Energy Prices and Investment in Energy Efficiency: Evidence from Chinese Industry 1997-2004*

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Abstract

The paper investigates the role of energy prices in reducing energy intensity in Chinese industry. For the short run, the paper estimates contemporaneous energy price elasticities; for the long run, the paper examines in the impact of energy prices on energy-saving investment. A central purpose of the paper is to identify those subsets of China's industrial firms that are the largest energy consumers and likely to be the most price responsive. Analyzing a unique panel data set which reports firm-level energy consumption and price, the paper shows three stylized facts: (i) real energy prices, which are regulated by government, are typically lowest for state-owned enterprises (SOEs), followed by domestic non-SOEs, and highest for foreign-funded firms. (ii) In descending order of energy intensity, the six most energy-intensive industries are: electricity and power generation, petroleum processing and coking, coal mining, chemical products, nonmetal products, and nonferrous metal products. Also these six industries face relatively lower energy prices than the rest of mining and manufacturing industries. (iii) In the short run, SOEs tend to be somewhat less responsiveness than their domestic non-SOE counterparts and foreign-funded firms. However, over the long-run, SOEs tend to be more responsive to rising energy prices by investing in new energy-efficient capital; the same price-investment channels are less robust for non-SOEs or foreign-funded firms. Last, in a DSGE model with a combination of putty-clay and putty-putty investment, the share of output produced by putty-clay investment is estimated through indirect inference. An economy with 69.8% of output produced by putty-clay investment is able to reproduce the energy price elasticities estimated directly from the firm-level data. The model also shows that a 10% increase in energy price will lead to a 3.1% decrease in energy intensity, which is associated with a 1.1% drop in output and a 4.2% drop in energy consumption.

Keywords: energy efficiency, energy price, putty-clay, investment, China

JEL classification: Q4, P2, E22

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1 Introduction

This paper investigates the role of energy prices and investment in achieving energy efficiency in China's industries. How to best reduce energy intensity in China is one of the most important questions on today's global environment and policy agenda. It has become especially relevant as China has quickly risen to the top ranks in global energy demand over the past few years. China has been the largest global energy consumer since 2010; in 2013 it accounted for 22.4% of the world's total energy consumption (BP statistics, 2014). In recent years China has been the world's leading coal producer and consumer, it accounts for close to half of the global coal consumption. Also, it is the world's second-largest oil consumer behind the United States (EIA, 2014). As a consequence, China becomes an important factor in world energy-related CO_2 emissions, releasing 8,715 million metric tons of CO_2 in 2011, accounting for 25.4% of global emission (IEA, 2013). Since 2006, China's CO_2 emissions have surpassed U.S. as the world's largest CO_2 emitter (World Bank, 2014).

This paper explicitly focuses on the question how China can reduce its energy intensity and become energy efficient in its industrial sector, which consumes two thirds of total national energy. What policy instruments can Chinese government use to promote energy efficiency and in which groupings of industrial enterprises will these instruments prove to be most effective? This paper particularly focuses on the potential role of prices in both short-term and long-term, as well as how they operate through investment to affect China's energy intensity.

I address these questions by analyzing a unique data set which reports firm-level energy consumption and price from 1997-2004. First, I document several new facts on the heterogeneity in energy intensity and prices among Chinese industrial firms. I identify six industries that are the most energy intensive and in which energy prices are relatively low. Only six industries are chosen not only because they consume about 80%-90% of total industrial energy, but also because these six industries constantly face lower energy prices than rest of the Chinese industrial enterprises. Second, I estimate short-run and long-run price elasticities for the whole sample and individual industrial sectors. Last, I propose a a dynamic stochastic general equilibrium (DSGE) model with a combination of putty-clay and putty-putty investment, which intends to reproduce the energy price elasticities estimated directly from the firm-level data. Then this model is used to quantitatively evaluate the impact of energy price on aggregate variables, such as output, energy use, and investment.

Among the key results, I find that state-owned enterprises (SOEs) are less responsive to energy prices than domestic non-state-owned enterprises (non-SOEs) and foreign-funded firms. A 10% increase in energy price leads to a short-run or contemporaneous 4.5% decrease in energy intensity for SOEs, and a 4.8% decrease for non-SOEs, and a 5.2% for foreign-funded firms. The price elasticity of SOEs is significantly smaller than their non-domestic counterparts and foreign-funded firms. In the long-run, price elasticities tend to become more equal among SOEs, non-SOEs and foreign-funded firms. In particular, over the long-run, SOEs tend to be more responsive to rising energy prices by investing in energy-saving capital, which in turn improves their energy efficiency, while this similar investment responsiveness does not hold for non-SOEs or foreign-funded firms. Further, in a DSGE model with a combination of putty-clay and putty-putty investment, an economy with 69.8% of output produced putty-clay investment is able to reproduce the energy price elasticities observed from the firm-level data. This estimated model suggests that a 10% increase in energy price will lead to a 1.1% drop in output and a 4.2% drop in energy consumption.

What do these estimates mean for energy policy? The estimated price elasticities in this paper indicate that if the Chinese government intends to reduce energy intensity by 10%, an effective policy instrument is to increase energy prices by 22% for SOEs, 20% for domestic non-SOEs, and 19% for foreign-funded firms. Moreover, because the energy price-investment channels work for SOEs, lowering SOEs' investment costs and financing costs could also be an effective policy. The absence of similar incentive for non-state and foreign enterprises may explain the relative unresponsiveness to investment in response to higher energy prices.

These new findings are highly relevant to China's environmental and energy policy. In November 2014, China and U.S. signed an agreement on climate change, in which Chinese government agreed that its CO_2 emissions will peak on or prior to 2030. The environmental issues have also received attention by China's top government since 2005. In the *11th Five Year Plan for National Economy and Social Development 2005-2010*, Chinese government set a target of decreasing energy consumption per unit of GDP by 20% during 2005-2010. In accordance with this national goal, the *Top-1000 Enterprise Program* was initiated in 2005. This program set energy intensity targets for the 1000 most energy-intensive industrial firms. And in the *12th Five Year Plan for National Economy and Social Development 2011-2015*, the targets were further reduced, decreasing energy consumption per unit of GDP by 16% and CO_2 emissions per unit of GDP by 17% by 2015. Accordingly, during the *12th Five Year Plan* , the *Top-1000 Enterprise Program* was extended to the 10,000 most energy intensive industrial firms. As Chinese government pays more attention to environmental issues, this targeting program intends to extend to and cover all industrial firms. All these policy initiatives underscore the question of how China can significantly reduce its energy intensity most efficiently so as to curtail climate change.

The paper is organized as follows: Section 2 describes the data set and summarizes several facts on the heterogeneity of energy intensity and prices, as well as energy pricing for Chinese industrial firms. In Section 3, estimation models are introduced and endogeneity issue of firm-level energy prices is addressed; short-run and long-run price elasticities are estimated for the whole sample and individual industrial sectors. Section 4 provides a brief description of estimating a DSGE model, which is used to quantitatively evaluate the impact of energy price on aggregate variables. Conclusions are drawn in Section 5.

2 Heterogeneity in Energy Intensity and Energy Price

The purpose of analysis in this section is to identify the relatively homogeneous sub samples that lie along an extremely heterogeneous continuum of energy intensity and prices across industries, regions, and ownership types. This exercise enables us to know which groupings of industrial firms have the greatest potential for reducing energy intensity using the energy price instrument.

2.1 Data set

The firm-level data used in this paper are a subset of the Large and Medium-size Enterprises (LME) data set collected by China's National Bureau of Statistics (NBS) from year 1997 to 2004. It provides financial and economic variables as well as energy consumption variables. Specifically, the energy data includes the amount of consumption, value of purchase and quantity of purchase for 21 energy types.

The sample used in this analysis is an unbalanced panel, consisting of approximately 35,000 firms. I clean the data set and exclude outliers by the following criteria. First, observations whose key financial variables (such as total assets, net value of fixed assets, sales, and gross value of industrial output) are missing are dropped. Second, observations whose profile variables have inconsistent number of digits (i.e., the region code should be 6 digits, the ownership code should be

3 digits, and the industrial code should be 4 digits) are dropped. Further, I delete observations according to the basic rules of generally accepted accounting principles if any of the following are true: (1) liquid assets are higher than total assets; (2) total fixed assets are larger than total assets; (3) the net value of fixed assets is larger than total assets; (4) the firm's identification number is missing. Last, both energy intensity and energy price, the two key variables this paper focuses, exhibit extremely large values. These unreasonably large values might be due to mis-reporting or measurement errors. Therefore, the observations with largest 1% value of energy intensity and energy price are trimmed off.

Two key variables of interest, energy intensity and real energy price, are constructed in the following way. First, energy intensity is constructed as the ratio of overall energy consumption to the real output. Real output corresponds to the variable gross value of industrial output (GVIO) at constant price level. Overall energy consumption is measured as physical quantity as tones of standard coal equivalence (SCE). Firms report their amount of consumption, value of purchase and quantity of purchase for 21 energy types. NBS weights the individual energy types to provide a measure of overall energy consumption. The weights are firm-specific adoption coefficients for those 21 energy types. Second, real energy price is constructed as the nominal energy price divided by the output price; both prices are at firm-level. The nominal energy price is calculated as the total value of purchase for 21 energy types divided by the total quantity of purchase, which is sum over 21 energy types. Each energy type is converted to standard coal equivalence by the adoption coefficients provided by NBS.[1] Output price is calculated as GVIO at current price level divided by GVIO at constant price level, which are both provided by NBS.

2.2 Energy intensity

This subsection presents some facts regarding heterogeneity in energy intensity, which is our measure of energy efficiency. As described in Section 2.1, energy intensity is the ratio of overall energy consumption to real output.

2.2.1 Energy intensity by 3 ownership types

In the sample, 50% of the firms are SOEs, 38% are domestic non-SOEs and the rest 12% are foreign-funded firms, a classification that combines firms from Hong Kong, Macau and Taiwan (HMT) and foreign firms. Table 1 presents the mean and median energy intensity across those 3 ownership types. On average, SOEs have the highest energy intensity, then non-SOEs, and foreign-funded firms have the lowest energy intensity. [2]

2.2.2 Energy intensity by 8 industrial sectors

From the perspective of industry, among the 38 (manufacturing and mining) industries in the sample, the electricity and power generation industry is the most energy intensive, followed by the petroleum processing and coking industry. This is due to the fact that these two industries use considerable amounts of energy as inputs. Power generation consumes a large amount of coal as its input to generate electricity, and petroleum processing and coking industry uses crude oil intensively to produce various type of refined oil. Mining industries have higher energy intensity than manufacturing industries. Among mining industries, coal mining and coking industry is the most intensive . Among manufacturing industries, the chemical

[1] The adoption coefficients for 21 types of energy are available from the author.

