above, or because they felt insulated from competition for other reasons). Private firms, by contrast, are more concerned than other groups (39.5%) about meeting industry standards. Consistent with the notion that state firms are more domestically focused while WFOEs are more export-market oriented, WFOEs are more concerned about discrimination in international trade (15.1%) relative to state-owned firms, which are barely concerned (1.9%). Interestingly, social image impacts were ranked highest by 16% of the joint ventures, while none of the WFOEs ranked social image as the top concern. Other ownership types fell in the middle at 7-8% of responding firms ranking social image as most important.

4. Estimation of the Input Demand Function for Electricity

Demand theory holds that firm electricity use should fall in response to rising prices. Alternative formulations of an input demand function for electricity are estimated to study the influence of ownership on firm electricity demand.

4.1 The basic equation

Starting from production theory, firms are assumed to produce output (Y) as a combination of inputs according to the following equation:

(1) $Y = f(K, L, E, M)$

The KLEM structure is widely used to model firm production behavior (see Van der Werf, E. (2008), Okagawa and Ban (2008), and Koesler and Schymura (2012) for more discussion). Firms are assumed to minimize costs, giving rise to the following formulation of the cost function in Equation (2), which is a function of the prices of capital (P_K), Labor (P_L), Energy (P_E), and materials (P_M), the level of output Y, following the general approach outlined in Fisher-Vanden et al., 2004:[10]

(2) $C = \gamma(P_K, P_L, P_E, P_M, Y)$

Shepard's Lemma holds that the demand function for each input is then equal to the derivative of the cost function with respect to the input price. This formulation is the starting point used to estimate the input demand function with respect to input price. However, since we lack data to estimate the full system of input demand equations and are mainly interested in electricity demand, we estimate a standard log-log form without estimating the full demand system.

This formulation provides the basic starting point for estimating an input demand function for electricity.[11] In addition to price, firm location (province), industry, and residual differences or changes in technology at the firm level have been shown to affect energy demand and its dynamics in previous studies. Electricity use and output are also closely related. Our specification allows for economies of scale by estimating a coefficient on output. The pooled OLS input demand function for energy is estimated as follows in Equation 3:

(3) $\ln E_{i,t} = \beta_0 + \beta_1 \ln P_{E_{i,t}} + \beta_2 \ln Y_{i,t} + \beta_3 Z_i + \beta_4 t_t + \epsilon$

The coefficient β_1 is the price elasticity of demand for electricity. To capture scale effects, log of output is included (and an elasticity of electricity use with respect to output, β_2, is estimated). Z_i is a vector of time-invariant dummy variables distinguishing firms by industry, province, and ownership. The residual year-to-year change in electricity demand is also captured with β_4, the coefficient on $t_{t,i}$. Due to concerns about the quality or unavailability of firm-level price data for other energy sources, coal prices are not included in the regression. Coal also accounts for a modest value share of energy use among the firms analyzed (on average less than 16%).

4.2 Constructing labor and capital prices

Based on theory, this expression should include prices for all inputs, including other energy types, labor, capital, and materials. Our survey includes observations of firm expenditures

[10] Fisher-Vanden et al. (2004) focus on determinants of energy intensity, rather than the quantity of energy demanded. We focus on quantity of energy demanded in order to allow the coefficient on output (right-hand side) to deviate from 1 (which is assumed in the energy intensity formulation) and capture the effects of production scale.

[11] Electricity accounted for at least half of the energy use in almost all firms in the sample. The average value share of electricity was above 84% in all ownership categories (considering only coal, coke, and electricity).

on capital purchases, stock, and wage payments, although we do not have information on other materials inputs and only reliable quantity information for other energy inputs.[12] To test robustness, we include capital and labor prices in an alternative specification of the pooled OLS regression as follows (Equation 4):

$$(4)\ \ln E_{i,t} = \beta_0 + \beta_1 \ln P_{E_{i,t}} + \beta_2 \ln P_{K_{i,t}} + \beta_3 \ln P_{L_{i,t}} + \beta_4 \ln Y_{i,t} + \beta_5 Z_i + \beta_6 t_t + \epsilon$$

To estimate prices for labor (wage rate) and capital, we adopt a conventional approach. Real capital price by adding together the total wage $W_{i,t}$; benefits $B_{i,t}$ (the firm's social security and health care contributions); unemployment insurance $U_{i,t}$; and housing allowances and other subsidies $H_{i,t}$, and the cost of training the employee $T_{i,t}$. This sum is then divided by the total number of workers, as follows:

$$(5)\ PL_{i,t} = \frac{W_{i,t}+B_{i,t}+U_{i,t}+H_{i,t}+T_{i,t}}{N_{i,t}}$$

The real capital rental price in each year by firm is estimated as follows:

$$(6)\ PK_{i,t} = \frac{D_{i,t}+F_{i,t}}{A_{i,t}}$$

Annual depreciation $D_{i,t}$ and interest payments $F_{i,t}$ are added together and divided by the value of total assets $A_{i,t}$ in each year t for each firm i.[13] With $PL_{i,t}$ and $PK_{i,t}$ added to the expression, their coefficients represent cross-elasticities between electricity and labor and electricity and capital, respectively.

Comparing the computed labor and capital prices, variation is found in the average values across ownership types as well as industries. Specifically, state-owned firms on average face labor prices that are 24% to 40% higher, while capital prices vary across ownership types in every year with no clear pattern. Capital and labor prices vary significantly across industries, while labor prices show no statistically significant differences with the exception of a high cost of labor in the extractive industry (which is also largely state-owned and is not included in the regression analysis given the industry's many unique characteristics). The labor price differences

[12] We do not include the price of materials. In the typical parameter settings of KLEM structure, the elasticity of substitution between the KLE bundle and other materials are zero. However, we do need the price of capital and labor, as well as other energy inputs. In the sample we observe that the value share of non-electricity energy inputs is very small although substitution may be important in some industries. In this analysis, we assume the elasticity of substitution between electricity and other non-electricity energy inputs is small, and leave out non-electricity energy inputs. We find in the data that the average ratio of firm electricity use to other energy inputs (in value terms) is around 44 to 1.3, so non-electricity inputs account for a very small share of input value. To some extent, the inclusion of industry-specific fixed-effects can also capture any constant effect associated with substitution dynamics.

[13] The formulation is guided by a standard approach for estimating the price of capital outlined by Jorgenson (1963), but represents an approximation using data available in the survey.

may reflect the cost of providing employees with benefits beyond salary, including housing subsidies and other services, which despite widespread reduction in the level of benefits during the reform period are still characteristic of large state-owned firms.

4.3 Model specifications

To explore the robustness of the relationships of interest, the relationship between prices and ownership is estimated in three different ways. First, the pooled OLS equation is estimated. However, pooled OLS may be biased by unobserved heterogeneity at the firm level. While we attempt to control for a range of firm-specific factors, we cannot rule out the possible influence of unobserved factors. We therefore also estimate the relationships of interest using fixed and random effects at the firm level. Fixed effects specifications account for an average within-group effect, while the random effects approach assumes the within-group effect is normally distributed. Fixed effects estimators are subject to concerns about higher variance, while random effects estimators are biased if the within-group (unit) effect is correlated with the regressor(s) of interest. These tradeoffs are discussed in parallel with the interpretation of the results.

5. Results

5.1 Pooled OLS regressions

Starting with all firms (excluding only primary energy supply firms in the oil extraction, gas, and electric power generation industries) the input demand function is estimated using pooled OLS.[14] Several alternative specifications are included, among them one with only firms for which electricity comprises over 90% of the energy input (*HE* for "high electricity"). Specifications that include the labor and capital prices are also included as described above. Finally, specifications are also included in which ownership and electricity price are interacted in order to analyze whether ownership affects the firm's response to electricity prices (in addition to a variable that captures the residual effect of ownership on energy demand directly). The regression estimates are shown in Table 7.

