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EFFECTS OF DEREGULATION AND VERTICAL UNBUNDLING ON THE PERFORMANCE OF CHINA'S ELECTRICITY GENERATION SECTOR*

Hang Gao†
Johannes Van Biesebroeck‡

The restructuring of the Chinese electricity sector in 2002 reshaped the market structure by vertically unbundling the dominant integrated firm and started the process of wholesale price liberalization. We estimate factor demands to study whether these reforms boosted productivity in the generation segment of the industry. Controlling explicitly for price-heterogeneity across firms and unobservable productivity shocks, we find that the reforms are associated with reductions in labor and material use of 7 and 5 per cent, respectively. These effects only appear two years after the reforms and are robust to many specification checks. The absolute magnitudes of the estimated restructuring effects vary in intuitive ways by location, firm size or age, and for different definitions of restructured firms.

I. INTRODUCTION

Launched in 2002, the latest phase in the reform of China's electricity industry was intended to bring genuine competition to the generation segment. It consisted of two parts: reshaping the market structure by vertically unbundling the dominant integrated firm and putting in motion a plan towards wholesale price liberalization (OECD [2010]). We study whether these reforms improved the efficiency of electricity generation.

This is particularly important for China, where the manufacturing sector accounts for an unusually large share of the economy and requires reliable and ever increasing amounts of electric power. Many provinces have suffered occasional brownouts in the last decade when generators whose costs surpassed the regulated electricity price halted production. Total electricity demand continues to grow and new capacity is constantly added. Given that China is the world's largest emitter of greenhouse gasses and almost

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†Authors' affiliations: Department of Economics, University of Leuven, Belgium.
e-mail: hang.gao@kuleuven.be.

‡Department of Economics, University of Leuven, Belgium and CEPR.
e-mail: jo.vanbiesebroeck@kuleuven.be.

half of its total CO_2 emissions come from electricity generation (World Bank [2012]), it is even an issue of global importance.

The reforms are likely to have an impact on operational efficiency through several channels. It intensified competition as more evenly matched firms jostle for market share in anticipation of a fully liberalized market. Firms needing vast amounts of capital to finance capacity additions could no longer afford to waste resources on inefficient operations. In line with the far-reaching restructuring of firms in other parts of the economy, the reforms signaled that exit became a distinct possibility for firms used to a soft budget constraint. It also put in place a clear end game for the sector, including a path towards genuine price competition and all firms' becoming residual claimants on their efficiency gains.[1]

We estimate the efficiency gains by building on the model of Fabrizio, Rose and Wolfram [2007], but incorporating a number of features unique to the Chinese situation. We advance the existing literature, in particular the study of Du, Mao and Shi [2008] that used two cross-sectional surveys, on three counts: (i) our data include a longer post-reform period and allow us to follow firms over time, (ii) we control explicitly for firm-heterogeneity in coal and electricity prices, and (iii) we verify the robustness of the estimates to alternative ways of defining restructured firms. We briefly elaborate on each contribution.

First, our data set includes the universe of all Chinese fossil fuel fired electricity generation companies between 1998 and 2007. As we can follow firms over time, we can include firm-fixed effects to capture the primary dimension of unobserved heterogeneity. Instrumental variables are only needed to control for the remaining endogeneity in the time dimension, potentially caused by output depending on productivity shocks. We introduce outside information—regional manufacturing output and employment—as proxies for local demand, to avoid relying solely on timing assumptions for identification. As we observe the industry for several years following the reforms, we can show that it took at least two years for the effects to materialize fully and we can compare the efficiency levels of state-owned and private new entrants.

Second, the continued existence of regulated prices, not only for electricity but also for coal, the primary input, complicates productivity growth calculations (Wang [2007]). The system of regulated generation tariffs is fairly constant over time and firm dummies will absorb most of the differences in levels. Dual track pricing in the coal market is more troublesome

[1] Full liberalization of the wholesale electricity price, in particular competitive bidding into regional power pools, was included in the reform plans, but put on hold at the end of 2005. Because the preparations between 2002 and 2005 had proceeded as planned and the government has repeatedly indicated that price liberalization is only postponed, not canceled, firms still have incentives to restructure in preparation for further liberalization.

as the importance of subsidized coal for firms that benefit from it has declined over time. The problem of missing price data is addressed by relying on institutional details of the electricity and coal markets that suggest firm age, size, location, and legal ownership structure are good predictors for the evolution of firm-level price differentials.[2]

Third, identifying the firms most directly affected by the reforms is not without ambiguity. Many firms in China have hybrid forms of ownership and even firms that are majority owned by the state sometimes enjoy large autonomy. Du *et al*. [2008] focused on plants previously owned by the State Power Company (SPC), the formerly dominant integrated firm. It is likely, though, that some of its subsidiaries that had already transformed to listed shareholder companies or that already had a diversified ownership structure were only indirectly affected by the 2002 reforms. At the same time, state-owned companies that were not SPC subsidiaries faced similar changes in their budget constraint, financing needs, and possibility of bankruptcy. With the reforms their preferential access to subsidized coal and their influence over regulated electricity prices declined as well. Following Zhang *et al*. [2001], we use the official ownership category in 2002 to identify 'restructured' firms in the benchmark specification and we perform sensitivity checks using alternative definitions.[3]

The estimates suggest a positive impact of the reforms on production efficiency. After 2002, factor demands decline more rapidly for formerly state-owned firms than for private and foreign-owned firms, but it takes at least two years for a significant gap to open up. Our preferred estimates suggest that restructured fossil fuel fired electricity generation firms eventually reduce their labor input by 7 per cent and material input (fuel and non-fuel combined) by 5 per cent relative to firms that are only indirectly affected by the reforms. Employment reductions are broadly based, but stronger for firms that are expected to be less efficient initially: firms that are smaller, older, and located in the West or Central region. Improvements in material efficiency show the opposite pattern for each firm characteristic which suggests that improving the two input productivities requires different actions. In the post-reform period, we find that the labor productivity disadvantage for new, state owned entrants is three times lower than in 2002, a statistically significant reduction, and no difference is found anymore for material input use.