[2] I also look at SOEs, non-SOEs and foreign firms' energy intensity year by year. From 1997 to 2004, SOEs are constantly more energy-intensive than non-SOEs and foreign-funded firms. Both mean and median energy intensity of SOEs are higher than that of non-SOEs and foreign-funded firms. Foreign-funded firms are the least energy-intensive, although in some years, the average energy intensity of foreign-funded firms is higher than of non-SOEs, its median energy intensity is always lower. Those summary statistics can be found at `https://sites.google.com/site/sarahletang0610/research-1`.

products, nonmetal products and nonferrous metal products are more energy intensive than the rest of manufacturing industries. Table 2 represents the mean and median energy intensity in 8 groups: electricity and power generation (elect), petroleum processing and coking (petro), coal mining, nonferrous metal products (iron), nonmetal products (cement), chemical products (chemical), other mining industries (other mining) and other manufacturing industries (other manu). Among manufacturing industries, instrumental equipment manufacturing and electronic component manufacturing are the least energy-intensive. [3]

2.2.3 Energy intensity by 5 regions

Regarding the geographic location of firms, I divided the whole sample into 5 regional groups: firms in the northern area (Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia), northeastern area (Liaoning, Jilin and Heilongjiang), eastern area (Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi and Shandong), southern area (Henan, Hubei, Hunan, Guangdong, Guangxi and Hainan) and western area (Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang). Table 3 presents summary energy intensity by the 5 regions: north, northeast, east, south and west. Overall, firms in the north and northeast are more energy-intensive than those in the south and east. This is due to the fact that heavy industries, such as coal mining, petroleum processing and etc, are concentrated in the northern and northeastern provinces, while light, energy non-intensive manufacturing, such as instrumental equipment and electronic component manufacturing are inclined to locate in the southern and eastern provinces.

2.2.4 Ownership effects or industry effects

Subsections 2.2.1, 2.2.2 and 2.2.3 show how energy intensity varies across ownership categories, industries and regions. To some degree, the ownership categories are correlated with firms' industries. SOEs are dominant in heavy industries, such as electricity and power generation, petroleum processing and coking or coal mining, which are also energy intensive.

To see whether energy intensity depends more on ownership categories or industries, I pick up a specific 4-digit level industry in each of four 2-digit level industries: electricity and power generation, chemical products, nonmetal products, and nonferrous metal products. The corresponding 4-digit level industries are: thermal power generation, nitrogen fertilizer, cement, and steel pressing. These 4-digit level industries are used to identify the role of ownership in differentiating firm's energy intensity. The upper Panel A in Table 4 shows the results of regressing energy intensity on firm's ownership dummies, controlling for the year and province effect[4] in thermal power generation, nitrogen fertilizer, cement and steel pressing, respectively. These results show that even at the 4-digit level industry, ownership still matters; SOEs have higher energy intensity than non-SOEs and foreign-funded firms.

In sum, the above analysis shows that: 1. SOEs are the most energy-intensive, then domestic non-SOEs, and foreign-funded firms are the least energy-intensive; 2. from the industry perspective, the electricity and power generation industry is the most energy-consuming industry, followed by the petroleum processing and coking industry, then coal mining, chemical products, nonmetal products, and nonferrous metal products ; 3. from the perspective of geographic locations, northern and northeastern provinces are more energy-intensive than eastern and southern provinces.

[3] I also look at the six industries' energy intensity year by year. It shows that these six industries, electricity and power generation, petroleum processing and coking, chemical products, nonmetal products, nonferrous metal products and coal mining industry, are consistently more energy-intensive than the rest of mining and manufacturing industries. Those summary statistics can be found at `https://sites.google.com/site/sarahletang0610/research-1`.

[4] Specifically, the regression equation is: $(\frac{EN}{Q})_{itjk} = \alpha_0 + \sum_{t=97}^{04} \delta_t Year_t + \sum_{j=1}^{3} \lambda_j Owner_j + \sum_{k=1}^{32} \varphi_k Province_k + \epsilon_{it}$. Here I use province dummies to control the regional effect. Using the regional dummies that are associated with the 5 regional groups defined in subsection 2.2.3 does not change the results. The results are available from the author.

2.3 Energy price

This subsection presents facts regarding the heterogeneity in real energy prices, which are constructed as the nominal energy price divided by the output price; both prices are at firm-level. The construction of real energy prices are described in subsection 2.1.

2.3.1 Setting energy prices: institutions and practice

After the price reform in 1994, China's dual-track pricing system was abolished, the price of energy was increasingly driven by the market forces. However, government intervention in energy price still exists. In Chinese industry, firm-level energy prices differ in terms of ownership category, industry and regional location. State-owned enterprises have been given favorable treatment or subsidies reflected in the low energy prices . Energy-consuming industries have been given lower energy prices by government, whose intention is to keep the production cost low in order to make those industries competitive in international markets. Provincial governments also play an important role in setting energy prices due to the imbalanced economic development across regions, such provinces like Guangdong, Zhejiang and Shanghai in eastern areas with relatively high GDP, the energy prices are relatively higher than Shanxi and Inner Mongolia, the inner areas with less economic development. In the sample, the average shares of coal, oil and electricity consumption of an individual firm are 64%, 9% and 20% correspondingly. Coal, oil and electricity are dominate among 21 types of energy. Therefore, in the following subsection, I focus on the price setting institutions for coal, oil and electricity respectively.

Coal pricing

The price of coal has been intentionally kept low by the government. The low coal price is due to the fact that on one hand China is resource abundant with coal, 13% of the world's total coal reserves are in China (IEA, 2014), and most of the coal is near the surface of the ground, so the extraction cost is relatively low. On the other hand, the majority of coal is sold to the thermal power sector. In the sample, about 40% of China's coal production was consumed by the thermal power plants. And the power generation sector is heavily subsidized by government, whose intention is to keep the price of electricity low for industrial production and in particular for the state-owned enterprises and the energy-intensive industrial sectors.

Before 1983, the price of coal was tightly controlled by the government, since coal is regarded as a strategic resource. In 1983, a dual-track price system was introduced; one price was set by government agencies, notably the State Planning Commission (SPC), the predecessor of the National Development and Reform Commission (NDRC), for plan-allocated quotas, and the other price was set by the market. Beginning in 1993, coal price liberalization was initially experimented with in eastern China and then introduced to the rest of the country (Wu, 2003). By 1996, coal prices were largely deregulated except for certain industries, which are chemical products, cement, iron and steel, and electricity and power generation. Those industries bought coal through long-term contracts at National Coal Association Conference, held annually by the SPC. Those energy consuming industries negotiated with coal supplier companies to get a bargain, and such arrangement was encouraged by the SPC. Since 2002, coal price regulations have been removed from chemical products, cement, iron and steel, but not from the electricity and power generation industry. Until December 2004, coal prices for power generation plants were not mandated to secure their coal price through long-term contract with coal suppliers (Li, 2007). However, the NDRC still recommends both power generation plants and coal companies to negotiate a long-term contract, in order to stabilize the price of coal.

Oil pricing

Before 1998, the price of oil was under tight regulation by the government. Although the dual-track price system was introduced in 1994, due to the dramatic change in oil prices driven by market force, oil price were still regulated by the government, whose purpose is to avoid oil price volatility. With the increasing dependence of import oil, China imported 6.6% of its oil in 1990, and rose to 30% in 1997, in June 1998, the government started to set domestic oil prices in accord with global oil prices (Hang and Tu, 2007). Specifically, the SPC adjusted domestic oil prices when the change in the Singaporean oil spot market price was more than 5%. Starting in 2001, the domestic oil price was pegged to a weighted average price of Amsterdam, Singapore and New York oil spot market.[5] Since then, China's domestic oil price has been based on international market price and adjusted monthly. Moreover, the SPC also sets the regional prices of refined oil products according to the international oil price. Hence, since 1998, oil prices in China have been largely driven by international market prices.

Electricity pricing

Compared to coal and oil, whose consumption are more concentrated in certain industries, e.g., 40% of coal is consumed by electricity and power generation industry, 20% of oil is consumed by petroleum processing and coking industry, the consumption of electricity is less concentrated among industries.

The price setting scheme for electricity can be decomposed into two steps: first power generation plants sell electricity to grid companies, who are in charge of power distribution and transmission; and the next step is grid companies selling electricity to end-users, either industries or residents. The first step price is referred as to the wholesale price, and the latter one is referred as the retail price. Until now, both wholesale and retail electricity prices have been tightly regulated.

The wholesale price is set by local governments, usually at the provincial level by the provincial pricing bureau, and with final approval from the central government's State Pricing Bureau under the SPC. The regulated prices are based on the power generator's age, fuel type(coal, hydro-power, nuclear power and etc), location and type of power generated (peak or off-peak). Substantial differentials persisted, because the differences are based on power generation plant's idiosyncratic characteristics. For example, in 2001, the average price paid by a generating plant constructed before 1985 was USD 0.029/kWh (0.24 yuan /kWh). For a new plant with prices approved in 1997, the set price was USD 0.049/kWh (0.41 yuan/kWh) (IEA, 2006). Such pricing schemes intended to encourage investment in the power generation sectors. Due to regional differences in economic development, it is difficult to implement a unified pricing system because poorer provinces may not be able to afford a higher electricity price. Besides some provinces have special endowment or resource-abundance, such as Guizhou or Sichuan have abundant hydro power, and Shanxi have abundant coal resources. Such resource-endowment differences among provinces are reflected in electricity prices across provinces.

The retail price for electricity is set according to a catalogue system prepared by the SPC pricing bureau. It serves as a means of giving preferential treatment to heavy industry, chemical plants, agriculture and irrigation, in terms of both the allocation and price of electricity . The catalogue forms the basis of end user tariffs through China. Each of the categories is assigned a catalogue price, which is used by the provincial pricing bureaus to calculate the final price (IEA, 2006). Due to the regional differences in economic development, each province and major municipality amends the uncatalogued price set by the State Pricing Bureau to suit its own policy goals and economic development, and may add a different suite of additional fees to the nationally approved ones. Therefore, the electricity prices vary considerably across different regions.