Focusing first on the estimated electricity price elasticities, the estimated elasticity is found to be -0.28 for the full sample, while firms with high share of electricity use have a lower electricity price elasticity (of -0.12).[15] Adding capital and labor prices to the model does not significantly change the estimated price elasticities (-0.29 for the full sample and -0.12 for the HE sample), although the capital price is found to have a low but statistically significant (and as expected, positive) effect (a 10% increase in capital price results in a 0.49% increase in energy demand). However, we remain concerned about bias in the OLS estimator because of the effects of unobserved heterogeneity across firms.

[14] We exclude firms in the oil extraction, gas, and electric power industries because as part of the primary segment of industry, because these firms exclusively produce energy intermediates, use very low electricity relative to primary energy, and primary energy makes up a large fraction of input that cannot be substituted.

[15] We also test specifications that include both the share of electricity in total energy demand as well as specifications that include the price of coal and do not observe large differences in the resulting pooled OLS coefficients.

The coefficient on output is less than one, suggesting that firms are realizing economies of scale in electricity input use—e.g. an increase in output results in a less than proportional increase in electricity demand. Interestingly, HE firms realize slightly greater economies of scale. Wide variation exists in the coefficients on industry and province. The industry variation is driven by differences in the energy requirements of industries, as production processes differ widely. In the following section, elasticities are estimated using several salient industry groupings. Provincial coefficients would be expected to pick up any systematic differences within industries across different provinces, which could be the result of provincial policies, oversight, and firm-government relationships. Coefficients on province are strongly significant although the effect on energy use is modest.

Finally, ownership does not have a significant effect on energy use in the pooled OLS specification using the full sample. In the HE firm sample, all ownership types reduce energy use relative to state-owned enterprises (the base variable). This effect is modest (-0.11 to -0.18), and is significant for all non-state firm types except for privately-owned companies.

When ownership and price are interacted, non-state ownership seems to have a much stronger effect on energy use—both directly as well as through the price channel. The partial effect of non-state ownership was found to lower energy use by between -0.29 and -0.44. Meanwhile, the interaction effect between price and ownership was also very strong, particularly for privately-owned firms, for which the partial ownership-price effect was -1.19 (with an overall price response of -0.41, given that when the interaction terms are included, the partial effect of price on energy demand becomes positive). State-owned firms, the reference category, were associated with a positive and significant price elasticity of electricity demand.[16]

5.2 Pooled OLS by industry and ownership

Given the significant heterogeneity across industry groupings, the pooled OLS regression is also estimated at the level of common industry groupings: energy-intensive industries, heavy manufacturing, and services plus other light manufacturing (described in Table 8). For each of the three categories, observed trends are described. The industry-specific regression results are shown in Table 9.

The energy-intensive industries group (all firms) exhibits higher elasticities (ranging from -0.61 to -0.64 in the specification with capital and labor prices) relative to the full sample. As in the full sample, these elasticities drop when only HE firms are included in the regression, falling to -0.15 to -0.11, which is in line with the elasticity estimate for HE firms across all industries. Heavy equipment manufacturing does not exhibit a significant price response in any of the specifications, possibly due to the small number of observations. The service and other light manufacturing industry group only exhibits a significant response when the regression is limited to HE firms. In contrast to the full sample regressions, concern is warranted in the case of the HE

[16] Several factors could explain why a positive partial effect is observed for state firms. For state firms, electricity represents a larger share of energy use on both a value and energy basis. If state firms can preferentially obtain short-term low-interest operating loans (*liudong zijin*) when energy input prices increase, electricity use may be observed to increase even as prices rise.

sample because focusing only on firms with high electricity use may also introduce additional unobservable effects correlated with energy use patterns that influence electricity demand. When estimated conditional on ownership, the pooled OLS regression also suggest private and stock-limited firms are significantly more responsive to electricity prices than other firm ownership types. The estimates are shown in abridged for in Table 10.

5.3 Controlling for unobserved heterogeneity across firms: Fixed and random effects

To mitigate the potential for bias by accounting for the impact of unobserved heterogeneity on the level of energy use, fixed and random effects models are estimated based on the formulations in Equations 5 and 6.

5.3.1 Conditioning on Ownership

First, we estimate instead input demand functions for electricity conditional on form of ownership. A limitation of this approach is that we do not know whether absence of significance stems from a low number of observations (particularly for the state firms category), large variation in responses, or a true lack of relationship. However, where it does yield significant estimates, we may be more confident in them given that fixed and random effects control for sources of heterogeneity at the firm level. Both the fixed (Table 11a) and random effects (Table 11b) estimates show the largest negative elasticities associated with joint ventures (FE: -0.77, RE: -0.55), followed by private firms (FE: -0.52, RE: -0.52) and then stock-limited firms (FE: -0.50, RE: -0.46). Electricity price elasticities for state firms (FE: -0.40, RE: 0.01), collective firms (FE: -0.36, RE: -0.32), and WFOEs (FE: -0.28, RE: -0.23) are not significant, though collective firms and WFOEs show greater evidence of significance. This evidence is consistent with the situation in which private, stock-limited, and joint venture firms are more price responsive than firms that are still under state control. WFOEs are also perhaps less likely to be price responsive in the short term as they may have committed resources to develop outsourced production on fixed-term contracts. Also, WFOEs primary markets were mostly overseas during this period, and these firms were competing with others manufacturing not only in China but worldwide. If China's electricity prices remained competitive despite modest increases, WFOEs may have had little incentive to adjust their electricity demand.

I now turn to evidence of non-price reductions in electricity demand, which are captured by the residual "year" dummy. This coefficient represents the composite effect of energy policy, technological change (policy-drive or autonomous), and any other year-specific effects. Coefficients are transformed to represent year-on-year percentage improvements, and the partial effect of year on electricity reduction is shown in Figure 5. Interestingly, level-log transformed values suggest that over the five years, state firms had the largest response through this non-price channel (FE: -28%, RE: -27%), while the next largest response (by private firms, FE:-21%, RE: -22%) is around 20-25% lower. Other firm ownership types showed a response of slightly lower magnitude than private firms. As this coefficient captures the effect of direct command-and-control channels for inducing efficiency—for example, by including energy saving in the performance evaluation criteria for industry leaders—it is perhaps not surprising that this effect is particularly strong for state firms.

5.3.2 Aggregate elasticity estimates

Fixed and random effects regressions are estimated using the full sample as well as the industry sub-groups, similar to the pooled OLS analysis above. For simplicity, we report only the fixed effects estimates in Table 12 and discuss the random effects in the text for comparison. The price elasticities estimated using the full sample (FE: -0.51, RE: -0.44) are larger in magnitude and more negative than the OLS estimate of -0.29. Interestingly, including firms with high electricity use exhibit only a slightly lower (in magnitude) elasticity (FE: -0.48, RE: -0.37), while the reduction in the magnitude of the elasticity observed in moving from the full to electricity-intensive samples observed in the OLS estimates was significantly larger. Estimating the regression using only energy-intensive firms (EINT), the elasticity of demand for electricity is higher (FE: -0.80, RE: -0.80). One explanation could be that energy-intensive firms have their own electricity generation facilities that they can employ during periods of shortages, and the inputs used to run these facilities are counted as use of direct primary energy. These firms may also be subject to stricter controls on electricity use (e.g. through rolling blackouts in times of regional shortages). The elasticity drops in magnitude to -0.76 (FE) and -0.69 (RE) and when only high electricity users are included. High value-added heavy manufacturing (HVA) industries have elasticities not far from the mean values for the whole sample (FE: -0.37, RE: -0.18) and that do not deviate much when only electricity-intensive firms are included (FE: -0.39, RE: -0.20). Values for the services and other light manufacturing (OSE) are only significant in the fixed effects regression for the case of high electricity demanding firms.

5.3.3 Fixed vs. random effects

In general, the fixed and random effects estimates for any given specification yield fairly similar coefficient estimates. For the full sample, industry-specific, and ownership-conditional specifications, the Hausman Test does not reject the null hypothesis (of no correlation between independent variables and firm-level effects), so the random effects model cannot be discarded in favor of the fixed effects model. For the HE specifications, the null hypothesis is rejected in the Hausman Test, suggesting a fixed effects model may be preferred. We note that the observed patterns—significant price response for private and other non-state firms and larger (in magnitude) non-price response for state firms—are robust to alternative specifications.