[2] The electricity tariff structure is somewhat inscrutable, but prices are fixed at a regional level and stable over time (Wang [2007]). The price of 'electricity coal' is still managed and kept 30–40 RMB per tonne below the market price, which applies for coal used in activities other than electricity generation and has largely been deregulated. The underpricing creates scarcity and large state-owned generators have preferential access to the subsidized coal from state-owned mines (Mathys [2011]).

[3] Furthermore, we verified the results using a matching technique from the treatment evaluation literature to control for the possibility of non-random treatment of firms.

Deregulation of the electricity sector is an ongoing process that affects many dimensions of industry competition and firm operations. Joskow [2008] provides an overview of experiences in several OECD countries. Newbery and Pollitt [1997] conduct a cost-benefit analysis of the reforms in the United Kingdom taking into account generator efficiency gains, but also effects on emissions, pricing, and investment incentives. The impact of deregulation on prices has been contentious, with Hattori and Tsutsui [2004] finding a tempering effect comparing across countries, while Borenstein, Bushnell and Wolak [2002] and Joskow and Kahn [2002] identify the abuse of market power as the main culprit in the failure of the California regulatory regime in the summer of 2000. Knittel [2002] reports evidence of rising efficiency at generation plants associated with the diffusion of incentive regulation.

The main purpose of the 2002 reforms in China was to improve production efficiency of electricity generation. Several studies have attempted to quantify *ex-post* operating efficiency gains from similar restructuring episodes in other countries. Newbery and Pollitt [1997] find that the move from a state-owned monopoly to a privatized, competitive generation market in the United Kingdom was accompanied by a significant reduction in employment. This represents both restructuring and privatization effects. Two studies exploit the differential timing of reforms across countries to identify efficiency gains following deregulation. For OECD countries, Steiner [2000] finds that while changes in legal rules only translate slowly into changes in conduct, unbundling of generation and introducing private ownership has a positive and significant impact on most performance measures. For 51 developing countries, Zhang, Parker and Kirkpatrick [2008] find favorable effects on service penetration, capacity expansion, labor efficiency, and prices for industrial users.

Hiebert [2002] provides the first plant-level econometric evidence. He analyzed the effect of U.S. restructuring over the 1988–1997 period using a stochastic frontier production function. He finds a substantial improvement in generation plant efficiency for coal plants in states that restructured in or before 1996, but no effect for gas fired plants in the same states nor for policies enacted in 1997. More recently, Fabrizio *et al.* [2007] control explicitly for the endogeneity of input choices and estimate productivity using the Olley-Pakes control function approach.[4] Their difference-in-differences method of measuring the effect of regulatory restructuring on U.S. electricity generation efficiency suggests that labor and non-fuel efficiency of investor-owned utilities in the states that passed restructuring legislation increased by 3 to 5 per cent relative to comparable firms in

[4] They stress that shocks to input productivity may induce firms to adjust their output target. Failing to recognize this leads to an upward bias in the estimated efficiency effects by a factor of almost two in some cases.

non-restructuring states, and by 6 to 12 per cent relative to municipal and federal plants insulated from restructuring incentives. They find little improvement in fuel efficiency.[5]

A final important point of comparison is Du *et al*. [2008], who evaluate the combined effect of reforms in 1997 and 2002 on the production efficiency of China's electricity generation industry. They closely follow the estimation approach in Fabrizio *et al*. [2007] and find large efficiency gains of 29 per cent in labor input and 35 per cent in non-fuel materials for the plants divested from the former Ministry of Electricity Power (MEP) or the State Power Company (SPC) relative to other firms, but no evidence of greater efficiency in fuel use. These effects are cumulative over a nine year period between two census years (1995 and 2004) and imply 2.9 and 3.4 per cent annual efficiency gains. As they only observe two cross sections of firms, they cannot control for unobserved firm differences.

The remainder of the paper is organized as follows. In Section II we review the electricity reforms in China. In Section III we present the empirical model and estimation strategy. The data is presented in Section IV and the results with robustness checks and sensitivity analysis in Section V. In Section VI we discuss broader implications and in Section VII the conclusions.

II. ELECTRICITY SECTOR RESTRUCTURING IN THEORY AND IN PRACTICE

Historically, the electricity sector in China was even more tightly controlled than in other countries. The central government determined prices and quantities for all final electricity users as well as for the coal input, and it had the final say in all investment decisions. To cope with rapidly expanding demand and frequent brownouts at the start of Chinese economic reforms, a gradual process of deregulation started in 1985. New objectives were introduced in several steps: attract private investment (1985), separate the administrative authority from the business operations (1997), and vertically unbundle generation and transmission to be followed by competition in the wholesale market (2002).