[5]See `http://www.in-en.com/finance/html/energy_1606160612586545.html`.

In short, although market force started to play a role since the phase-out of dual-track price system in the mid-1990s in energy market, energy prices are still under both central and local government's supervision (USITC, 2007; Rosen and Houser, 2007), because the government has considered energy as a strategic resources and fundamental to the country's economy (Li, 2007; Hang and Tu, 2007; Wu, 2003). Therefore, through an extensive, somewhat decentralized system of the regulation of coal, oil and electricity prices, energy prices for industrial firms are largely regulated by the government.

2.3.2 Energy price by 3 ownership types

Table 5 presents the mean and median energy prices for 3 ownership categories from 1997-2004. On average, foreign-funded firms face the highest energy price, in comparison to SOEs and non-SOEs. Although the average energy prices of SOEs are somewhat similar to that of non-SOEs in year 1999, 2000 and 2001, the median energy prices of SOEs are consistently lower than that of non-SOEs. Figure 1 plots the kernel density of logarithm of energy price[6] by 3 ownership categories from 1997-2004 respectively. The distribution of foreign-funded firms' energy price is constantly rightwards to the SOEs and non-SOEs. Although the energy price distributions of SOEs and non-SOEs are similar, SOEs exhibit relatively fatter left tails compared to non-SOEs. The state-owned firms on the fatter left tails are the electricity and power generation firms. The fact that SOEs face relatively lower energy price compared to their domestic non-SOE counterparts and foreign-funded firms is consistent with the observation that energy prices in SOEs are usually subsidized (Rosen and Houser, 2007).

2.3.3 Energy prices by 8 industry sectors

From the perspective of industry, firms in electricity and power generation industry consistently pay the lowest energy price from 1997-2004, followed by firms in petroleum processing and coking industry. Mining industries face lower price than manufacturing industries. Among mining industries, coal mining and coking industry, which is the most energy intensive mining industry, faces lower price than other mining industries. In manufacturing industries, the most energy-intensive industries, such as chemical products, nonmetal products and nonferrous metal products, face lower prices than other mining and manufacturing industries. Table 6 represents the mean and median energy prices in eight industrial sectors: electricity and power generation (elect), petroleum processing and coking (petro), coal mining, nonferrous metal products (iron), nonmetal products (cement), chemical products (chemical), other mining industries (other mining) and other manufacturing industries (other manu). It shows that the six most energy-intensive industries consistently face lower energy price than other mining and manufacturing industries in China. Among the rest of manufacturing industries, instrumental equipment manufacturing and electronic component manufacturing face the highest energy prices.

Figure 2 plots the kernel density of logarithm of energy price by the above eight industrial sectors from 1997-2004 respectively. Again, the electricity and power generation industry and petroleum processing and coking industry stand out, which face the lowest energy price. The low energy price in electricity and power generation industry is mainly due to government subsidies, because high electricity price would undermine the competitiveness of manufacturing industries. Historically, coal was sold to the power generation sector at subsidized prices, sometimes at half, or even less than half of the production cost (Lam, 2005).

[6] Because the lower bound of energy price is zero, the distribution of energy price is highly skewed to the left. To make the price distribution more symmetric, logarithm of energy price is used.

2.3.4 Energy prices by 5 regions

Regarding geographic locations, Table 7 presents the summary energy prices by the 5 regions: north, northeast, east, south and west. Overall, energy prices in the north and northeast are lower than that in the south and east. This is due to the imbalanced resource endowment across provinces. Take coal for instance, most of the coal reserves are in the northern regions of China, specifically concentrated in Shanxi and Inner Mongolia, while most consumption takes place in eastern and southern coastal area, such as Shanghai, Guangdong and Fujian, which are among China's least coal-abundant provinces (Lam, 2005; Aden et al., 2010).

2.3.5 Ownership effects or industry effects

Subsections 2.3.2, 2.3.3 and 2.3.4 show how energy price varies across firm's ownership categories, industries and regions. As mentioned in before, firm's ownership categories, industries and regions are somehow correlated, and geographic regions are more exogenous than ownership and industry categories. In order to see whether energy price depends more on ownership categories or industries, four specific 4-digit level industries: thermal power generation, nitrogen fertilizer, cement and steel pressing, are selected to compare their energy prices among 3 ownership categories. The lower Panel B of Table 4 shows the results of regressing energy price on firm's ownership dummies, controlling year and provincial effect[7] in the four 4-digit level industries respectively. Those regression results suggest that at 4-digit level industry, ownership does not matter as much as it does in energy intensity. The coefficients in front of ownership dummies are not significant in thermal power and steel pressing, and slightly significantly positive, at 10 % level, in nitrogen fertilizer and cement.

In sum, the analysis in this section shows that: 1. SOEs pay the lowest energy prices, then domestic non-SOEs, and foreign-funded firms pay the highest energy prices. 2. From the perspective of industry, the two most energy intensive industries, electricity and power generation and petroleum processing and coking, face the lowest energy price, followed by chemical products, nonmetal products and nonferrous metal products. 3. From the perspective of geographic location, the northern and northeastern provinces have relatively lower energy prices than that in the eastern and southern provinces.

2.3.6 Price changes over time

Table 5, 6 and 7 show that energy prices stayed low from 1999-2003, and experienced a sharp increase in 2004. This pattern of change in average annual energy price is more related to China's macroeconomic conditions and international energy market. Starting in 1999, there were economic downturns in China after Asian financial crisis, industrial energy demand decreased and its price became low. As the economy started to recovery in 2003, combining with the accession to WTO in December 2001, the expansion of industrial output led to an increase in energy demand, which in turn drove up the energy price. On the other hand, the severe weather conditions caused disruption in coal and oil production, and especially the power generation sector. The abrupt and large increase in energy price in 2004 is consistent with the observation that China experienced an acute shortage of energy[8] (Lam, 2005). A sharp increase in energy price from 2003 to 2004 was mainly due to increased industrial demand and decreased energy supply.

The increasing energy price in 2004 was not the phenomenon only in China. International energy prices also experienced

[7] Specifically, the regression equation is: $(\frac{P_{EN}}{P_Q})_{itjk} = \alpha_0 + \sum_{t=97}^{04} \delta_t Year_t + \sum_{j=1}^{3} \lambda_j Owner_j + \sum_{k=1}^{32} \varphi_k Province_k + \epsilon_{it}$. Here I use province dummies to control the regional effect. Using the regional dummies that are associated with the 5 regional groups defined in subsection 2.2.3 does not change the results. The results are available from the author.

[8] Abundant new articles reported the energy shortage in China 2003-2004, see http://www.people.com.cn/GB/jingji/1045/2259009.html; http://news.xinhuanet.com/fortune/2003-12/15/content_1231210.htm.

a sudden increase from 2003 to 2004. As shown in Figure 3, both international coal[9] and oil prices[10] experienced an increase from 2003 to 2004. The annual fluctuations of energy price calculated from the sample share a similar pattern to that of Australia thermal coal FOB, a slight decrease from 1998 to 1999, and a large increase from 2003 to 2004.

The above discussions suggest that the although dual-track system was abolished in mid-1990s and market force was then introduced and started to play a role in determining energy prices, the governments still have certain control over firm's energy prices. From the perspective of price movement, annual average energy price is largely driven by market force and macroeconomic conditions, while the deviation of individual firm's energy price to the annual average is largely determined by the government's regulation and energy price policy. The analysis in subsections 2.3.2, 2.3.3 and 2.3.4 indicates that government assigns energy prices to firms according to their ownership categories, industries and provinces.

3 Energy Demand Price Elasticity

In this section, I estimate the energy price elasticities using the firm-level data. There are two sets of price elasticities: short-run price elasticity that measures the contemporaneous impact of energy price on energy intensity, and the long-run price elasticity that captures the dynamic impact of price on energy intensity. First, the energy demand equation is derived from firm's cost-minimization problem; the endogeneity of energy price is resolved by using an aggregated energy price, which is the average price at 3-digit industry and provincial level. Later on, short-run price elasticities are estimated for the full sample and individual industrial sectors respectively; and long-run price elasticities are estimated via a distributed lag model.

3.1 Estimation equations

I follow Fisher-Vanden et al. (2004) to construct the energy demand equation, which is derived from the firm's cost minimization problem. Assuming a constant-return to scale Cobb-Douglas cost function, [11] the functional form is as follows:

$$C(P_K, P_L, P_E, P_M) = A^{-1} P_K^{\alpha_K} P_L^{\alpha_L} P_E^{\alpha_E} P_M^{\alpha_M} Q \tag{1}$$

where Q is the quantity of output, P_K is the price of capital input, P_L is the price of labor, P_E is the price of energy input, and P_M is the price of intermediate material. The coefficient α_X is the elasticity of output X $(X = K, L, E, M)$. A is the productivity term defined as [12]

$$A^{-1} = exp(\sum_{t=97}^{04} \delta_t Year_t + \sum_{h=1}^{38} \gamma_h Industry_h + \sum_{j=1}^{3} \lambda_j Owner_j + \sum_{k=1}^{32} \varphi_k Province_k) \tag{2}$$

From Shepherd's lemma, the energy intensity equation is:

$$\frac{E}{Q} = \frac{\alpha_E}{A} \frac{P_Q}{P_E} \tag{3}$$

[9] I use Australia thermal coal FOB as a proxy of international coal price. Coal prices in other regions, such as South Africa and Columbia, show a similar pattern.

[10] The international oil price is the average of average spot price of Brent, Dubai and West Texas Intermediate, equally weighed.

[11] Here I assume Cobb-Douglas cost function, instead of translog cost function, which exhibits more flexibility, because of data availability. Rental price of capital and price of material are not available in the sample.

[12] In the rest of analysis, the regional dummies are all at provincial level, not the 5 regional groups defined in subsection 2.2.3.

where

$$P_Q = P_K^{\alpha_K} P_L^{\alpha_L} P_E^{\alpha_E} P_M^{\alpha_M} \tag{4}$$

Substituting for A defined in equation (2) and taking logarithms on both sides, the estimation equation is obtained as following:

$$Ln(\frac{E}{Q})_{it} = \alpha_0 + \alpha_1 Ln(\frac{P_E}{P_Q})_{it} + \sum_{t=97}^{04} \delta_t Year_t + Z_{it} + u_{it} \tag{5}$$

where Z_{it} includes firm's ownership, industry and province dummies, $Z_{it} = \sum_{h=1}^{38} \gamma_h Industry_h + \sum_{j=1}^{3} \lambda_j Owner_j + \sum_{k=1}^{32} \varphi_k Province_k$.