6. Discussion and Conclusions

This analysis suggests that the drivers of electricity demand at the firm level in China differ by ownership type. State firms seem to be less responsive to prices and more responsive through non-price channels, while non-state firms (especially private, stock-limited, and joint venture firms) respond more strongly to electricity prices. This analysis motivates research focused on better understanding these two channels, and how each will interact with ongoing economic reform as well as energy and environmental policies. The pooled OLS results show a statistically and economically significant partial effect of ownership through larger (in magnitude) price responses for private, stock-limited, and joint venture firms, relative to state-owned firms. The fixed and random effects regressions conditional on ownership suggest that non-state firms have moderate negative elasticities, while state-owned firms show no significant effect.

I posit four preliminary and possibly complementary explanations for the lack of an observed price response by state-owned firms:

(1) Electricity prices do not influence electricity demand in state firms, because mechanisms exist to shield firms from (or offset) the effects of price changes.
(2) State firms actively engage in bargaining over electricity pricing decisions. The impact of electricity price increases is directly offset only in the case of state firms.
(3) State firms are operating as monopolies and can more easily pass along increased cost to consumers.
(4) Electricity use efficiency in state firms has increased for non-price reasons, reducing the cost of energy per unit of output and counteracting cost pressure to reduce energy use.

There is perhaps the greatest evidence for (1) given that state firms had access to short term loans (*liudong zijin*) during the Eleventh FYP, which provided additional operating funds in times of economic stress. Other firm types had limited or no similar access. Cheap access to such funds to offset operating losses could have allowed state firms to purchasing electricity at existing levels when other firms felt pressure to conserve. The potential indirect role of (4) is also likely important, given that state firms had access to subsidies to support energy efficiency investments—it is straightforward to reason that these improvements (subsidized or paid by the state) would have offset any competitive disadvantage state companies faced. Perhaps less evidence supports (3), given that recent research has suggested most state-owned enterprises are subject to competition in product markets (a notable exception is electric power distribution companies, which are often characterized as monopolies, but these firms are not the focus here). The direct bargaining hypothesis (2) is more suspect because it requires state firms to possess influence over National Development and Reform Commission regulators in charge of pricing, or at least access to sources of remuneration that could directly offset costs through other political connections.

Which of these explanations (if any) holds will affect both the magnitude and distribution of the impacts of electricity price reforms or carbon pricing. If state firms are indifferent to electricity prices (because increases are somehow offset by compensating policies or benefits), non-state firms may face an additional disadvantage as a result of higher prices. If the second hypothesis holds true, the political feasibility of electricity price adjustments may be limited by the impacts it will have on state-owned firms and by the relative influence of state firms and policymakers in the bargaining process. In cases (1) through (3), the preferred access of state-owned firms would need to be diminished (e.g. through further ownership and management reform) before the price channel will be available as a policy lever for controlling energy demand. However, it is worth noting that the state command-and-control channel seems to have been largely effective, an important consideration in firm decisions to make investments in efficiency. A question remains how costly such approaches are to the broader economy, especially when policymakers view preferential access for firms perceived to be vital to economic function as part of the nation's industrial policy and development strategy.

The present analysis has several limitations. This analysis fundamentally relies on the estimation of a demand function for one energy carrier (electricity) as an input to production. Due to data constraints, neither the price of material inputs nor (perhaps more importantly) the price of other energy input commodities is included in the regression. With additional data, it would be possible to estimate this system of equations. Another possible limitation is the low within variation of the reported electricity price, given that the price is closely managed by the state and was slowly revised upwards several times between 2005 and 2009 to reflect the cost of a feed-in tariff for renewables as well as the increasing cost of electricity inputs such as coal, which were rising over the same period.

The differential response of state-owned firms has implications for the energy system impact of future economic reform and for energy and environmental policy in China. Broadly, different responses observed across ownership types will affect the distribution of impacts under any reform or policy that leads to a liberalization (or increase) in electricity prices. Typically, differences in firm responses to price increases are explained by differences in marginal cost of reducing demand. However, the relationship between institutional factors—such as ownership—and the nature of this "marginal cost" should be carefully examined. Political costs to industry leaders (for example, reprimand or diminished career prospects for failing to obtain a target) as well as economic costs transmitted through political channels (access to and cost of operating funds and investment capital) are likely to play an important role in the achievement of sustainability objectives in China and elsewhere.

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Figure 1 Comparison of energy intensity by industry in China, the European Union, Japan, and the United States.

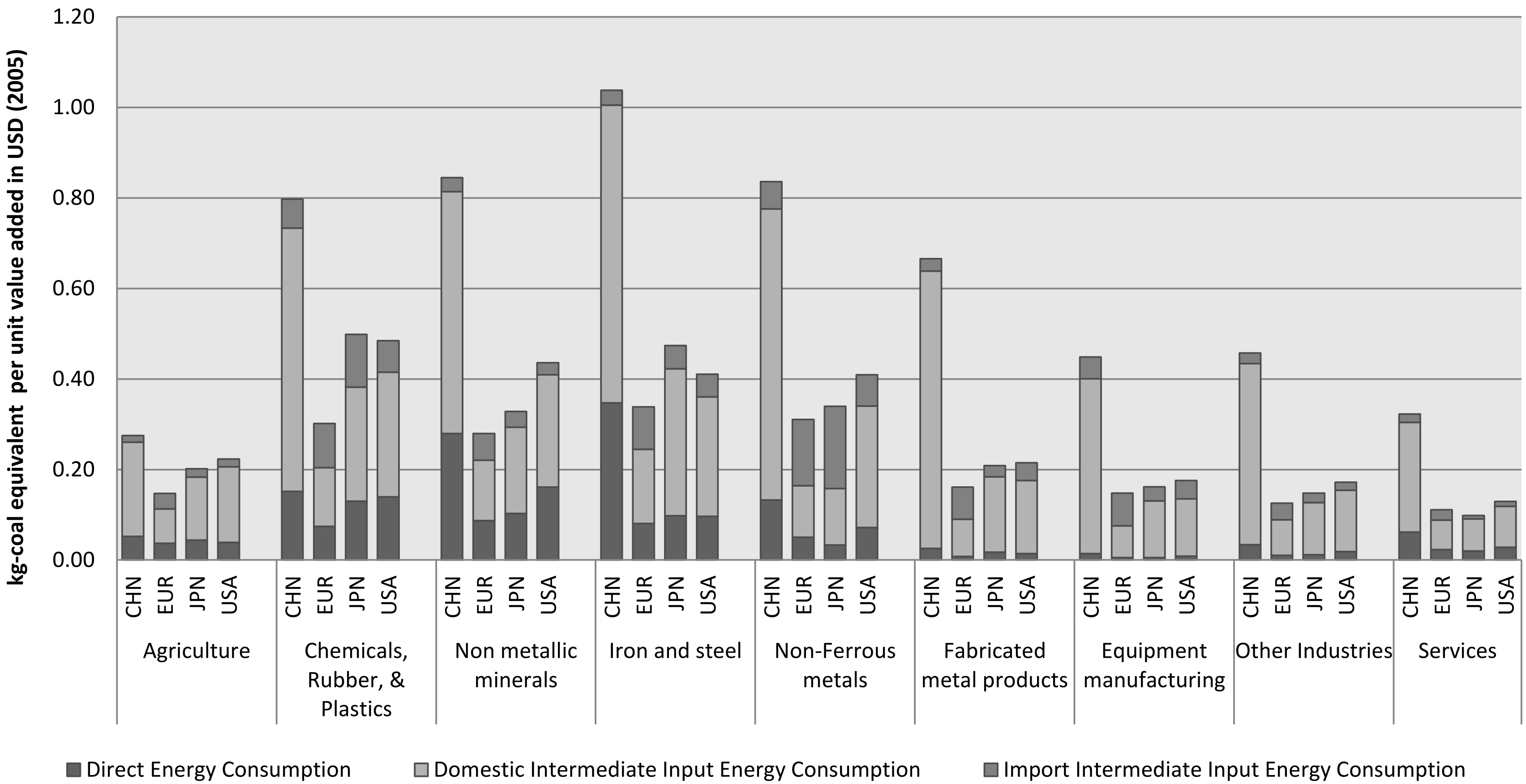


Table 1 Industry categories, number of sampled firms, and a comparison of firm average direct primary energy and direct electricity intensities and trends by industry from 2005 to 2009. Intensity is expressed in kilograms of coal equivalent divided by value of a firm's total output. Electricity conversion uses the coal-equivalent method (2004) assuming 349 g coal equivalent per kilowatt-hour generated. (Berrah, 2007, p. 196).