To relieve lack of capital and power shortages—excess demand in 1985 amounted to 450–500 TWh or nearly 12% of annual generation (Wang [2007])—the government enacted the policy of 'Temporary Provision on Promoting Fund-Raising for Investment in the Electricity Sector and Implementing Different Electricity Tariffs.' It allowed for the first time

[5] Bushnell and Wolfram [2005] focus specifically on the effect of divestitures on fuel efficiency. They find a 2% gain for divested plants, but a similar efficiency gain for plants that remained under utility ownership but now face incentive regulation. They conclude that changes in incentives rather than ownership were the main drivers of fuel efficiency improvement.

investment in electricity generation from local governments, domestic enterprises, and even foreign companies for units above a minimum scale. By the end of the 1990's, more than half of all electricity was generated by plants not controlled by the central government (Du *et al*. [2008]).[6]

As the transmission lines and distribution grid were still owned by the Ministry of Electricity Power (MEP), the new independent power producers (IPP's) provided electricity at wholesale tariffs set by the government. State-owned plants continued to sell at lower 'plan' prices. The independent generation tariffs were determined according to rate-of-return regulation principles also used in Western countries.[7] They were reset every year based on accounting cost information, but varied also by type of company and with the origin of the capital. Tariffs differed greatly across plants, even within the same firm and sometimes even across generation units within a single plant. Large price differentials persisted over time.

Following these initial reforms, electricity tariffs set by the government increased rapidly. The next stage of deregulation occurred in 1997 when the MEP was split into two bodies. A new public utility, the State Power Company (SPC), took over the majority of state-owned electricity assets, including generation plants, transmission, and distribution grids. The State Economic and Trade Committee became the new regulator and took over administrative and decision-making functions. One of its immediate actions was to slow down the increase in electricity prices.

In 2002, the next and thus far the latest phase of reforms had as its primary objective the introduction of real competition in the generation sector. It transformed the structure of the industry by dismantling the SPC and it established an independent regulator that was to develop competitive wholesale and retail markets with liberalized pricing organized in five power-regions.

The SPC's generation and transmission assets were divested into five generation and two transmission companies.[8] The generation companies were created such that none had more than 20% market share in any of the new power-regions. The divestiture decentralized operations considerably, making possible the celebrated Chinese practice of local experimentation with regulation and reforms. To limit conflicts of interest and improve efficient dispatching of generation units, the transmission companies were forced to divest all their generation assets, except for hydro pump-storage capacity.

[6] In the remainder, we denote firms controlled by the central or provincial government as state-owned, units owned by local levels of government are only included when indicated explicitly.

[7] The objective was to recover investments within a fixed period, generally within 10 years.

[8] The five generation companies are China Huaneng Corporation, China Datang Corporation, China Huadian Corporation, China Guodian Corporation and China Power Investment Corporation, and the two transmission companies are State Grid Company and China Southern Grid Company.

The new independent regulatory agency, the State Electricity Regulatory Commission (SERC), was created to supervise and establish a legal framework for the electricity market (Pittman and Zhang [2010]). It was in charge of technical and environmental standards for the industry and could investigate anti-competitive behavior. Most importantly, it was to become the main source of strategy and proposals to establish a market-oriented pricing mechanism for electricity.

Five competitive regional wholesale electricity markets were scheduled to be established by the end of 2005 or early 2006 (Xu and Chen [2006]). Eventually. generators were expected to bid into these regional power pools and their bids would establish grid-accessing priority.[9] This arrangement would benefit more efficient generators and encourage all firms to improve their productivity.

The 2002 reforms were likely to influence the operational efficiency of generators in several ways. We discuss five possible mechanisms.

First, it unambiguously strengthened competition. Total generation capacity of the former SPC only accounted for 40% of the Chinese total and competition with IPP's was already important in many regions, but in some regions it was very dominant. Many of the relatively independent subsidiaries of the SPC (some had even transformed into listed shareholder companies) took the divestiture as a clear signal that they should go their own way and compete more aggressively. The State-owned Asset Supervision and Administration Commission (SASAC) was created in March, 2003, to better manage China's state-owned enterprises and it immediately formulated clear performance evaluation programs to encourage more profit-oriented behavior by management. Now that competing firms were more evenly matched, a process of more intense and direct competition for market share developed.

Second, simultaneously with the electricity sector reform, the government announced a stop to its policy of guiding coal prices and allowed a market to develop. Coal prices immediately rose and the government was reluctant to allow these cost increases to be reflected in electricity generation tariffs. Given that almost 80% of electricity is generated from coal, this had a severe impact on the financial health of all generators. In 2004 a formula was implemented to pass on 70% of coal price increases to the grid.[10] Incumbent state-owned generators often continued to have access to

[9] The New Electricity Trading Arrangement in the U.K. was a comparable mechanism (Wang [2007]); many other countries established similar regional power pools at the wholesale level.

[10] The actual implementation was rather more complicated and involved many deviations. Subsequently, SERC launched the 'Coal and Electricity Prices Co-Move' policy to arbitrate disputes over coal and electricity pricing, but it seems that both sides and even the end users of electricity are unsatisfied with this regime (Wang [2007]). The evolution of prices for electricity, fuel, and the general consumer price index are illustrated in Figure A.1 in the Appendix.

subsidized coal under the old 'plan' prices, but the absolute volume of those allotments were relatively constant and became gradually less important. Rising input prices provided strong incentives to conserve coal and operate plants more efficiently. State-owned generators that only recently had become residual claimants on their own profits had a lot of scope for efficiency enhancements. Subsequently, explicit policy objectives to lower CO_2 emissions in light of China's increased contribution to global warming provided further incentives to increase efficiency.[11]

Third, developments in the manufacturing sector clearly signalled that inefficient and loss-making firms would no longer be tolerated. The fraction of the manufacturing workforce employed by state-owned enterprises was reduced by approximately three quarters, sometimes through bankruptcy. By the end of the 1990's, SOE's had been forced to scale back non-salary benefits, such as the provision of company housing, schooling, etc. Large generation firms also started to focus more narrowly on their core business, making possible huge labor-savings. Given the generators' limited ability to pass cost increases on to customers, efficient operation became a necessary condition for survival.