On the other hand, the energy price setting equation is:

$$Ln(\frac{P_E}{P_Q})_{it} = \beta_0 + \sum_{t=97}^{04} \delta_t^{'} Year_t + Z_{it} + v_{it} \tag{6}$$

It is reasonable to assume that $E(u_{it}v_{it}) = 0$. Since Z_{it} represents firm's characteristics, such as ownership category, industry and location, which can be treated as exogenous, so it is reasonable to assume that $E(Z_{it}u_{it}) = E(Z_{it}v_{it}) = 0$.

The equation (6) is motivated by the institutions of energy price setting in Chinese industries. As discussed in Section 2.3, market force started to play a role in determining energy prices in the mid-1990s, nevertheless the government still have controls on energy prices. Specifically the central and local governments assign energy prices according to firm's ownership categories, industries and geographic locations. In equation (6), the year dummies intend to capture the movement of annual average energy prices, which is driven by market force; firm's characteristic variable Z_{it} intends to capture the deviation of individual firm's energy price to its annual average, which reflects the energy price setting policy that firms energy price is assigned in according to their ownership categories, industries and provinces. Therefore, firm-level energy price can be modeled as equation (6).

The system of two equations (5) and (6) exhibits the recursive form, essentially the energy intensity $Ln(\frac{E}{Q})$ does not appear on the right-hand side of equation (6). The recursive form of the system enables us to consistently estimate energy demand elasticity α_1 by focusing on the demand equation (5) alone. [13]

Further to address the endogeneity of firm-level energy prices, I construct an aggregated energy price, which is calculated as the average energy price at the 3-digit industrial and provincial level. The following regression analysis uses this aggregated energy price.

3.2 Estimation of short-run price elasticity

This subsection estimates contemporaneous price elasticities. The price elasticity of SOEs is significantly smaller than their non-domestic counterparts and foreign-funded firms. Specifically, a 10% increase in energy price leads to a contem-

[13] Estimation of equation (6) shows that year dummies and Z_{it} together explains about 65-70% variation of energy price. Regarding industry dummies, I try 2-digit level industry dummies, 3-digit and 4-digit level industry dummies. I also applied equation (6) to both unbalanced and balanced sample. For unbalanced sample, the year dummies and firm's characteristics explain 65-70% of variations in energy price; for balanced sample, the explanatory power of year dummies and firm's characteristics goes to 70-75%. For both unbalanced and balanced sample, the regressions with 2-digit level industry dummies have relatively lower R-square 65%, and those with 4-digit level industry dummies have the highest R-square 75%. Besides the firm's characteristic dummies Z_{it}, I also add other regressors that capture firm's characteristics, such as firm's scale dummy, affiliation dummy, and several firm-level specific variables, such as firm's capital-labor ratio, exporting dummy, and energy combinations, which are consumption shares of coal, oil and electricity. Including energy combinations increase the R-square from 65% to 75%, however other variables rarely increase the R-square in equation (6). The results are available from the author.

poraneous 4.5% decrease in energy intensity for SOEs, and a 4.8% decrease for non-SOEs, and 5.2% for foreign-funded firms.

The short-run price elasticity is estimated for the full sample and 8 industrial sectors, which are the six energy-intensive industries: electricity and power generation (elect), petroleum processing and coking (petro), chemical products (chemical), nonmetal products (cement), nonferrous metal products (iron), coal mining, plus other mining industries (other mining) and other manufacturing industries (other manu) respectively. The six industries identified in Section 2 not only have relatively high energy intensity and low energy price, but also their shares of energy consumption are high. On average, these six industries altogether consume 84% of industrial energy in the sample from 1997-2000, and about 90% from 2001-2004.

In order to compare the responsiveness to energy price among SOEs, non-SOEs and foreign-funded firms, the short-run price is estimated by modifying equation (5) as follows:

$$Ln(\frac{E}{Q}) = \beta_0 + \beta_1 Ln(\frac{P_E}{P_Q}) + \beta_2 Ln(\frac{P_E}{P_Q}) * NonSOE + \beta_3 Ln(\frac{P_E}{P_Q}) * Foreign + controls + \varepsilon \qquad (7)$$

where $NonSOE$ is a dummy variable for domestic non-SOEs, and $Foreign$ is a dummy variable for foreign-funded firms. The control variables include year, industry and province dummies and their interactions with $NonSOE$ and $Foreign$. The reference firms are SOEs, whose price elasticity is β_1. β_2 captures the differences in price elasticities between SOEs and non-SOEs, and β_3 captures the differences in price elasticities between SOEs and foreign-funded firms.

Table 8 and Table 9 report the three key coefficients, β_1, β_2 and β_3, for the full sample and 8 industrial sectors. [14] The energy prices used in the regressions are average energy prices at 3-digit industrial and provincial level. Table 8 consists of the OLS estimations, and Table 9 are fixed effect estimations, which controls for the firm's unobservable fixed effects. For both OLS and fixed effects, the price elasticities for SOEs, non-SOEs and foreign-funded firms are consistently significantly negative for all the sub groups. In general, SOEs' price elasticity is significantly smaller in magnitude, in comparison with the non-SOEs or foreign-funded firms.

A possible explanation why SOEs are less responsive than non-SOEs and foreign-funded firms might be that the government interferes with SOEs energy prices, such as giving SOEs preferential treatment. Besides price interference, the government interferes with SOEs' decision makings, imposing some social objectives on SOEs. Historically, the SOEs had to shoulder the social responsibility of creating employment, and providing employees with various kinds of fringe benefits and service facilities like housing, education and medical care (Lam, 2005). The work of Cooper et al. (2010) quantitatively verified that SOEs usually pay higher severance fee than than non-SOEs and foreign-funded firms, suggesting that SOEs undertake more social objective, especially in employment creation and stabilization. Another explanation is that SOEs production technology is more likely to be putty-clay, which means there is no substitutability among capital, labor and energy once investment has been installed, while non-SOEs and foreign-funded firm's production technologies are more putty-putty, which means capital, labor and energy are substitutable after investment has been installed. [15]

As robustness check, I re-do the regression in equation (7) using the firm-level energy prices and the 4-digit industrial and provincial level average energy prices. With firm-level price or alternative aggregate energy price, the price elasticities for SOEs, non-SOEs and foreign-funded firms are consistently significantly negative for all sub samples. And SOEs' price

[14] Thermal power generation industry, a 4-digit level industry, is dominant in the electricity and power generation industry, which is a 2-digit level industry. The regression result on the thermal power generation industry is also reported

[15] This idea is further explored in my paper "Energy Usage and Vintage Capital: A Putty-clay Approach" at `https://sites.google.com/site/sarahletang0610/research-1`.

elasticity remains significantly smaller in magnitude, in comparison with non-SOEs or foreign-funded firms.[16][17]

3.3 Estimation of long-run elasticity

This subsection estimates the long-run effect of price on energy intensity. The long-run price elasticities tend to become more equal among SOEs, non-SOEs and foreign-funded firms. In particular, over the long-run, SOEs tend to be more responsive to rising energy prices by investing in new physical capital to improve their energy efficiency, while similar investment responsiveness does not hold for non-SOEs or foreign-funded firms.

The long-term price elasticity is estimated by including lagged energy prices into energy intensity equation. The long-run elasticity is estimated as follows:

$$Ln(\frac{E}{Q})_t = \beta_0 + \beta_1 Ln(\frac{P_E}{P_Q})_t + \beta_2 Ln(\frac{P_E}{P_Q})_{t-1} + \ldots + \beta_8 Ln(\frac{P_E}{P_Q})_{t-7} + controls + \varepsilon \tag{8}$$

where the control variables include year dummies, firm's ownership, industry and province dummies. The lagged energy price terms intend to capture the dynamic effect of price on energy intensity. Equation (8) is estimated by three sub samples: SOEs, non-SOEs and foreign-funded firms separately, and the results are reported in Table 10 . The left panel of Table 10 corresponds to the estimation results for SOEs, the middle panel corresponds to non-SOEs, and the right panel is for foreign-funded firms. Longer lagged price terms were added, however they are not reported due to their coefficients are insignificant.

The coefficients in Table 10 are all significantly negative. The contemporaneous impact of energy price on energy intensity is larger than that of lagged energy prices, for all SOEs, non-SOEs and foreign-funded firms.

Table 11 reports the cumulative impact of energy prices for SOEs, non-SOEs and foreign-funded firms respectively. The cumulative effect for SOEs is calculated based on the result in column (4) of Table 10, and non-SOEs are based on column (8) of Table 10, and foreign-funded firms are from column (11) of Table 10. 10% increase in energy price over 5 years will lead to 9.37% decrease in energy intensity for SOEs, 10.43% for non-SOEs, and 1% increase in energy price over 4 consecutive years will decrease energy intensity by 7.74% for foreign-funded firms. Those cumulative effect for SOEs, domestic non-SOEs and foreign-funded firms are also graphed in Figure 4.

As robustness check, I re-estimate equation (8) using the firm-level energy prices and the average energy prices at the 4-digit industrial and provincial level. These two sets of regression results share the similar pattern as that shown in Table 10.[18]

Next, I investigate through what channel firms can decrease its energy intensity in the long-run. One hypothesis is that when facing high energy price, firms have incentive to invest in energy-efficient capital, which in turn reduces energy intensity. To test this hypothesis, I apply the following two-step estimations:

$$Ln(\frac{E}{Q})_t = \alpha_0 + \alpha_1 Ln(\frac{P_E}{P_Q})_t + \alpha_2 Ln(\frac{NVFA}{OVFA})_t + \alpha_3 * Lag\, Ln(\frac{P_E}{P_Q})_t + controls + \xi \tag{9}$$

$$Ln(\frac{NVFA}{OVFA})_t = \gamma_0 + \gamma_1 * Lag\, Ln(\frac{P_E}{P_Q})_t + controls + \zeta \tag{10}$$

[16]The regression results can be found at https://sites.google.com/site/sarahletang0610/research-1

[17]Due to a large increase in energy price in 2004, I also re-do the regression in equation (7) excluding all observations in 2004, SOEs are still less responsive to energy price in comparison to their domestic non-SOEs and foreign-funded firms. The results are available from the author.