I.D.	Industry Name	Number of Firms	Primary Energy Intensity (Sample)		Change (%)	Electricity Intensity (Sample)		Change (%)
			2005	*2009*		*2005*	*2009*	
1	Coal, oil, and gas exploration	32	0.082	0.056	-31%	0.149	0.134	-10%
2	Ferrous and non-ferrous metals mining	12	0.075	0.057	-24%	0.204	0.167	-18%
3	Food and food processing	55	0.006	0.003	-40%	0.144	0.120	-16%
4	Textiles	59	0.003	0.003	-6%	0.138	0.117	-15%
5	Wood processing and furniture manufacturing	10	0.019	0.010	-47%	0.153	0.131	-14%
6	Paper and products	30	0.005	0.004	-20%	0.210	0.172	-18%
7	Oil refining and nuclear fuel processing	137	0.021	0.014	-31%	0.258	0.236	-8%
8	Chemicals, pharmaceuticals, plastics, and rubber manufacturing	103	0.070	0.044	-37%	0.303	0.242	-20%
9	Cement	32	0.680	0.385	-43%	0.333	0.253	-24%
10	Iron and steel	140	0.280	0.198	-29%	0.435	0.377	-13%
11	Fabricated metal products	143	0.008	0.005	-29%	0.333	0.211	-37%
12	General and special equipment manufacturing	109	0.025	0.016	-35%	0.216	0.159	-26%
13	Transportation equipment manufacturing	72	0.006	0.004	-24%	0.124	0.084	-32%
14	Electrical machinery and equipment manufacturing	28	0.005	0.003	-29%	0.099	0.068	-31%
15	Communications, computers and other electronics	21	0.003	0.003	3%	0.054	0.053	-2%
16	Electricity and heat	12	2.231	1.863	-16%	0.126	0.122	-3%
17	Gas production and supply	17	0.251	0.176	-30%	0.100	0.095	-5%
18	Other industries, including services	32	0.008	0.005	-34%	0.163	0.135	-17%

Table 2 Composition of shareholding structure (%) and authority (number of firms) by ownership type in 2005.

	State	Collective	Corporate	Private	HKMT	Foreign	SASAC	Province	City	County	No Authority
State	93%	0%	5%	2%	0%	0%	10	18	18	4	3
Collective	1%	69%	9%	11%	10%	0%	2	1	29	22	23
Stock-Limited	6%	8%	40%	44%	0%	1%	4	18	120	44	39
Private	1%	0%	21%	77%	1%	0%	1	2	158	56	97
WFOE	1%	0%	5%	11%	27%	55%	2	3	20	7	20
Joint Venture	3%	9%	37%	10%	11%	31%	0	3	54	5	16

Table 3 Summary statistics by ownership type.

		2005		2009	
	Firm age in 2005	**Output**	**# of Employees**	**Output**	**# of Employees**
State-owned	26	2,162,132	3486	3432080	3842
Collectively-owned	12	90,274	334	138972	269
Stock-limited	3	241,212	474	512472	630
Private	9	70,733	179	148890	213
WFOE	8	504,284	387	1006079	663
JV	9	152,480	359	252671	371

Table 4 Share of primary energy and electricity use by ownership type (in sample).

Year	**2005**		**2009**	
Ownership	**Electricity**	**Total Primary Energy**	**Electricity**	**Total Primary Energy**
State	29.2%	3.2%	21.8%	3.6%
Collective	3.6%	5.2%	2.9%	3.0%
Stock-Limited	35.4%	62.6%	42.2%	63.5%
Private	14.0%	19.2%	14.7%	19.8%
WFOE	11.8%	7.5%	13.9%	7.9%
Joint Venture	5.9%	2.3%	4.4%	2.2%

Table 5 Change in primary energy intensity and electricity intensity by ownership type, 2005 to 2009.

	Primary energy intensity % change	**Electricity intensity % change**
State	-15.6%	-22.6%
Collective	-12.8%	-18.7%
Stock-Limited	-19.5%	-19.8%
Private	-32.7%	-23.3%
WFOE	-51.5%	-26.2%
Joint Venture	-29.9%	-21.7%

Figure 2 Number of firms and composition of ownership type, by industry.

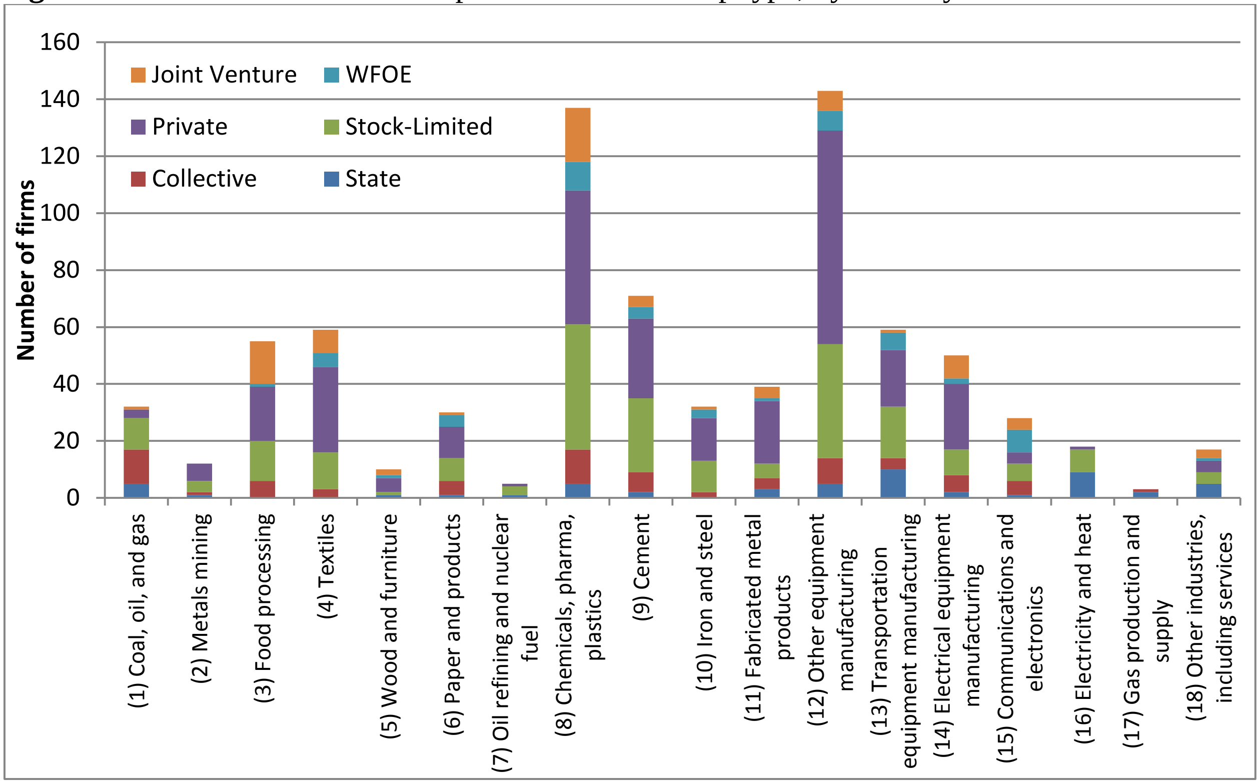


Figure 3 Distribution of firms within each ownership category in terms of self-assessment of its technological status.