Fourth, demand was growing at breakneck speed and all market participants were eager to invest in new generation capacity to defend or improve their market share. This required vast amounts of capital and firms could not afford to waste money on inefficient operations. Without the divestiture, it would have been difficult for the SPC to participate wholeheartedly in the construction of new plants without establishing dominant positions in some regions. Given the more level playing field, all firms now competed aggressively for the investment rights needed to fill the new sources of demand.

Fifth, and perhaps most importantly, the reforms put forward a clear end-game for the industry. The plans to deregulate prices and establish competitive wholesale bidding did move forward at first and trials were organized in two regions in 2004 and 2005. Supply shortages, lack of interregional transmission capacity, and allegations of unfair behavior by the transmission companies in charge of dispatch lead to a decision to postpone price deregulation in 2006. Nevertheless, market participants anticipated that price competition would be implemented eventually. The wholesale price for new plants was already fixed at a constant level by region and fuel type, and regulated prices for older generation units were

[11] The State Environment Protection Agency (SEPA) was enhanced in 2003 to monitor more closely the environmental behavior of power plants and to ensure compliance with the relevant laws and regulations (OECD [2010]). Two planning documents 'China's Future Energy Policy' by the Development Research Center [2004] and 'Medium and Long Term Energy Conservation Plan' by the National Development and Reform Commission [2004] set pollution targets for the power sector and outline steps to close down old and inefficient plants.

expected to converge to these regional averages. Gradually, firms were becoming residual claimants on their efficiency improvements.

The industry structure and regulatory regime have been fairly stable since the 2002 reforms. As a developing country, the first priority for China's central planners was to assure supply and connect all end users to the grid. When this task was completed, more or less by the late 1990's, attention turned to operational efficiency. Plans to liberalize the sector were drawn up during the capacity glut that followed the Asian financial crisis (1999–2000) and implemented in 2002, as discussed. The impetus for reform subsided when the economy recovered quickly from recession and boomed following China's entry into the WTO. New electricity shortages caused by the unexpectedly strong demand and the reluctance of some producers to generate power at a loss when coal prices increased more rapidly than electricity prices, shifted focus back to supply assurance. However, by the time of the 2008–2009 cyclical downturn, the focus was again on efficiency and conservation. The postponement of real price competition in the wholesale market is perceived as a temporary pause in the ongoing reform process and firms are competing to be in a strong position when the next phase starts.

In terms of future reforms, SERC has confirmed its plan to work towards genuine price competition (Zhang [2008]), but the State Council [2007] indicated that it would not happen in the immediate future.[12] The dispersed market structure and surveillance of anti-competitive behavior have to be more firmly established and dispatch rules need to be more reliable before price liberalization would be contemplated. Even the OECD [2010] has counseled a cautious approach and recommended in particular to first strengthen the rule of law.

After a cyclical decline in electricity demand, a large further increase is expected between 2010 and 2020. Given China's current status as the world's leading emitter of CO_2, renewable energy and conservation have become more prominent, which fits well with a continued focus on operational efficiency.

III. EMPIRICAL MODEL

III(i). *Estimating Equations*

The derivation of the key estimating equations follows Fabrizio *et al.* [2007] with a few modifications. Given that Chinese electricity generation firms do not have direct control over prices, and that demand is highly inelastic, a cost minimization framework is most appropriate to model short-run firm

[12] Given SERC's lack of autonomy, the National Development and Reform Commission, an important department of the State Council, remains the primary institution in charge of counteracting anti-competitive behavior and setting end-user pricing.

behavior. The Leontief functional form for the production function reflects the inability to substitute in the short run between fuel, on one hand, and capital and labor input, on the other hand:[13]

$$(1)\qquad \begin{aligned} Q &= \min_{M,L}\{f_1(M,\beta,\varepsilon_M),\, f_2(K,L,\alpha,\varepsilon_L)\} \\ &\text{s.t.}\quad Q \geq \bar{Q} \end{aligned}$$

It is an intuitive specification at the plant level, but should also be appropriate for the particular sample of firms we work with. While several of the observations in our data set belong to a single ultimate owner, most of the firms only operate a single large generation unit.[14] In 2002, almost three quarters of the total thermal generation capacity, and even more of the actual generation, was accounted for by 855 units of at least 100 MW each (OECD, 2010). Our sample contains 1,023 active firms in that year, implying an average of only 0.84 large generation units per firm. By 2006, the average number of large units per firm had increased to 1.08, but they accounted for an even larger share of total generation.

Several factors limit the scope for substitution even further. Only 4% of electricity generated by fossil fuel came from oil or gas-fired plants. Relative price changes for competing fuels, an important reason for substituting between plants in other countries, hardly plays a role in China. As fuel-intensity is relatively constant within a technology, substitution between plants has a limited impact on relative input use. Congestion on the transmission grid also limits the possibility of satisfying local demand with faraway supply and thus limits substitution between plants within a firm. Moreover, the remnants of the dual-track pricing system insulates some plants entirely from market forces. Young [2000] describes how market prices give appropriate incentives at the margin for efficient resource allocation in spite of a large volume of transactions being conducted at regulated 'plan' prices. However, the 'plan' prices in this industry were fixed at the plant not the firm level, and existing plants have little scope to 'grow out of the plan.' This again blunts incentives for intra-firm substitution.