[18]The regression results can be found at https://sites.google.com/site/sarahletang0610/research-1

where $Lag\,Ln(\frac{P_E}{P_Q})_t = \frac{1}{S}\sum_{j=1}^{S} Ln(\frac{P_E}{P_Q})_{t-j}$, which is the moving average of lagged energy prices.

In the first step, besides the current and lagged moving-averaged energy prices, the ratio of net value of fixed assets (NVFA) to original value of fixed assets (OVFA) also enters into the energy intensity equation as shown in equation (9). In the second step, the ratio of NVFA to OVFA responds to the moving average of lag energy prices, as shown in equation (10). The ratio of NVFA to OVFA serves as a proxy that characterize vintage structure of physical capital. The older a firm's capital structure, the lower NVFA relative to OVFA, and vice versa. Under the assumption that new investment takes one year to be productive, current energy price does not enter into equation (10). Here I use moving average of lagged energy prices, instead of individual lagged energy prices, in order to keep parsimony of the estimation equations , and smooth out short-term fluctuation.

Table 12 reports the estimation results of equation (9), which shows how vintage structure affecting energy intensity. In Table 12, equation (9) was estimated by 3 sub samples individually: SOEs, non-SOEs and foreign-funded firms. Current and lagged energy prices are consistently significantly negative in all regressions. Only SOEs and non-SOEs use new investment as an instrument to reduce its energy intensity, while foreign-funded firms do not reduce energy intensity through new investment. The negative coefficient in front of NVFA to OVFA means that firms with higher ratio of NVFA to OVFA tend to be more energy efficient. This suggests the SOEs and/or non-SOEs reduce their energy intensity by investing new capital that is relatively more energy efficient.

Table 13 reports the estimation results of equation (10), which shows how vintage structure responding to lag energy prices. The ratio NVFA to OVFA of SOEs responds to the lagged energy prices, high energy prices in the past encourage SOEs to make more new investment, which leads to higher ratio of NVFA to OVFA. For non-SOEs , their new investment responds to lagged energy prices to some degree, while the ratio of NVFA to OVFA for foreign-funded firms does not respond to lagged energy prices. That the responsiveness of SOEs' vintage structure to energy price might due to the fact that SOEs get subsidies from the government when energy prices are relatively higher, and SOEs are less financially constrained, compared to non-SOEs or foreign-funded firms. The less responsiveness of new investment to past energy prices for non-SOEs might be due to the fact that non-SOEs are more financially constrained, compared to SOEs. Higher energy price means less profit, which tightens their cash-flow constraint.

The two step regressions show that in the long-run, rising energy price will induce firms to invest in energy efficient capital, especially for SOEs. This indicates that lowering firms' investment cost and financing cost could be a useful policy instrument. This policy instrument has been applied to the *Top-1000 Enterprise Program* started in 2005. Before the initiation of the *Top-1000 Enterprise Program*, a pilot project that implementing voluntary agreement for energy efficiency was implemented in Shandong Jinan Iron and Steel Company and Shandong Laiwu Iron and Steel company in 2003. The two companies were two leading iron and steel producers in China. In the voluntary agreement, the two companies promised to reach a total energy saving target of 300,000 ton sce in 3 years. In order to reach their voluntary agreement targets, both companies released more investment on energy efficiency technical renovation, and in exchange the two companies have access to low-interest loans (Hu, 2007; Price et al., 2002). The policy instrument that providing or helping firms getting access to low-interest loan, which will be used in energy-efficiency investment, has been adopted in the *Top-1000 Enterprise Program* in 2005. The findings in the paper suggest that providing low-interest loan or lowering firm's financial cost, especially in making energy-efficient investment, tend to be an effective policy instrument for firms to achieving energy efficiency.

4 Extension

The estimations of energy price elasticities in Section 3 raise two interesting questions: (1) why energy intensity is not as elastic to energy price as anticipated by the Cobb-Douglas production? (2) What are the effects of increasing energy prices on aggregate variables such as energy use and output? If there is a 10% increase in energy price, how will energy usage and output change as a result of price increase? Those cannot be answered by previous regression analysis.

To answer the above two questions, [19] I propose a two-sector model with 3 inputs: capital, labor and energy. In the first sector, the *ex ante* production technology is of the Cobb-Douglas form, but for installed capital goods, production possibilities take the Leontief form: there is no substitutability of capital, labor and energy *ex post*. [20] In the second sector, the production technology takes the Cobb-Douglas form both *ex ante* and *ex post*. I refer to the first sector as the putty-clay investment model, and the second sector as a putty-putty investment model.

With the calibrated parameters in preference, production and energy price process , the two models are solved and simulated. In the putty-clay model, the price elasticity is relatively low, around 0.076, while in the putty-putty model, the price elasticity is nearly unity. In order to reproduce the price elasticities 0.365, which are directly estimated from the firm-level data, a combination of putty-clay and putty-putty investment is needed.

Through indirect inference, we estimate that an economy in which 69.8%[21] of output is produced by the putty-clay investment while the 30.2% balance is produced by putty-putty investment can reproduce the low price elasticity of 0.345, which is close to 0.365, as observed from the actual data. The comparison between the two-sector model and the data is represented in Table 14. The two-sector model successfully reproduces the contemporaneous impact of energy price on its intensity, and the impacts of lagged energy prices are in the right direction. Based on the estimated share of 69.8%, the 2-sector model predicts a 1.1% drop in output and 4.2% drop in energy usage when there is a 10% increase in energy price. Figure 5 and Table 15 show the percentage deviations of output, energy usage and energy intensity in response to a 10% increase in energy price. [22]

5 Conclusions

The paper investigates the role of energy prices in reducing energy intensity in Chinese industry. For the short run, the paper estimates contemporaneous energy price elasticities; for the long run, the paper examines in the impact of energy prices on energy-saving investment. A DSGE model, which intends to reproduce the energy price elasticities observed from the firm-level data, is used to quantitatively evaluate the impact of energy price on aggregate variables.

Analyzing a unique panel data set which reports firm-level energy consumption and price, the paper shows: (i) real energy prices, which are regulated by government, are typically lowest for SOEs, followed by domestic non-SOEs, and highest for foreign-funded firms. (ii) In descending order of energy intensity, the six most energy-intensive industries are: electricity and power generation, petroleum processing and coking, coal mining, chemical products, nonmetal products, and nonferrous metal products. Also these six industries face relatively lower energy prices than the rest of mining

[19] For detailed description of this section, please see my paper "Energy Usage and Vintage Capital: A Putty-clay Approach" at `https://sites.google.com/site/sarahletang0610/research-1`.
[20] This putty-clay investment model is described in Wei (2003).
[21] Standard error of this parameter is 0.33%.
[22] The estimated share and impulse responses are obtained based on the two-sector model, which is calibrated using SOEs data in the sample. The estimation and prediction results for domestic non-SOEs and foreign-funded firms are very similar, and they can be found at `https://sites.google.com/site/sarahletang0610/research-1`.

and manufacturing industries. (iii) In the short-run, SOEs tend to be somewhat less responsiveness than their domestic non-SOE counterparts and foreign-funded firms. However, over the long-run, SOEs tend to be more responsive to rising energy prices by investing in new energy-efficient physical capital, which in turn improves their energy efficiency, while the price-investment channels does not appear to operate for non-SOEs or foreign-funded firms.

Moreover, in a DSGE model with a combination of putty-clay and putty-putty investment, an economy with 69.8% of output produced putty-clay investment is able to reproduce the energy price elasticity estimated directly from the firm-level data. This output share is estimated through indirect inference. This two-sector model predicts that a 1.1% drop in output and a 4.2% drop in energy usage in response to a 10% increase in energy price.

The findings show that energy price plays an important role in achieving energy efficiency. Since the government exercises certain control over energy prices, a feasible policy instrument for reducing energy intensity would be to increase energy prices, especially for those energy-intensive industries. In the long-run, rising energy prices will induce firms to invest in energy-efficient capital, especially for SOEs. Thus, lowering firms' investment costs and financing costs could be a useful policy instrument. This policy instrument has been applied to the *Top-1000 Enterprise Program* started in 2005. In this program, the most energy-intensive firms have voluntarily reduced their energy intensity, in exchange for low-interest loan for energy-efficient investment. To the extent that SOEs are favored with such investment incentives, the findings in the paper suggest this tends to be an effective policy instrument for firms in achieving energy efficiency. The absence of similar incentive for non-state and foreign enterprises may explain their relative unresponsiveness to investing in response to higher energy prices.

In this paper, I focus on the impact of price of overall energy, which is a combination of 21 energy types. A natural extension of this research is to break the overall energy into more detailed energy types, such as coal, oil, and electricity, and to investigate the effect of changes in relative coal, oil and electricity prices on energy consumption and intensity. Another extension is to collect and analyze available data regarding China's energy consumption and price after 2004, to see whether the movement of energy prices and energy intensities in Chinese industry appear to be largely consistent with the results of this paper, which focuses on the years 1997-2004.

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6 Tables

Table 1: Summary Statistics of Energy Intensity by Ownership 1997-2004

1997-2004	SOE	NonSOE	Foreign
mean	1.200	0.821	0.664
median	0.455	0.280	0.106
N	17951	13364	4022

Note: the unit is ton sce/ 1000 RMB output at constant price. N stands for the number of firms.

Table 2: Summary Statistics of Energy Intensity by Industry Sector 1997-2004

1997-2004	Elect	Petro	Coal Mining	Iron	Cement	Chemical	Other Mining	Other Manu
mean	4.435	3.243	2.420	0.827	0.795	0.790	0.629	0.245
median	4.704	2.869	1.284	0.619	0.770	0.625	0.407	0.115
N	3356	807	1178	1656	5862	5474	795	16209

Note: the unit is ton sce/ 1000 RMB output at constant price. N stands for the number of firms.

Table 3: Summary Statistics of Energy Intensity by Region 1997-2004

1997-2004	North	Northeast	East	South	West
mean	1.333	1.426	0.746	0.942	1.073
median	0.477	0.461	0.189	0.375	0.443
N	5184	3372	12664	8648	5469

Note: the unit is ton sce/ 1000 RMB output at constant price. N stands for the number of firms.