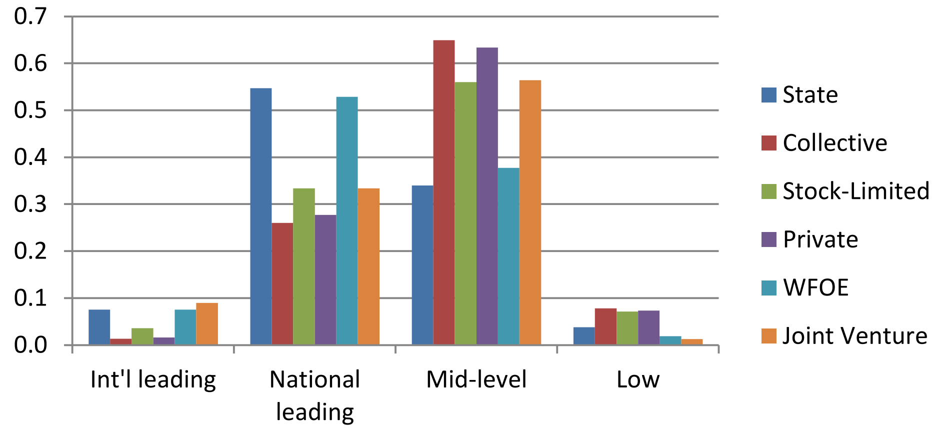
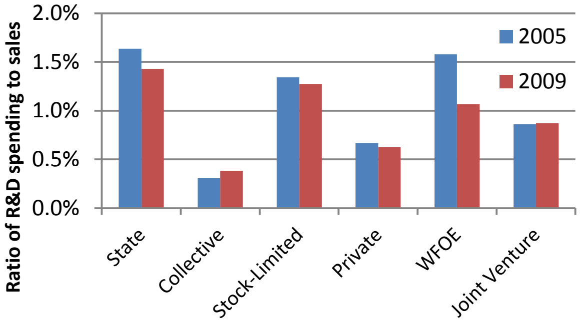


Figure 4 Ratio of R&D spending to sales a) by ownership type and b) by authority.

a)



b)

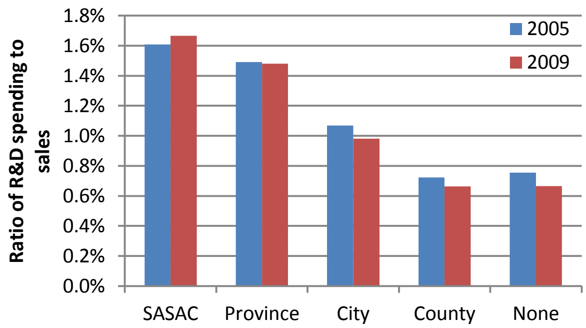


Table 6 Factors ranked as the most important reason for concern about reducing emissions.

Ownership by type	(1) Not reducing emissions will affect the company's social image	(2) Without reducing emissions, the company will be punished by laws and regulations	(3) It is difficult to achieve the industry standards without reducing emissions	(4) Not reducing emissions will be subject to discrimination in international trade	(5) It is difficult to deal with the shortage in energy supply without reducing emissions	(6) Not reducing emissions will affect the evaluation of business leaders	(7) Not reducing emissions will encounter obstacles in credit facilities	(8) The climate change induced by high emissions will affect business operations	(9) Emissions will lead to high energy prices, thus being a threat to business survival
State	7.5%	30.2%	26.4%	1.9%	3.8%	20.8%	9.4%	0.0%	0.0%
Collective	7.9%	38.2%	23.7%	9.2%	9.2%	1.3%	7.9%	1.3%	1.3%
Stock-Limited	7.6%	32.1%	31.7%	8.9%	7.6%	2.2%	7.6%	0.0%	2.2%
Private	6.8%	35.3%	39.5%	4.9%	4.9%	0.0%	7.4%	1.0%	0.3%
WFOE	0.0%	32.1%	22.6%	15.1%	15.1%	0.0%	11.3%	3.8%	0.0%
Joint Venture	16.0%	33.3%	36.0%	4.0%	8.0%	0.0%	2.7%	0.0%	0.0%

Table 7 Pooled OLS results for electricity input demand function with alternative specifications. HE – includes only firms that use > 90% electricity. PL – price of labor, PK – price of capital.

* p<0.05 ** p<0.01 *** p<0.001	(1) All firms	(2) Firms with HE	(3) PL, PK	(4) PL, PK + HE	(5) HE + interaction	(6) PL, PK + HE + interaction
Log electricity price	-0.282***	-0.116*	-0.293***	-0.116*	0.768**	0.747**
	(-6.08)	(-2.32)	(-6.37)	(-2.35)	(2.89)	(2.98)
Log K price			-0.0000503	-0.0188		-0.0197
			(-0.00)	(-0.71)		(-0.76)
Log L price			0.0493***	0.0487***		0.0475***
			(6.68)	(5.62)		(5.55)
Log output	0.972***	0.954***	0.965***	0.949***	0.957***	0.952***
	(211.35)	(178.08)	(190.20)	(170.68)	(174.96)	(170.08)
Collectively-owned	0.0635	-0.120*	0.0136	-0.188**	-0.292*	-0.346**
	(1.61)	(-2.11)	(0.34)	(-3.24)	(-2.48)	(-3.01)
Stock-limited	0.0511	-0.120*	0.0273	-0.160**	-0.410***	-0.449***
	(1.51)	(-2.29)	(0.80)	(-3.10)	(-3.64)	(-4.14)
Privately-owned	0.0579	-0.105	0.0118	-0.166**	-0.449***	-0.499***
	(1.64)	(-1.88)	(0.33)	(-2.95)	(-3.90)	(-4.46)
Wholly foreign-owned	0.0347	-0.128*	0.00476	-0.179**	-0.332*	-0.389**
	(0.78)	(-2.05)	(0.11)	(-2.81)	(-2.47)	(-2.92)
Joint venture	0.0671	-0.176**	0.0358	-0.221***	-0.446***	-0.482***
	(1.81)	(-3.08)	(0.96)	(-3.94)	(-3.65)	(-4.11)
Log electricity price * State-owned					0	0
					(.)	(.)
Log electricity price * Collectively-owned					-0.497	-0.450
					(-1.75)	(-1.66)
Log electricity price * Stock-limited					-0.934***	-0.934***
					(-3.45)	(-3.65)
Log electricity price * Privately-owned					-1.187***	-1.146***
					(-4.28)	(-4.38)
Log electricity price * Wholly foreign-owned					-0.604	-0.634*
					(-1.90)	(-2.07)
Log electricity price * Joint venture					-0.853**	-0.825**
					(-2.78)	(-2.82)
Base: Ferrous and non-ferrous metals mining	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Food and food processing	-0.317***	-0.349***	-0.328***	-0.349***	-0.365***	-0.367***
	(-6.89)	(-5.08)	(-6.81)	(-4.97)	(-5.61)	(-5.54)
Textiles	-0.358***	-0.361***	-0.365***	-0.362***	-0.384***	-0.386***
	(-7.72)	(-5.21)	(-7.53)	(-5.11)	(-5.82)	(-5.76)
Wood processing and furniture manufacturing	-0.263***	-0.345**	-0.280***	-0.365**	-0.347**	-0.369***
	(-4.19)	(-2.82)	(-4.36)	(-3.10)	(-3.00)	(-3.32)
Paper and products	-0.0119	0.0294	-0.0294	0.0210	0.00383	-0.00508
	(-0.22)	(0.37)	(-0.53)	(0.26)	(0.05)	(-0.07)
Oil refining and nuclear fuel processing	0.304***	0.229*	0.323***	0.242**	0.181*	0.194*
	(3.38)	(2.49)	(3.55)	(2.58)	(1.98)	(2.07)
Chemicals, pharmaceuticals, plastics, and rubber manufacturing	0.343***	0.343***	0.337***	0.344***	0.327***	0.328***
	(7.53)	(5.06)	(7.10)	(4.95)	(5.10)	(5.01)
Cement	0.178**	0.627***	0.174**	0.624***	0.609***	0.606***
	(3.16)	(8.05)	(3.00)	(7.89)	(8.12)	(8.01)
Ferrous and non-ferrous metals	0.791***	0.809***	0.793***	0.816***	0.807***	0.811***
	(16.15)	(10.52)	(15.54)	(10.26)	(11.11)	(10.84)
Fabricated metal products	0.372***	0.340***	0.369***	0.341***	0.314***	0.315***
	(8.08)	(4.90)	(7.69)	(4.81)	(4.76)	(4.70)