In equilibrium both terms in the production function will hold with equality. A first-order Taylor approximation to any monotonically increasing $f_1(\cdot)$ function leads to a log-linear material demand equation:

$$(2)\qquad \ln M_{it} = \beta_Q \ln Q_{it} + \beta_i + \beta_t + \varepsilon_{it}^M$$

[13] This specification was first used in Van Biesebroeck [2003] to capture a similar inability to substitute between components and other production factors in automobile assembly plants.

[14] This is especially likely for firms owned by regional governments or by foreign-owned firms, respectively 15 and 19 per cent of observations at the start of the period.

M comprises both fuel and non-fuel expenditures,[15] and the error term ε^M captures measurement error and factors that affect a firm's material efficiency. We include time and firm-fixed effects to soak up some of the productivity heterogeneity. Because we only observe output and material input in value terms, we face a missing data problem for input and output prices which is discussed and addressed below.

Capital and labor input are assumed to be substitutable to some extent. Assuming that the $f_2(\cdot)$ function takes the Cobb-Douglas functional form, as Fabrizio *et al.* [2007] do, implies a coefficient of one on output in the labor demand equation which is rejected by the data. Instead, we assume a more general CES production function,

$$Q = \gamma(\alpha K^{\rho} + (1-\alpha)L^{\rho})^{\frac{\nu}{\rho}} e^{\varepsilon_L},$$

where α captures the relative importance of capital, ν the returns to scale, and $1/(1-\rho)$ is the elasticity of substitution ($\rho < 1$).

We treat capital input K as quasi-fixed in the short run as this is predetermined before labor and material input are decided. In the Chinese electricity sector, this applies even more strongly as the investment strategy of firms is subject to government approval. The main task of the plant manager is to choose labor input each period to minimize the total wage bill, while satisfying the output constraint and taking into account the capital stock which can vary over time. The first order condition for labor amounts to

$$W = (1-\alpha)\nu\lambda Q^{\frac{\nu-\rho}{\nu}} L^{\rho-1},$$

where W is the wage level and λ the Lagrange multiplier associated with the output constraint, i.e., the shadow price of output.

In logarithms, the additive term $\ln \lambda_{it}$ appears in the demand equation and it is expected to vary with the available capital, the market environment, and firm-specific characteristics, such as the ownership structure. As proxies, we include the capital stock, time and firm-fixed effects. Fabrizio *et al.* [2007] use 'plant-epoch' fixed effect for periods in between large investments, but we explicitly include the capital stock as generation capacity is adjusted more frequently at the firm level (our unit of analysis).

[15] We only observe total expenditures on intermediate material inputs, which combines 'fuel material input' and 'industrial intermediate inputs'. The latter consists of transportation cost, repairs and storage cost, and intermediate service inputs, such as interest expenditure, advertising, insurance, education and travel cost. Assuming that total material input is proportional to output is an often-used justification to estimate a production function in value added terms—see Van Biesebroeck [2007] for a discussion.

The estimating equation for labor demand is

$$\ln L_{it} = \alpha_Q \ln Q_{it} + \alpha_W \ln W_{it} + \alpha_K \ln K_{it} + \alpha_i + \alpha_t + \varepsilon_{it}^L, \tag{3}$$

with $\alpha_Q = (\nu - \rho)/(\nu(1 - \rho)) > 0$ for realistic values of the parameters and $\alpha_W = -1/(1-\rho) < 0$. ε_{it}^L captures measurement error, productivity shocks, and remaining variation over time in the shadow price of output.

To consistently estimate the restructuring effects, we need to address the missing price bias, the identification and selection of restructured firms, and the simultaneity between input efficiency shocks and output. We discuss each complication in turn.

III(ii). *Missing Price Bias*

To estimate equations (2) and (3), we ideally would like to use physical quantities for inputs and output. As these are unavailable for material inputs (coal) and electricity output, we have to use input expenditures and electricity revenue instead. Firm-specific deviations from the average price level are then omitted variables that enter the error term (Klette and Griliches [1996]). They can cause inconsistent estimates if they influence the output level or are correlated with the restructuring effect.

On the output side, the constraints on electricity pricing discussed earlier limit the scope for different price evolutions across firms. State-owned companies sell most of their electricity at pre-determined transfer prices to the distribution networks. The IPP's sell at differentiated tariffs, but these are determined by a constant formula that includes the firms' ownership type, the date and size of initial investment, and market trends that are common to all firms. To the extent that the cross-sectional heterogeneity is constant, it will be captured by the included firm-fixed effects.

On the input side, the dual-track price system provides some firms with access to power coal at a low regulated price for some of their input needs. Other firms, especially younger IPP's, have to pay higher market prices. As the differential between the 'plan' and the market price fluctuated over time, see for example Wang [2007], the value of preferential access also fluctuated and this is likely to have induced some output variation.[16] Note, at the same time, that the gradual phase-out of subsidized coal gives restructuring firms greater incentives to operate their plants more efficiently, providing an important channel for the reforms to be efficiency enhancing.

[16] There have been instances of firms deliberately choosing to halt production to avoid losses when coal prices soared on the deregulated market and regulated electricity prices did not adjust.