Table 4: Comparison of Energy Intensity and Price among Ownership Type at 4-digit Industry Level

Panel A: Dependent variable: energy intensity				
	thermal power	nitrogen fertilizer	cement	steel pressing
NonSOE	-0.588***	-0.107***	-0.095***	-0.210***
	(0.089)	(0.034)	(0.018)	(0.059)
Foreign	-0.853***	-0.237	-0.096***	-0.347***
	(0.114)	(0.256)	(0.036)	(0.109)
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
N	2462	2002	2684	463
R^2	0.181	0.217	0.206	0.382

Panel B: Dependent variable: energy price				
	thermal power	nitrogen fertilizer	cement	steel pressing
NonSOE	0.000	0.024*	0.016*	-0.012
	(0.004)	(0.014)	(0.009)	(0.046)
Foreign	0.006	0.034	0.036*	0.037
	(0.005)	(0.106)	(0.019)	(0.085)
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
N	2462	2002	2684	463
R^2	0.271	0.462	0.358	0.535

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: the upper Panel A reports the results of regressing energy intensity on ownership, year and province dummies for the four 4-digit level industries individually. The lower Panel B reports the results of regressing energy price on ownership, year and province dummies for the four 4-digit level industries individually. NonSOE is the dummy variable for domestic non-SOEs, Foreign is the dummy variable for foreign-funded firms. The reference firms in all regressions are the SOEs from Shanghai in year 1997.

Table 5: Summary Statistics of Energy Prices by Ownership

Year	Statistics	SOE	NonSOE	Foreign
1997	mean	0.673	0.742	0.901
	median	0.474	0.500	0.612
1998	mean	0.694	0.788	0.997
	median	0.490	0.541	0.696
1999	mean	0.176	0.171	0.403
	median	0.071	0.072	0.129
2000	mean	0.195	0.190	0.360
	median	0.071	0.077	0.142
2001	mean	0.212	0.211	0.384
	median	0.073	0.078	0.141
2002	mean	0.150	0.178	0.233
	median	0.070	0.081	0.132
2003	mean	0.103	0.127	0.230
	median	0.063	0.076	0.135
2004	mean	0.882	1.099	1.681
	median	0.640	0.784	1.405

Note: the unit is 1000 RMB/ton sce.

Table 6: Summary Statistics of Energy Prices by Industry Sector

Year	Statistics	Elect	Petro	Coal Mining	Iron	Cement	Chemical	Other Mining	Other Manu
1997	mean	0.197	0.265	0.749	0.556	0.602	0.658	0.723	0.858
	median	0.098	0.246	0.537	0.381	0.430	0.526	0.572	0.601
1998	mean	0.180	0.274	0.774	0.599	0.603	0.702	0.800	0.927
	median	0.082	0.261	0.592	0.420	0.411	0.566	0.504	0.678
1999	mean	0.049	0.059	0.209	0.198	0.128	0.164	0.145	0.265
	median	0.010	0.029	0.080	0.068	0.052	0.069	0.091	0.110
2000	mean	0.031	0.068	0.128	0.182	0.130	0.178	0.185	0.304
	median	0.011	0.033	0.093	0.070	0.054	0.072	0.113	0.123
2001	mean	0.038	0.080	0.161	0.225	0.153	0.190	0.173	0.330
	median	0.012	0.032	0.093	0.075	0.055	0.079	0.087	0.126
2002	mean	0.033	0.069	0.115	0.122	0.103	0.182	0.300	0.234
	median	0.011	0.032	0.058	0.069	0.057	0.082	0.110	0.128
2003	mean	0.029	0.051	0.081	0.093	0.090	0.112	0.143	0.197
	median	0.011	0.030	0.057	0.065	0.060	0.077	0.095	0.122
2004	mean	0.202	0.326	0.729	0.824	0.914	1.052	1.105	1.551
	median	0.123	0.277	0.598	0.656	0.658	0.858	0.989	1.223

Note: the unit is 1000 RMB/ton sce.

Table 7: Summary Statistics of Energy Prices by Region

Year	Statistics	North	Northeast	East	South	West
1997	mean	0.559	0.592	0.806	0.794	0.559
	median	0.435	0.422	0.581	0.521	0.382
1998	mean	0.560	0.491	0.910	0.832	0.601
	median	0.443	0.383	0.654	0.542	0.401
1999	mean	0.110	0.097	0.308	0.142	0.164
	median	0.057	0.052	0.101	0.072	0.065
2000	mean	0.078	0.424	0.264	0.142	0.175
	median	0.054	0.117	0.094	0.068	0.079
2001	mean	0.089	0.456	0.336	0.143	0.139
	median	0.056	0.148	0.104	0.071	0.060
2002	mean	0.091	0.089	0.192	0.156	0.263
	median	0.055	0.055	0.101	0.071	0.098
2003	mean	0.084	0.089	0.156	0.162	0.114
	median	0.050	0.056	0.102	0.078	0.060
2004	mean	0.758	0.737	1.421	1.283	0.752
	median	0.536	0.512	1.104	0.849	0.530

Note: the unit is 1000 RMB/ton sce.

Table 8: Short-run Price Elasticity by Industrial Sector Using 3-digit Industrial and Provincial Average Energy Price (OLS)

	(1) Full sample	(2) Elect	(3) Thermal	(4) Petro	(5) Coal Mining	(6) Iron	(7) Cement	(8) Chemical	(9) Other Mining	(10) Other Manu
Pe	-0.452***	-0.298***	-0.233***	-0.197***	-0.248***	-0.186***	-0.221***	-0.243***	-0.224***	-0.285***
	(0.009)	(0.021)	(0.020)	(0.050)	(0.056)	(0.044)	(0.020)	(0.025)	(0.038)	(0.015)
Pe*NonSOE	-0.032**	-0.019	-0.042	-0.352***	-0.562***	-0.134*	0.003	-0.072*	-0.018	-0.045*
	(0.015)	(0.045)	(0.036)	(0.078)	(0.201)	(0.072)	(0.029)	(0.040)	(0.081)	(0.023)
Pe*Foreign	-0.070***	-0.130*	-0.218***	0.090		-0.156	-0.002	-0.114		-0.190***
	(0.023)	(0.067)	(0.048)	(0.233)		(0.165)	(0.051)	(0.081)		(0.031)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Owner	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	35337	3356	2462	807	1178	1656	5862	5474	795	15432
R^2	0.703	0.620	0.305	0.557	0.270	0.601	0.616	0.656	0.607	0.505

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: the dependent variable is log of energy intensity; Pe is log of energy price, which is calculated as the average energy price at the 3-digit industrial and provincial level. NonSOE is the dummy variable for domestic non-SOEs, and Foreign is the dummy variable for foreign-funded firms. All coefficients are estimated through OLS. In the column "Full sample", the industry dummies are of 2-digit industry level, and in the rest columns the industry dummies are of 4-digit level industry, except no industry dummies in the column "Thermal", because Thermal power industry is already a 4-digit industry. Pe*Foreign is not available in "Coal Mining" and "Other Mining", due to the fact there are no foreign-funded firms in all mining industries in the sample.

Table 9: Short-run Price Elasticity by Industrial Sector Using 3-digit Industrial and Provincial Average Energy Price (Fixed Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Full sample	Elect	Thermal	Petro	Coal Mining	Iron	Cement	Chemical	Other Mining	Other Manu
Pe	-0.072***	-0.123***	-0.119***	-0.121***	-0.072***	-0.044*	-0.050***	-0.063***	-0.054**	-0.053***
	(0.006)	(0.019)	(0.016)	(0.040)	(0.028)	(0.024)	(0.011)	(0.011)	(0.026)	(0.010)
Pe*NonSOE	-0.047***	-0.087**	-0.044	-0.148**	-0.083	-0.071*	-0.009	-0.014*	0.016	-0.067***
	(0.010)	(0.037)	(0.028)	(0.064)	(0.108)	(0.040)	(0.008)	(0.009)	(0.055)	(0.015)
Pe*Foreign	-0.073***	-0.229***	-0.247***	-0.032		-0.038	-0.065***	-0.010		-0.076***
	(0.015)	(0.056)	(0.038)	(0.168)		(0.094)	(0.014)	(0.022)		(0.020)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm's fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	35337	3356	2462	807	1178	1656	5862	5474	795	15432
R^2	0.069	0.088	0.183	0.250	0.061	0.198	0.027	0.054	0.435	0.077

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: the dependent variable is log of energy intensity; Pe is log of energy price, which is calculated as the average energy price at the 3-digit industrial and provincial level. NonSOE is the dummy variable for domestic non-SOEs, and Foreign is the dummy variable for foreign-funded firms. All coefficients are estimated through fixed effects method. Pe*Foreign is not available in "Coal Mining" and "Other Mining", due to the fact there are no foreign-funded firms in all mining industries in the sample.

Table 10: Long-run Price Elasticity by Ownership Using 3-digit Industrial and Provincial Average Energy Price (OLS)

	SOE				NonSOE				Foreign		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Pe_t	-0.350***	-0.373***	-0.363***	-0.365***	-0.390***	-0.427***	-0.462***	-0.465***	-0.443***	-0.362***	-0.370***
	(0.013)	(0.016)	(0.021)	(0.030)	(0.018)	(0.024)	(0.033)	(0.044)	(0.033)	(0.041)	(0.052)
Pe_{t-1}	-0.253***	-0.158***	-0.153***	-0.108***	-0.261***	-0.138***	-0.129***	-0.090**	-0.198***	-0.106**	-0.058
	(0.013)	(0.017)	(0.023)	(0.032)	(0.017)	(0.024)	(0.034)	(0.045)	(0.031)	(0.044)	(0.054)
Pe_{t-2}		-0.216***	-0.156***	-0.191***		-0.242***	-0.180***	-0.190***		-0.190***	-0.127**
		(0.016)	(0.022)	(0.029)		(0.021)	(0.031)	(0.038)		(0.038)	(0.052)
Pe_{t-3}			-0.181***	-0.128***			-0.250***	-0.154***			-0.220***
			(0.020)	(0.027)			(0.026)	(0.036)			(0.045)
Pe_{t-4}				-0.146***				-0.144***			
				(0.027)				(0.034)			
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	11437	7327	4598	2831	8342	4891	3042	1803	2540	1530	954
R^2	0.706	0.729	0.748	0.758	0.688	0.708	0.731	0.751	0.767	0.793	0.827

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: the dependent variable is log of energy intensity, Pe_t is log of energy price in year t, Pe_{t-1} is log of energy price in year t-1, and so forth. Longer lag price terms were added, but due to insignificancy they are not reported in this table. The energy prices are calculated as the average energy price at the 3-digit industrial and provincial level.