General and special equipment manufacturing	-0.0121	-0.0295	-0.0167	-0.0265	-0.0412	-0.0388
	(-0.26)	(-0.43)	(-0.35)	(-0.37)	(-0.63)	(-0.58)
Transportation equipment manufacturing	-0.593***	-0.467***	-0.589***	-0.454***	-0.489***	-0.477***
	(-12.45)	(-6.50)	(-11.92)	(-6.21)	(-7.12)	(-6.88)
Electrical machinery and equipment manufacturing	-0.853***	-0.685***	-0.851***	-0.680***	-0.700***	-0.696***
	(-16.52)	(-9.74)	(-15.98)	(-9.39)	(-10.43)	(-10.13)
Communications, computers and other electronics	-1.204***	-1.039***	-1.199***	-1.029***	-1.047***	-1.038***
	(-24.62)	(-14.58)	(-23.64)	(-14.13)	(-15.53)	(-15.12)
Other industries, including services	-0.275***	-0.132	-0.277***	-0.121	-0.143	-0.134
	(-4.22)	(-1.52)	(-4.13)	(-1.36)	(-1.72)	(-1.57)
2006	-0.0323	-0.0234	-0.0381	-0.0292	-0.0248	-0.0303
	(-1.63)	(-0.99)	(-1.91)	(-1.23)	(-1.06)	(-1.28)
2007	-0.112***	-0.112***	-0.118***	-0.115***	-0.111***	-0.114***
	(-5.69)	(-4.81)	(-5.79)	(-4.70)	(-4.82)	(-4.69)
2008	-0.138***	-0.135***	-0.143***	-0.137***	-0.136***	-0.138***
	(-6.97)	(-5.94)	(-6.96)	(-5.66)	(-6.02)	(-5.70)
2009	-0.217***	-0.220***	-0.224***	-0.222***	-0.219***	-0.220***
	(-10.76)	(-9.56)	(-10.15)	(-8.52)	(-9.58)	(-8.49)
Shandong	-0.0132	0.0473	-0.000700	0.0711	0.0534	0.0765*
	(-0.48)	(1.24)	(-0.03)	(1.89)	(1.45)	(2.08)
Shanxi	-0.103***	-0.0578*	-0.129***	-0.0821***	-0.0554*	-0.0791***
	(-4.85)	(-2.50)	(-5.98)	(-3.53)	(-2.40)	(-3.40)
Hebei	-0.0500*	-0.0825***	-0.0432*	-0.0720**	-0.0745**	-0.0647**
	(-2.57)	(-3.52)	(-2.23)	(-3.06)	(-3.16)	(-2.74)
Jilin	-0.0498*	0.00633	-0.0566**	-0.00834	0.0172	0.00340
	(-2.27)	(0.21)	(-2.62)	(-0.28)	(0.56)	(0.11)
Sichuan	-0.0740***	-0.0341	-0.0665**	-0.0265	-0.0229	-0.0157
	(-3.34)	(-1.34)	(-3.01)	(-1.05)	(-0.89)	(-0.62)
_cons	-4.054***	-3.622***	-3.946***	-3.475***	-3.371***	-3.225***
	(-50.66)	(-30.79)	(-39.64)	(-25.76)	(-23.26)	(-20.20)
N	3735	2250	3735	2250	2250	2250
R2	0.9395	0.9397	0.9355	0.9402	0.9405	0.9411

Table 8 Aggregation used in industry-specific estimation.

Aggregated industry category	***Energy-intensive industries (EINT)***	***Heavy manufacturing (HM)***	***Services and other light manufacturing (OSE)***
Total # of firms	424	352	156
# of EI firms	164	189	96
Included industries	2 Ferrous and non-ferrous metals mining 5 Wood processing and furniture manufacturing 6 Paper and products 7 Oil refining and nuclear fuel processing 8 Chemicals, pharmaceuticals, plastics, and rubber manufacturing 9 Cement 10 Iron and steel	11 Fabricated metal products 12 General and special equipment manufacturing 13 Transportation equipment manufacturing 14 Electrical machinery and equipment manufacturing	3 Food and food processing 4 Textiles 15 Communications, computers and other electronics 18 Other industries, including services

Table 9 Industry-specific electricity price elasticities (covariates included in the regression are the same as in Table 7 above and are not shown).

* p<0.05 ** p<0.01 *** p<0.001	(1) EINT	(2) EINT + HE	(3) EINT + PL, PK	(4) HM	(5) HM + HE	(6) HM + PL, PK	(7) OSE	(8) OSE + HE	(9) OSE + PL, PK
Log electricity price	-0.636	-0.109	-0.613	0.105	0.0391	0.099	-0.044	-0.359	-0.048
	(-8.57)	(-1.19)	(-8.36)	(1.48)	(0.56)	(1.40)	(-0.43)	(-3.04)	(-0.47)

Table 10 Abridged table of estimates of electricity price elasticities by ownership, with other covariates not reported.

	(1) State	(2) Collective	(3) Stock Limited	(4) Private	(5) Joint Venture	(6) Foreign
Log electricity price	-0.021	-0.056	-0.318	-0.509	0.017	-0.063
	(-0.07)	(-0.31)	(-3.93)	(-5.68)	(0.09)	(-0.45)
N	185	320	1030	1550	265	385

Table 11 Coefficients for a) fixed-effects and b) random effects models conditional on ownership classification.

a)

	State	Collective	Stock-Limited	Private	WFOE	JV
Log electricity price	-0.404	-0.356	-0.503**	-0.520***	-0.279	-0.777***
	(-0.66)	(-1.19)	(-2.84)	(-3.42)	(-1.02)	(-3.69)
Log labor price	0.147	-0.00509	-0.0103	0.0382	0.0546	0.0476
	(1.48)	(-0.10)	(-0.43)	(1.67)	(1.46)	(1.50)
Log capital price	0.0164	-0.0361**	-0.000316	0.00171	0.0180	0.0219
	(0.45)	(-3.07)	(-0.04)	(0.25)	(0.91)	(1.47)
Log output	0.969***	1.028***	0.977***	0.997***	0.948***	0.970***
	(18.76)	(43.84)	(66.59)	(61.03)	(34.75)	(39.17)
2006	-0.0628***	-0.0302*	-0.0383***	-0.0387***	-0.0335**	-0.0550***
	(-4.00)	(-2.44)	(-5.43)	(-4.08)	(-2.76)	(-5.62)
2007	-0.170***	-0.114***	-0.107***	-0.127***	-0.0912***	-0.104***
	(-6.05)	(-4.26)	(-10.47)	(-12.16)	(-4.38)	(-5.77)
2008	-0.207***	-0.146***	-0.132***	-0.171***	-0.117***	-0.134***
	(-6.00)	(-4.86)	(-10.76)	(-11.89)	(-4.89)	(-7.08)
2009	-0.314***	-0.218***	-0.199***	-0.242***	-0.214***	-0.195***
	(-5.78)	(-4.75)	(-10.21)	(-11.33)	(-5.21)	(-6.42)
Constant	-4.380***	-4.410***	-3.813***	-4.164***	-3.834***	-4.110***
	(-5.71)	(-13.14)	(-20.87)	(-20.78)	(-11.22)	(-13.76)
N	185	320	1030	1550	265	385

b)