The importance for our application is that average prices faced by the two groups of restructured and control firms potentially evolved differently. For example, a more rapid increase in the average (relative) coal price paid by restructured firms would induce an upward trend in their measured material input expenditures even without any change in output or productivity. This would bias the estimated productivity benefits of the reforms downward. In contrast, if the average electricity price increased more rapidly for restructured firms, we would overestimate the restructuring benefits.

The evolution of the relative prices faced by the two groups of firms is difficult to determine as there are two opposing trends. The growing importance of market prices increases the relative price ratio, i.e., it raises the average prices for restructured firms relative to prices faced by control firms. In contrast, the growing gap between subsidized and regulated prices, because subsidized prices tend to increase more slowly than market prices, reduces the relative price ratio.[17] Given that differences in coal and electricity prices have opposite effects, it is even harder to sign the expected bias.

To address this measurement problem, Du *et al.* [2008] replaced the dependent variable in the material demand equation (plant-level fuel input) with provincial fuel use and the explanatory variable in both equations (plant-level electricity output) with the provincial thermal electricity output. Using the aggregate output variable as an instrument instead of a proxy would be a more standard approach, but that would be impossible for the dependent variable in the material equation. The weak correlation between firm-level and provincial variables in our sample makes this approach problematic anyway.[18]

An alternative solution would be to include deflated aggregate sales as an additional control in the input demand equations. Klette and Griliches [1996] have shown that this absorbs all output price heterogeneity if the industry can be characterized as monopolistically competitive with constant elasticity of substitution demand. In the Chinese electricity sector, however, it is implausible that firm-level price changes should always be proportional to province-wide demand changes. Market power by regional

[17] These effects can be seen from the following change in the relative price ratio:

$$\%\Delta\left(\frac{\bar{P}_{\text{REST}}}{\bar{P}_{\text{CONT}}}\right)=\frac{s^1+(1-s^1)(P_S^1/P_M^1)}{s^0+(1-s^0)(P_S^0/P_M^0)}-1.$$

The 0 and 1 superscripts denote time, s is the share of the input or output of restructured firms (REST) subject to market prices which is assumed to be one for the control group (CONT), and P_S/P_M indicates the relative subsidized-to-market price ratio. Because the price ratio is less than one in both periods, an increase in s raises the average price more for restructured firms. However, as $P_S^1/P_S^0 < P_M^1/P_M^0$ the subsidized-to-market price ratio falls over time and the average price rises more slowly for restructured firms.

[18] The coal market was only liberalized at the very end of the time period that Du *et al.* [2008] study and heterogeneous price changes were less of a problem for them.

monopolies or political connections allow some firms to interfere in the price regulation process or to obtain preferential access to subsidized coal.

In a case study of the Chinese power coal market, Mathys [2011] investigates which variables—firm characteristics and market features—have the most explanatory power for plant-level electricity prices and access to regulated power coal. Location is found to be the most important factor as it determines ease of access to domestic mines, to imported coal, and to the congested transportation infrastructure. It also controls for deviations from average electricity prices. Relative price differences within provinces tend to be stable, but there is some variation in provincial price regulation over time. Firm age, size, and ownership are found to matter as well, as they help predict historical plan allocations and bargaining power.[19]

In the estimation equations, we replace the implicitly included difference between firm-specific and average prices with a set of interaction terms. Province dummies and age are collinear with the firm and time-fixed effects, but their interactions with other, time-variable variables are valid controls. Firm-size and the share of state-ownership do vary over time and can be included directly, in addition we interact them with the provincial dummies and firm-age. The ownership variable is correlated with the restructuring dummy and we will report results including and omitting this variable in the set of price controls.

III(iii). *Identifying Treated Firms*

All firms were affected indirectly by the 2002 reforms as the industry restructured and competition intensified. Firms with links to the central or provincial governments were further impacted because their ownership, objectives, and often their management changed, in addition to the regulatory framework governing their actions. Because in China the state interferes in the economy in myriad ways, one can define the group of firms affected most directly by the reforms in several ways as well.

In the benchmark model, we classify firms that were officially denoted as state-owned in 2002 as 'treated.' This is the most common way to delineate the state sector, see for example Zhang *et al.* [2001]. For this group of firms the $STATE_0$ dummy is set to unity for the entire period and to zero for firms in the control group, which are of private, foreign, collective, or mixed ownership. They are identified from the variable 'legal structure of Chinese company ownership' as either state-owned companies (type 110) or state-solely-funded corporations (type 151).

[19] The legacy of the planned period allowed state-owned firms to access 'plan' power coal prices guided by National Development and Reform Commission and, equally important, guaranteed transportation by the Ministry of Railways.

Du *et al*. [2008] adopted an alternative definition and labeled as 'treated' those plants originally controlled by the SPC, the integrated public utility, or the Ministry of Electricity Power. On one hand, it excludes from the former group some units owned by the central government through other departments or by provincial governments. On the other hand, it includes some SPC subsidiaries that already had mixed ownership in 2002 even though it is uncertain that all these firms were directly impacted by the 2002 restructuring. Some subsidiaries had already transformed to shareholding companies and were listed on the stock exchange. Their management and operations are more likely to have been stable following the reforms. Legal entities that are either subsidiaries of the SPC prior to 2002 or that are subsidiaries of the Big Five generators created from the SPC breakup can be identified in the data set based on their name.[20]

Using the first definition, 36% of firms active in 2002 are considered treated and they account for 40% of industry revenue. The second definition ends up with a more narrow definition and the corresponding shares are only 22% of firms, but 50% of revenue. A third, broader definition of treatment is to include all firms with majority state-ownership of their capital in 2002, including local governments, which is observed independently from the firms' formal ownership type classification. In this case 44% of firms active in 2002 are considered treated and they account for the same share of aggregate revenue. We will present estimates using all three definitions.