Table 11: Cumulative Price Effect on Energy Intensity by Ownership

	SOE	NonSOE	Foreign
	(1)	(2)	(3)
1-year	-0.365***	-0.465***	-0.370***
	(0.030)	(0.044)	(0.052)
2-year	-0.473***	-0.555***	-0.428***
	(0.030)	(0.043)	(0.054)
3-year	-0.663***	-0.745***	-0.555***
	(0.032)	(0.044)	(0.055)
4-year	-0.791***	-0.899***	-0.774***
	(0.035)	(0.050)	(0.057)
5-year	-0.937***	-1.043***	
	(0.031)	(0.049)	

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: the cumulative price effect for SOEs are calculated based on the estimates in column (4) of Table 10, the effects for non-SOEs are based on column (8) of Table 10, and the effects for foreign-funded firms are based on column (11) of Table 10. The row "1-year" reports the contemporaneous effect of 1% increase in price on energy intensity. The row "2-year" reports the cumulative impact on energy intensity if energy price increases by 1% in two consecutive years, and so forth.

Table 12: Energy Intensity Responding to Capital Vintage Structure NVFA/OVFA by Ownership (OLS)

Panel A:SOE	(1)	(2) 2-year	(3) 3-year	(4) 4-year
Pe_t	-0.450***	-0.363***	-0.358***	-0.349***
	(0.009)	(0.016)	(0.020)	(0.027)
$(NVFA/OVFA)_t$	-0.129***	-0.164***	-0.152***	-0.148***
	(0.020)	(0.031)	(0.038)	(0.047)
Lagged Pe		-0.375***	-0.488***	-0.576***
		(0.017)	(0.024)	(0.034)
Panel B: NonSOE	(1)	(2) 2-year	(3) 3-year	(4) 4-year
Pe_t	-0.482***	-0.409***	-0.429***	-0.440***
	(0.012)	(0.024)	(0.030)	(0.039)
$(NVFA/OVFA)_t$	-0.102***	-0.173***	-0.203***	-0.191***
	(0.023)	(0.036)	(0.051)	(0.065)
Lagged Pe		-0.389***	-0.575***	-0.598***
		(0.026)	(0.035)	(0.049)
Panel C: Foreign	(1)	(2) 2-year	(3) 3-year	(4) 4-year
Pe_t	-0.522***	-0.348***	-0.325***	-0.360***
	(0.022)	(0.040)	(0.048)	(0.065)
$(NVFA/OVFA)_t$	0.062	0.024	0.027	0.069
	(0.044)	(0.059)	(0.066)	(0.093)
Lagged Pe		-0.305***	-0.421***	-0.381***
		(0.044)	(0.057)	(0.080)

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: the dependent variable is log energy intensity, Pe_t is log of current energy price, $(NVFA/OVFA)_t$ represents current vintage structure in capital, and Lagged Pe is the moving average of lagged log energy price. Panel A report the results for SOEs, and Panel B corresponds to non-SOEs, and Panel C corresponds to foreign-funded firms. In the column (1), no lagged moving average energy price is included; in the column (2), Lagged Pe is the moving average of energy prices in the past 2 years, and so forth for the rest of columns. All regressions include year, industry and province dummies. The energy prices are calculated as the average energy price at the 3-digit industrial and provincial level.

Table 13: Capital Vintage Structure NVFA/OVFA Responding to Lagged Energy Price by Ownership (OLS)

Panel A: SOE	(1) 2-year	(2) 3-year	(3) 4-year	(4) 5-year	(5) 6-year	(6) 7-year
Lagged Pe	0.026***	0.037***	0.064***	0.067***	0.091***	0.095**
	(0.006)	(0.008)	(0.012)	(0.016)	(0.025)	(0.042)
Panel B: NonSOE	(1) 2-year	(2) 3-year	(3) 4-year	(4) 5-year	(5) 6-year	(6) 7-year
Lagged Pe	0.018*	0.021*	0.022	0.001	-0.025	-0.061
	(0.009)	(0.012)	(0.016)	(0.022)	(0.032)	(0.057)
Panel C: Foreign	(1) 2-year	(2) 3-year	(3) 4-year	(4) 5-year	(5) 6-year	(6) 7-year
Lagged Pe	-0.010	-0.014	0.014	0.014	-0.006	-0.180
	(0.017)	(0.026)	(0.033)	(0.052)	(0.093)	(0.180)

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: the dependent variable is log of $(NVFA/OVFA)_t$, and Lagged Pe is moving average of lagged log energy price. In the column "2-year", Lagged Pe corresponds to moving average of log energy prices in the past 2 years, and so forth for the rest of columns. The upper Panel A reports the results from SOEs, the middle Panel B reports results from non-SOEs, and the lower Panel C corresponds to the results from foreign-funded firms. All regressions include year, industry and province dummies. The energy prices are calculated as the average energy price at the 3-digit industrial and provincial level.

Table 14: Comparison between Two-sector Model and Data

Coefficients	Two-sector Model	Data
Pe_t	-0.345***	-0.365***
	(0.002)	(0.030)
Pe_{t-1}	-0.043 ***	-0.108***
	(0.001)	(0.032)
Pe_{t-2}	-0.044 ***	-0.191***
	(0.001)	(0.029)
Pe_{t-3}	-0.042 ***	-0.128***
	(0.001)	(0.027)
Pe_{t-4}	-0.001	-0.146***
	(0.001)	(0.027)

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: in the columns labeled "Two-sector Model", the coefficients are estimated from the simulated data generated by the model in which 69.8% output is produced by putty-clay investment. In the columns labeled "Data", the coefficients are regressed on the actual data, they are the coefficients reported in the column (4) of Table 10.

Table 15: Impact of A 10% Increase in Energy Price

Year	Output Q_t	Energy Usage EN_t	Energy Intensity EN_t/Q_t
t	-1.094	-4.213	-3.184
$t+1$	-0.081	-2.729	-1.717
$t+2$	-1.033	-2.130	-1.108
$t+3$	-1.105	-1.947	-0.852
$t+4$	-0.802	-1.142	-0.344
$t+5$	-0.674	-0.808	-0.135

Note: this table reports the percentage deviation of output, energy usage and energy intensity in response to a one-time 10 % increase in energy price. The deviations are calculated from the two-sector model in which 69.8% output is produced by putty-clay investment. All values are in percentage(%).