	State	Collective	Stock-Limited	Private	WFOE	JV
Log electricity price	0.00728	-0.320	-0.458***	-0.516***	-0.234	-0.548**
	(0.02)	(-1.32)	(-3.30)	(-4.19)	(-0.90)	(-2.80)
Log labor price	0.100	-0.0144	-0.0182	0.0426	0.0539	0.0465
	(1.00)	(-0.28)	(-0.78)	(1.86)	(1.45)	(1.52)
Log capital price	0.0173	-0.0347**	0.00291	0.00362	0.0196	0.0285
	(0.47)	(-2.98)	(0.36)	(0.55)	(1.01)	(1.81)
Log output	0.972***	1.026***	0.975***	0.996***	0.948***	0.952***
	(29.27)	(43.69)	(78.37)	(67.93)	(36.74)	(37.36)
2005 (base)	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
2006	-0.0537***	-0.0284*	-0.0370***	-0.0392***	-0.0325**	-0.0491***
	(-3.85)	(-2.35)	(-5.49)	(-4.26)	(-2.69)	(-4.65)
2007	-0.175***	-0.112***	-0.106***	-0.128***	-0.0925***	-0.107***
	(-6.28)	(-4.17)	(-10.65)	(-12.27)	(-4.33)	(-6.12)
2008	-0.199***	-0.143***	-0.130***	-0.173***	-0.118***	-0.129***
	(-5.78)	(-4.73)	(-10.96)	(-12.24)	(-4.80)	(-6.80)
2009	-0.328***	-0.215***	-0.198***	-0.244***	-0.218***	-0.203***
	(-6.07)	(-4.74)	(-10.83)	(-11.88)	(-5.28)	(-7.15)
Jiangsu	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Shandong	-0.376	-0.0130	-0.0606	-0.00522	0	-0.609***
	(-1.54)	(-0.06)	(-0.83)	(-0.04)	(.)	(-4.15)
Shanxi	-0.198	-0.427**	-0.262***	0.0335	0.713***	-0.130
	(-0.97)	(-2.65)	(-3.74)	(0.40)	(4.47)	(-1.34)
Hebei	0.363	-0.125	-0.180*	0.0201	0.589***	0.0896
	(0.72)	(-0.66)	(-2.10)	(0.35)	(6.74)	(0.68)
Jilin	-0.108	-0.0324	-0.0906	-0.0548	0.380*	0.0700
	(-0.72)	(-0.14)	(-1.45)	(-0.58)	(2.27)	(0.67)
Sichuan	-0.141	-0.0901	-0.203**	0.0257	0.604***	-0.116
	(-0.61)	(-0.40)	(-2.64)	(0.32)	(3.91)	(-0.93)
Base: Ferrous and non-ferrous metals mining	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Food and food processing	0	-0.900*	-0.0272	-0.512**	0	0
	(.)	(-2.54)	(-0.11)	(-2.95)	(.)	(.)

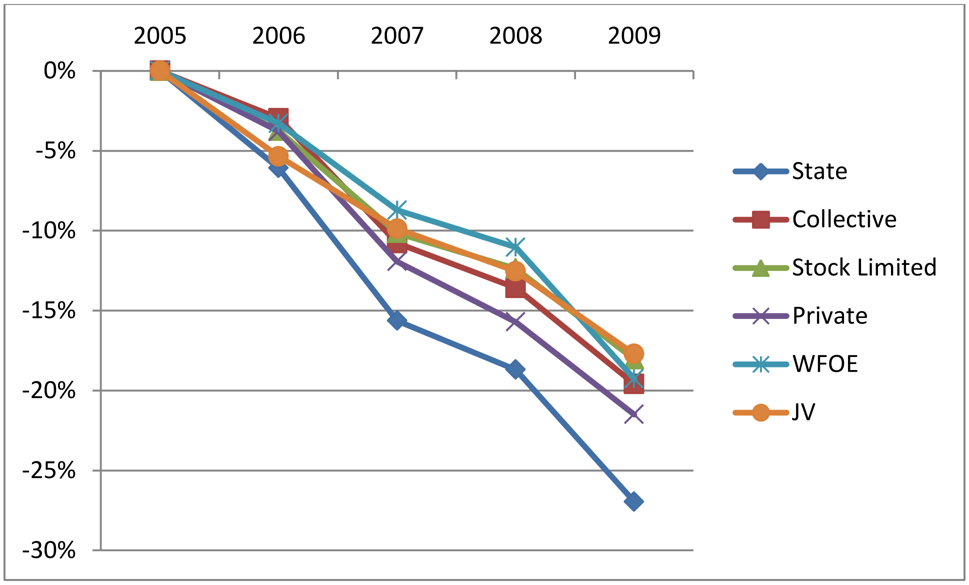
Textiles	0	-0.895*	-0.317	-0.963***	-0.128	-1.364***
	(.)	(-2.45)	(-1.48)	(-7.12)	(-0.60)	(-11.16)
Wood processing and furniture manufacturing	0	-1.191**	-0.289	-0.994***	-0.557***	-1.626***
	(.)	(-2.91)	(-1.33)	(-7.27)	(-8.12)	(-8.90)
Paper and products	1.203*	0	-0.372	-1.129***	-0.0613	-1.021***
	(2.20)	(.)	(-1.70)	(-6.22)	(-0.71)	(-6.73)
Oil refining and nuclear fuel processing	0.979	-0.696*	-0.0923	-0.596**	-0.333	-1.038***
	(1.90)	(-1.98)	(-0.42)	(-3.05)	(-1.43)	(-5.06)
Chemicals, pharmaceuticals, plastics, and rubber manufacturing	1.794**	0	0	0	0	0
	(3.14)	(.)	(.)	(.)	(.)	(.)
Cement	1.508**	-0.371	0.296	-0.398**	0.225	-0.669***
	(2.63)	(-1.01)	(1.41)	(-3.01)	(1.13)	(-7.95)
Ferrous and non-ferrous metals	1.480**	-0.631	-0.0832	-0.382*	0.674	-0.657***
	(2.63)	(-1.61)	(-0.35)	(-2.24)	(1.40)	(-5.19)
Fabricated metal products	0	0	0.807***	0.0363	0.692**	0
	(.)	(.)	(3.77)	(0.25)	(3.28)	(.)
General and special equipment manufacturing	1.378**	-0.396	0.284	-0.227	0	-0.768***
	(2.90)	(-1.08)	(1.30)	(-1.65)	(.)	(-5.92)
Transportation equipment manufacturing	0.596	-0.694*	-0.0940	-0.656***	0.0565	-0.987***
	(1.11)	(-2.01)	(-0.44)	(-4.72)	(0.37)	(-6.40)
Electrical machinery and equipment manufacturing	0.450	-1.071**	-0.809***	-1.278***	-0.368	-1.463***
	(0.79)	(-2.78)	(-3.63)	(-9.05)	(-1.76)	(-12.27)
Communications, computers and other electronics	-0.264	-1.350***	-0.824***	-1.587***	-0.992***	-1.866***
	(-0.89)	(-3.68)	(-3.64)	(-9.69)	(-6.87)	(-13.03)
Other industries, including services	-0.460	-1.983***	-1.367***	-1.713***	-1.256***	-2.129***
	(-0.89)	(-5.45)	(-5.92)	(-10.80)	(-8.47)	(-16.24)
Base: Ferrous and non-ferrous metals mining	0.358	0	-0.0705	-0.819***	-0.514**	-1.190***
	(0.61)	(.)	(-0.22)	(-3.96)	(-3.17)	(-6.85)
_cons	-4.761***	-3.340***	-3.503***	-3.471***	-4.200***	0
	(-7.84)	(-6.46)	(-12.95)	(-14.65)	(-13.16)	(.)
N	185	320	1030	1550	265	385

Table 12 Coefficients on fixed-effects models for full sample and by industry subcategory.