The objective of the analysis is to assess whether the reforms boosted productivity in restructured fossil fuel-fired electricity generation firms. As we need to include firm fixed-effects to help control for the missing price bias and an endogeneity problem (below), we cannot identify differences in the level of input demand between restructured firms and a control group of IPPs. We only measure whether their input demands evolved differently over time by interacting the constant $STATE_0$ dummy with a set of time dummies or a single post-reform dummy.

Introducing both the price and restructuring controls in the factor demands leads to the following two estimating equations:

(4)

$$\ln(EMPLOYMENT_{it}) = \alpha_i + \alpha_R \ln(REVENUE_{it}) + \alpha_W \ln(WAGE_{it}) + \alpha_P' X_{it} + \sum_{\tau=2}^{T} (\alpha_\tau + \lambda_\tau STATE_{0i}) \cdot I_{[YEAR_{it}=\tau]} + \varepsilon_{it}^L$$

[20] The names of the Big Five subsidiaries usually include the group information, i.e. Huaneng, Datang, Huadian, Guodian or Diantou. Some firms with unrelated names are still defined as treated if a majority of their capital is controlled by one of the Big Five firms.

$$\ln(MATERIAL_{it}) = \beta_i + \beta_R \ln(REVENUE_{it}) + \beta_P' X_{it} + \sum_{\tau=2}^{T} (\beta_\tau + \mu_\tau STATE_{0i}) \cdot I_{[YEAR_{it}=\tau]} + \varepsilon_{it}^M \quad (5)$$

The set of α_i and β_i intercepts are firm-fixed effects. Electricity output is replaced by *REVENUE*. The vector X_{it} represents the set of variable-interactions to control for firm-level price differences, as discussed earlier. The coefficients are allowed to differ in the two equations as $\alpha_P' X$ only controls for firm-specific electricity prices, while $\beta_P' X$ additionally controls for coal price differences. The capital control in the labor equation is included in X_{it}.

The uninteracted time dummies, α_τ and β_τ, control for changes in aggregate demand, but also for indirect, industry-wide effects of the reform, e.g., changes in average electricity prices. They are normalized to zero in the first year of the sample. The coefficients of interest are λ_τ and μ_τ.

III(iv). *Estimation*

Estimation faces a potential simultaneity issue as productivity shocks that affect factor demands are likely to be correlated with output. If output is determined exogenously or fixed before productivity shocks are realized, e.g., by the central or provincial government bureaucracy, there would not be a problem.[21] However, it might be possible for managers to adjust electricity production to some extent after observing idiosyncratic shocks to labor and material productivity. This endogeneity problem is likely to be more severe in the material input equation, as fuel use is closely tied to output. Adjusting a level of employment that was based on demand expectations is not always easy, especially in a highly regulated sector with a lot of state ownership.

Fabrizio *et al.* [2007] used aggregate electricity demand at the state level as an instrument for plant-level output. For this approach to be effective, firm-level electricity revenue and province-level electricity consumption need to be positively correlated. In our sample, the association is very weak: the correlation is only 0.067 pooling all firm-year observations. There are several reasons for this, some of them unique to the Chinese situation.

First, the correlation is diminished because of heterogeneity in electricity prices which is largely outside the firms' control. Second, many provinces are large and contain regions where firms are *de facto* local monopolies, only partially affected by provincial demand fluctuations. Transmission capacity is often a binding constraint on the system (OECD [2010]). Third,

[21] The exact timing assumptions for input and output decisions and the realization of shocks that Van Biesebroeck [2003] employs would also work here.

provincial demand and production are often unbalanced. For example, under the 'West Development Strategy' the government launched a vast project to transport electricity from western provinces to the developed coastal area. Weak instruments will lead to large standard errors and in finite samples to inconsistent and biased estimates (Verbeek [2008]).

An important advantage of our analysis over Du *et al*. [2008] is the availability of a relatively long panel (ten years), allowing us to include firm fixed effects. These already soak up the heterogeneity in the cross-firm dimension and reduce the simultaneity problem in the quasi-differenced equations. As instruments for firm level revenue, we use information from outside the electricity sector to proxy for the localized electricity demand faced by the generators. Total manufacturing output and employment in the same 6-digit region ($\overline{diq}$) turn out to be more strongly correlated with firm-level electricity output than provincial electricity demand.[22] In a robustness check, we add annual provincial temperature and electricity consumption as additional instruments which are weaker, but still significant in a first-stage regression.

We implement two standard alternative approaches to address the simultaneity problem which are valid only in the absence of autocorrelated errors. The factor demands can be estimated in first differences using twice lagged revenue as instrument for the change in revenue (Blundell and Bond [1998]). We also use lagged firm level revenue as a proxy for current revenue, still including firm fixed effects. It allows consistent estimation of all coefficients except for the output elasticity, which is not of direct interest.