7 Figures

Figure 1: Distribution of Log Energy Price by Ownership and Year

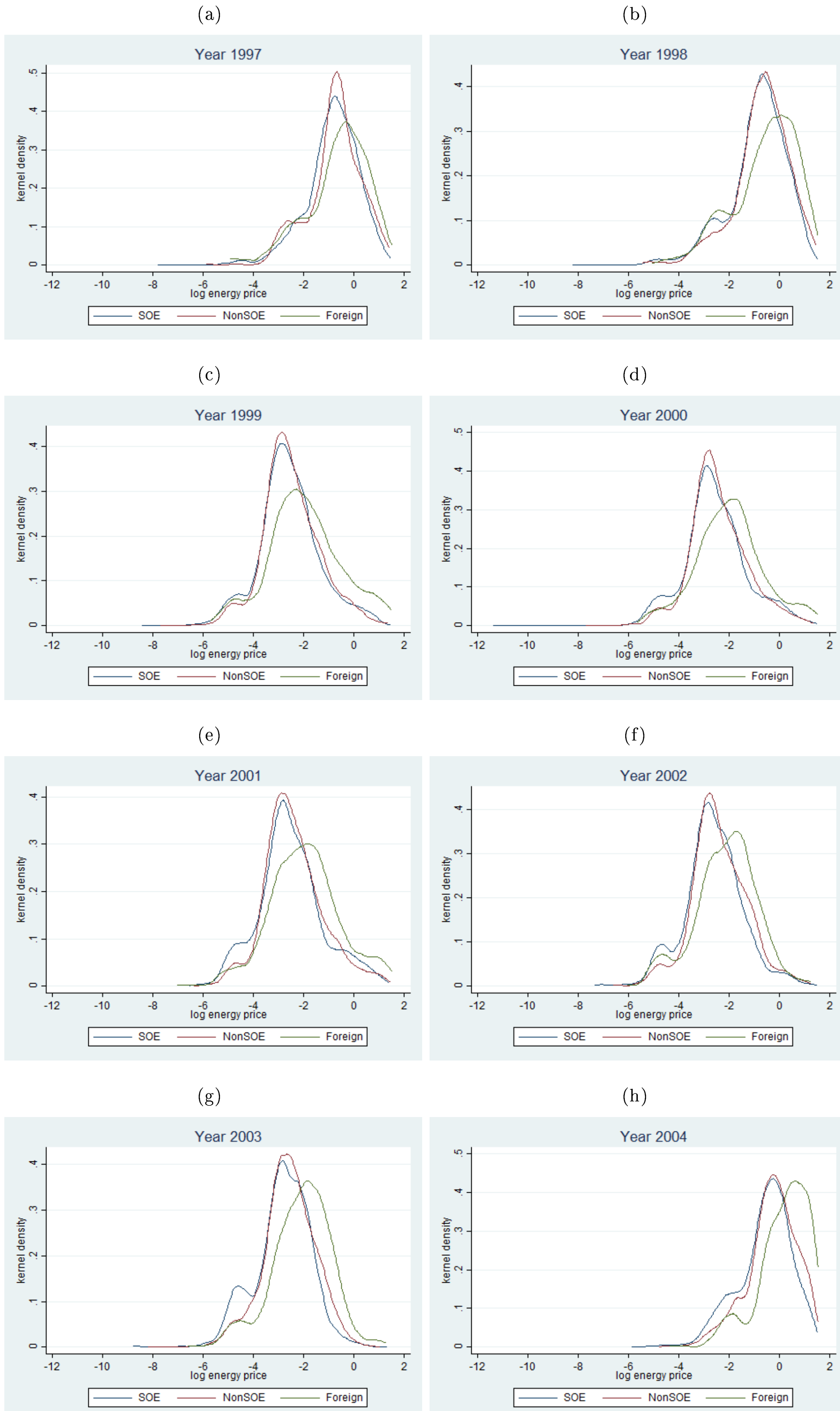


Figure 2: Distribution of Log Energy Price by Industry Sector and Year

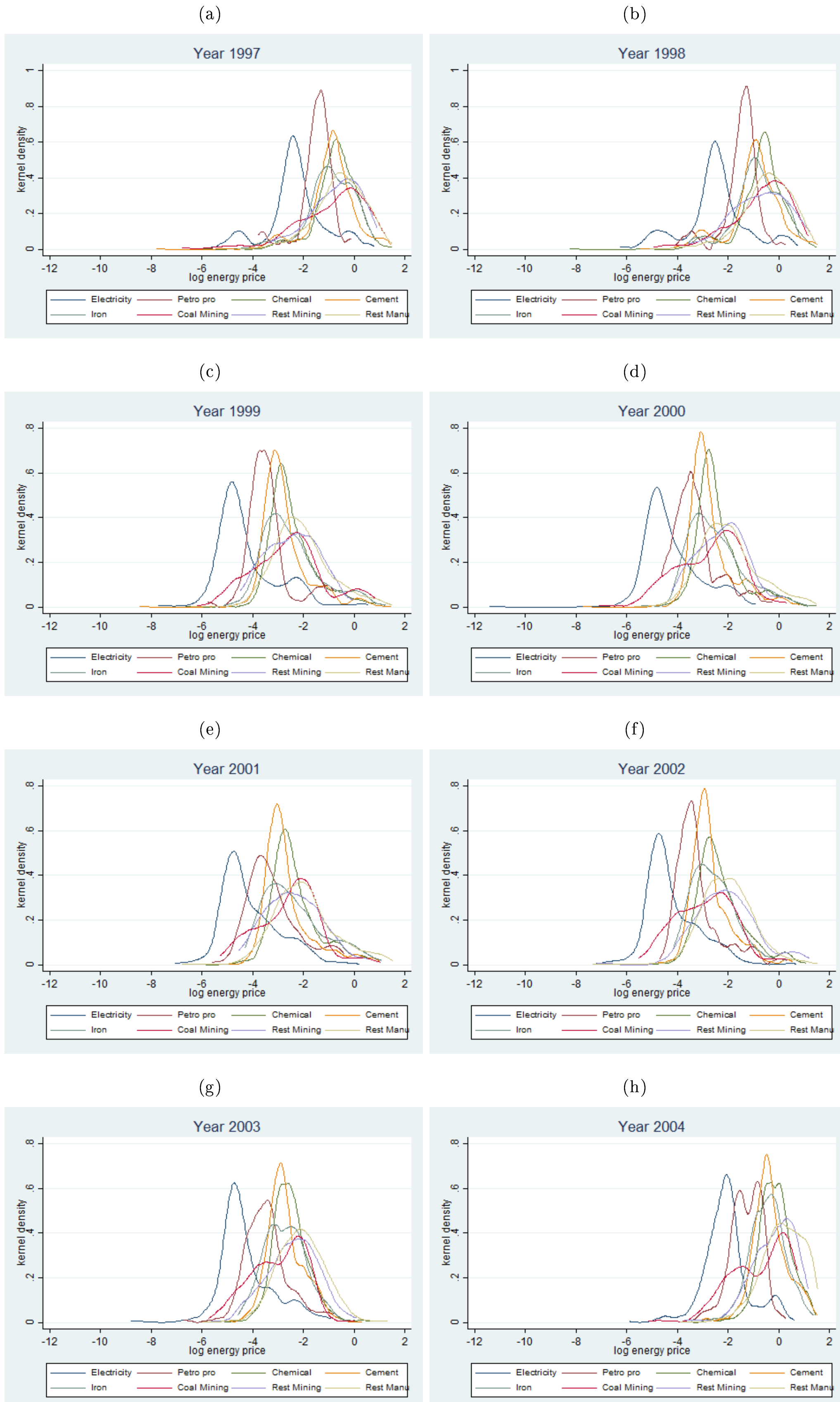
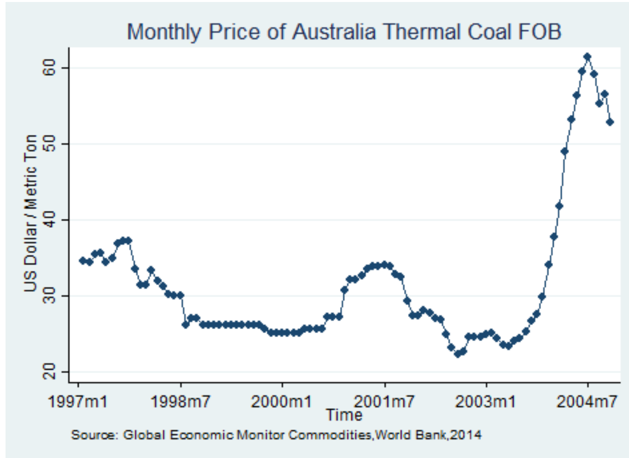


Figure 3: International Coal and Oil Price

(a)



(b)

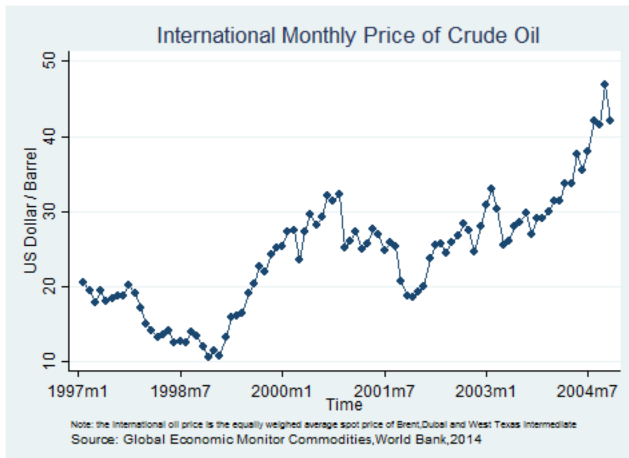
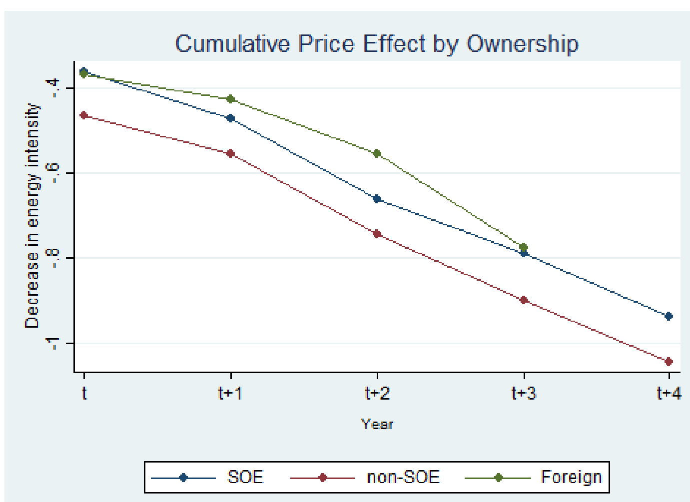
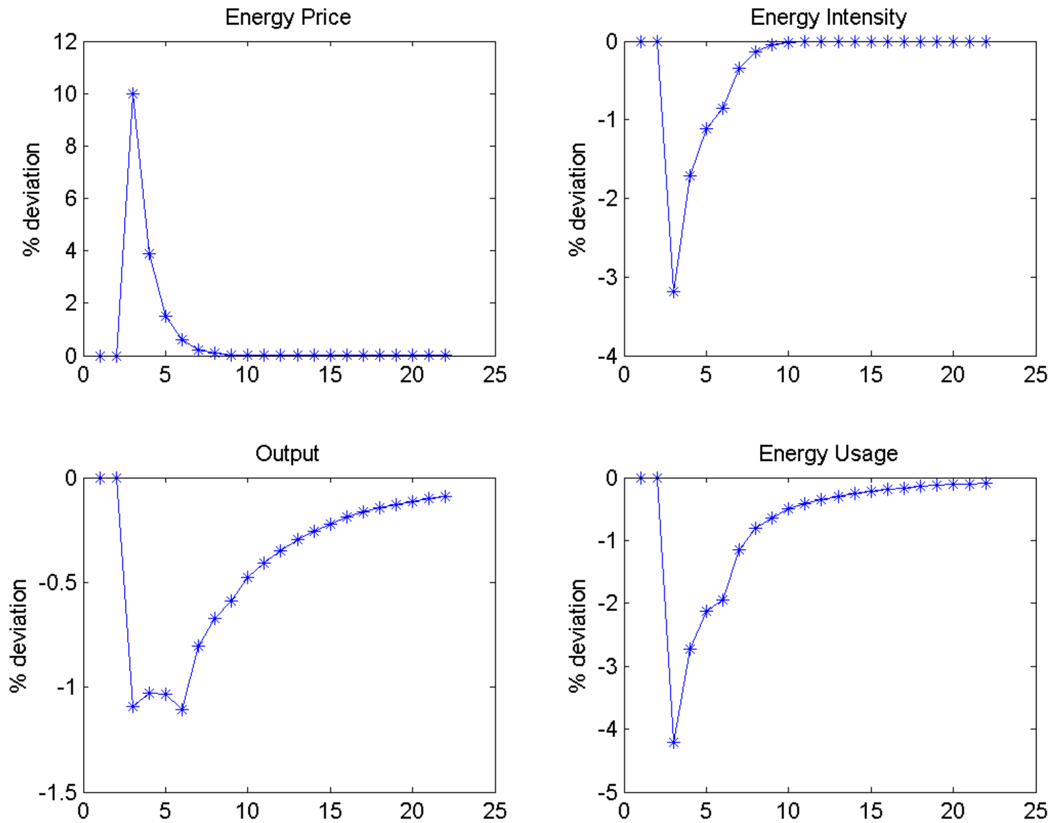


Figure 4: Cumulative Price Effect on Energy Intensity by Ownership



Note: the vertical axis represents the amount of cumulative reduction in energy intensity if energy price increases by 1% in current year t , next year $t+1$, $t+2$ and so forth. The cumulative price effect for SOEs are calculated based on the estimates in column (4) of Table 10, non-SOEs are based on column (8) of Table 10, and foreign-funded firms are based on column (11) of Table 10.

Figure 5: Impulse Response Following the Energy Price Shock (%) in Two-sector Model



The x-axis is the number of years after the energy price shock.