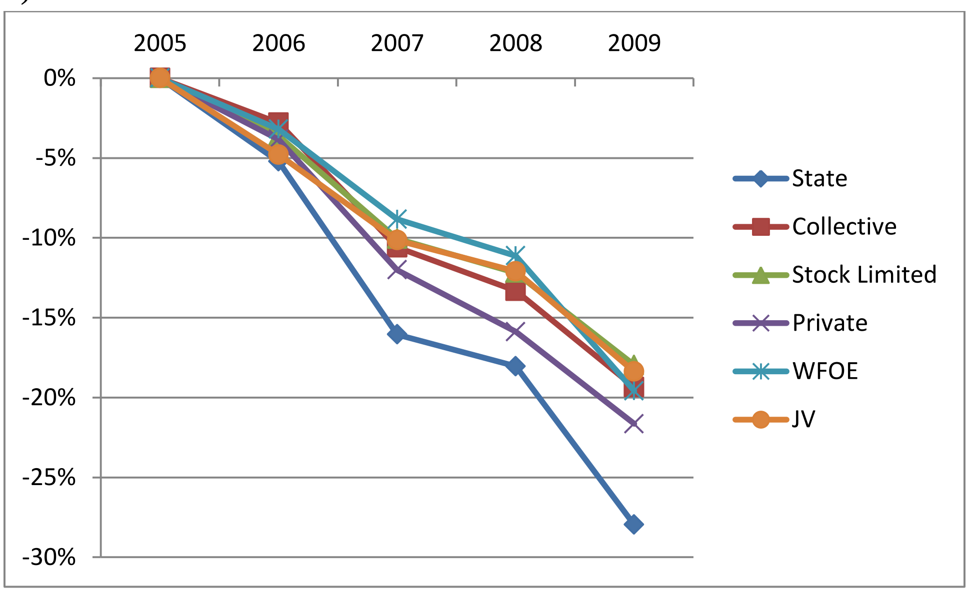
	ALL	HE	EINT – ALL	EINT – HE	HVA – ALL	HVA – HE	OSE – ALL	OSE – HE
Log electricity price	-0.508***	-0.476***	-0.800***	-0.756***	-0.370**	-0.393**	-0.369	-0.515*
	(-5.35)	(-4.36)	(-8.53)	(-5.34)	(-2.93)	(-2.99)	(-1.64)	(-2.11)
Log labor price	0.0299*	0.0198	-0.00285	-0.0113	0.0393*	0.0310	0.0310	0.0161
	(2.25)	(1.31)	(-0.16)	(-0.42)	(2.12)	(1.80)	(1.13)	(0.53)
Log capital price	0.000814	0.00129	-0.0145**	-0.0139*	0.00232	0.0104	0.0100	0.00702
	(0.18)	(0.24)	(-3.03)	(-2.16)	(0.29)	(1.24)	(1.06)	(0.65)
Log output	0.987***	0.967***	1.004***	1.012***	0.999***	0.948***	0.971***	0.963***
	(107.21)	(92.49)	(117.68)	(77.68)	(54.54)	(55.43)	(51.81)	(38.38)
2006	-0.0402***	-0.0396***	-0.0273***	-0.0245***	-0.0692***	-0.0687***	-0.0138	-0.0159
	(-8.33)	(-6.28)	(-5.94)	(-4.03)	(-7.11)	(-5.52)	(-1.47)	(-1.95)
2007	-0.117***	-0.116***	-0.0636***	-0.0717***	-0.198***	-0.180***	-0.0538***	-0.0523**
	(-18.83)	(-15.86)	(-8.14)	(-5.96)	(-20.80)	(-19.44)	(-3.50)	(-2.81)
2008	-0.152***	-0.149***	-0.0902***	-0.0988***	-0.262***	-0.239***	-0.0539**	-0.0516*
	(-19.37)	(-17.05)	(-9.98)	(-7.19)	(-19.43)	(-21.11)	(-3.11)	(-2.40)
2009	-0.224***	-0.220***	-0.135***	-0.146***	-0.363***	-0.325***	-0.109***	-0.106**
	(-18.58)	(-15.59)	(-9.00)	(-6.18)	(-18.92)	(-17.70)	(-4.07)	(-3.25)
Constant	-4.086***	-3.757***	-3.923***	-3.883***	-4.293***	-3.613***	-4.432***	-4.221***
	(-35.98)	(-30.20)	(-32.36)	(-22.67)	(-20.55)	(-19.85)	(-17.89)	(-12.84)
N	3735	2577	1485	909	1455	1079	500	354

Figure 5 Per cent non-price driven change in electricity demand in the ownership-conditional a) fixed effects and b) random effects models relative to 2005.

a)



b)



APPENDIX

Figure A1 Monthly coal prices in a sample of cities in China in the provinces covered by the survey, 2005 to 2009. (CNY – Chinese Yuan)

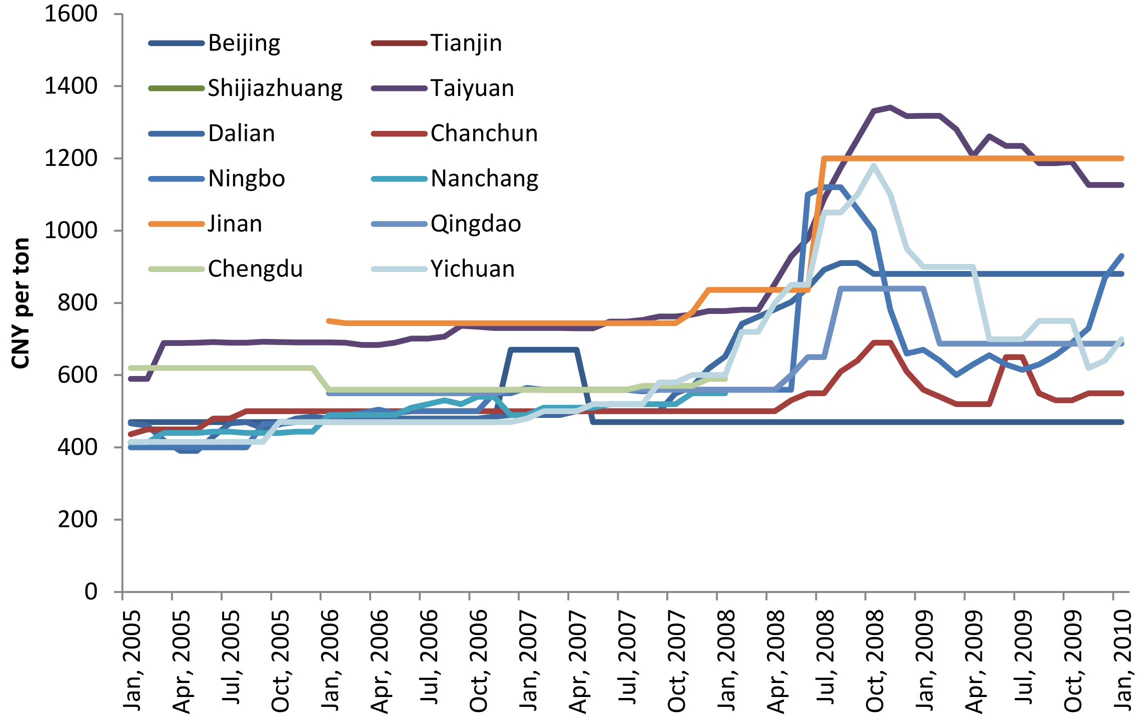


Table A1 Mapping of NBS ownership classification to ownership classification in sample of firms.

National Bureau of Statistics Classification	Ownership Classification in Sample
Domestically-funded enterprises	Private
State-owned enterprises	State
Collectively-owned enterprises	Collective
Joint Ownership	Joint Venture
Limited Liability Company/Stock Holding Company	Stock-Limited
Private	Private
Hong Kong Macau Taiwan	Wholly Foreign Owned Enterprise
Foreign Enterprises	Wholly Foreign Owned Enterprise

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