Equations (4) and (5) follow a typical difference-in-differences setup. Negative values for λ_τ and μ_τ after 2002 would indicate larger efficiency gains for restructured than for control firms, always relative to each group's own initial average input use. Bertrand, Duflo and Mullainathan [2004] argue that serial correlation may underestimate the standard error of the treatment effects and hence overstate significance levels in conventional difference-in-differences. One solution they suggest is to use longer time differences. We collapse the panel into a pre and post-reform period, which should help if the serial correlation does not span the entire period. Conservatively, we also cluster the standard errors at the firm level and we implement the randomized inference approach suggested by the same authors.

IV. DATA AND SUMMARY STATISTICS

The firm-level data we use are collected through annual surveys by China's National Bureau of Statistics. The sample covers the 1998 to 2007 period

[22] In China, 75% of electricity demand comes from industry (OECD [2010]).

and includes all firms in the fossil fuel fired electricity generation sector (Chinese Industrial Classification code 4411) that are either state-owned or have annual sales above 5 million RMB. Because the threshold is far below any viable scale of operation, we can safely assume that the sample includes the universe of generation firms.[23]

As mentioned before, electricity revenue (*REVENUE*) and intermediate input expenditures (*MATERIAL*) are observed in value terms, not in physical quantities. The latter contains the expenditures on both fuel and non-fuel inputs. The *WAGE* variable is defined as the total labor compensation, including wage and nonwage expenditures, divided by total employment (*EMPLOYMENT*).[24]

Four variables are included in the polynomials to control for electricity and coal price differences. Firm size is measured by total fixed assets, firm age is calculated from the reported year of creation, the percentage of capital that is state-owned captures the ownership structure, and provincial dummies capture location and transportation conditions. The uninteracted provincial effects are absorbed by the firm-fixed effects, but the interactions with the other three variables do vary over time.

Table I contains summary statistics for all firm characteristics, listing the state-owned 'treated' firms separately from the control group. We report these statistics for 2002 at the eve of the reforms. 23% of firms active before 2002 exit the sample before the reforms are launched. These tend to be relatively small, and only account for 15% of revenue over that period. At the same time, 31% of firms active in 2002 were not yet in the sample in 1998. To follow firms over time, we rely primarily on the officially assigned firm-identifiers. For firms that exit, we verify whether they re-enter in subsequent years with a different ID using information on birth date, postal code, and name. 10% of the firms in our sample have at some point undergone a restructuring that changed their ID.

The statistics in the last column indicate that average revenue is 17 per cent higher for state-owned firms, but the difference is not significantly different from zero. These firms also employ more than twice as many workers and the wage bill as a share of revenue is much higher. As expected, state-owned firms tend to be a lot older and the average share of their

[23] The sales threshold of 5 m RMB equals approximately $US 600,000 during the sample period. A back of the envelope calculation suggests that each installed megawatt of generation capacity yields 1.93 million RMB of annual revenue (24 hours × 365 days × 55% average capacity utilization rate × 400 RMB/MWh average wholesale price for electricity generated from fossil fuel). Each firm with more than 3 MW of installed generation capacity should be included in the sample.

[24] For the summary statistics, revenues are deflated to 1998 with the ex-factory price index for the electricity industry, inputs with the fuel and energy purchase power index, and the labor remuneration with the consumer price index. The deflators do not influence the estimates as the model contains a full set of time dummies.

TABLE I
SUMMARY STATISTICS BY OWNERSHIP CATEGORY (IN 2002)

	State-owned firms	Control firms	Differences in means
Revenue (mil. RMB)	353	303	50
	(1008)	(636)	(51)
Employment	1,149	531	617
	(3107)	(722)	(127)***
Material / Revenue	0.855	0.750	0.105
	(1.411)	(0.360)	(0.059)*
Employment / Revenue	13.851	6.380	7.471
	(34.49)	(9.14)	(1.44)***
Fixed Asset / Revenue	2.371	2.003	0.368
	(5.612)	(4.428)	(0.323)
Wage / Revenue	0.146	0.076	0.070
	(0.291)	(0.081)	(0.012)***
Age	22.6	10.8	11.8
	(16.6)	(9.9)	(0.8)***
State-owned capital (%)	0.828	0.214	0.613
	(0.364)	(0.362)	(0.024)***
Observations	369	654	

Notes: Standard deviations in brackets. ***, **, * denote significance at 1%, 5%, or 10% level.

capital that is owned by the state is four times as high. Without controlling for anything, the employment-revenue and material-revenue ratios are significantly higher for treated firms.[25]

V. RESULTS

V(i). *Benchmark Estimates*

The impact of the 2002 reforms on input use is estimated using equations (4) and (5). Panel (a) in Figure 1 plots the coefficients and 95% confidence intervals for the year dummies in the labor demand equation. The black markers (solid line) are for the firms that were state-owned in 2002 and the grey markers (dashed line) are for the control group of IPP's. Labor efficiency is fairly constant for both groups in the initial years and until 2004 there is no discernable difference. In later years, the improvement for restructured firms accelerates and a gap opens up which is statistically significant at the 10%, but not at the 5% level. It reduces the employment difference between the two groups that was apparent from the summary statistics. By the end of the sample period in 2007, the 0.088 log-points difference implies that labor input in restructured firms has decreased by 8.0 per cent more than the 5.1 per cent decline for other firms.[26]

[25] Similar calculations for firms active in 1998 confirm the higher employment/revenue ratio for 'treated' firms. The difference for the material/revenue ratio is in the same direction but not statistically significant.

[26] A difference of –0.088 in log-points translates into an $exp(-0.088) - 1 = 8.4$ per cent difference. At the reduced input level of the control group, it amounts to an additional 8.0 percentage points decline.

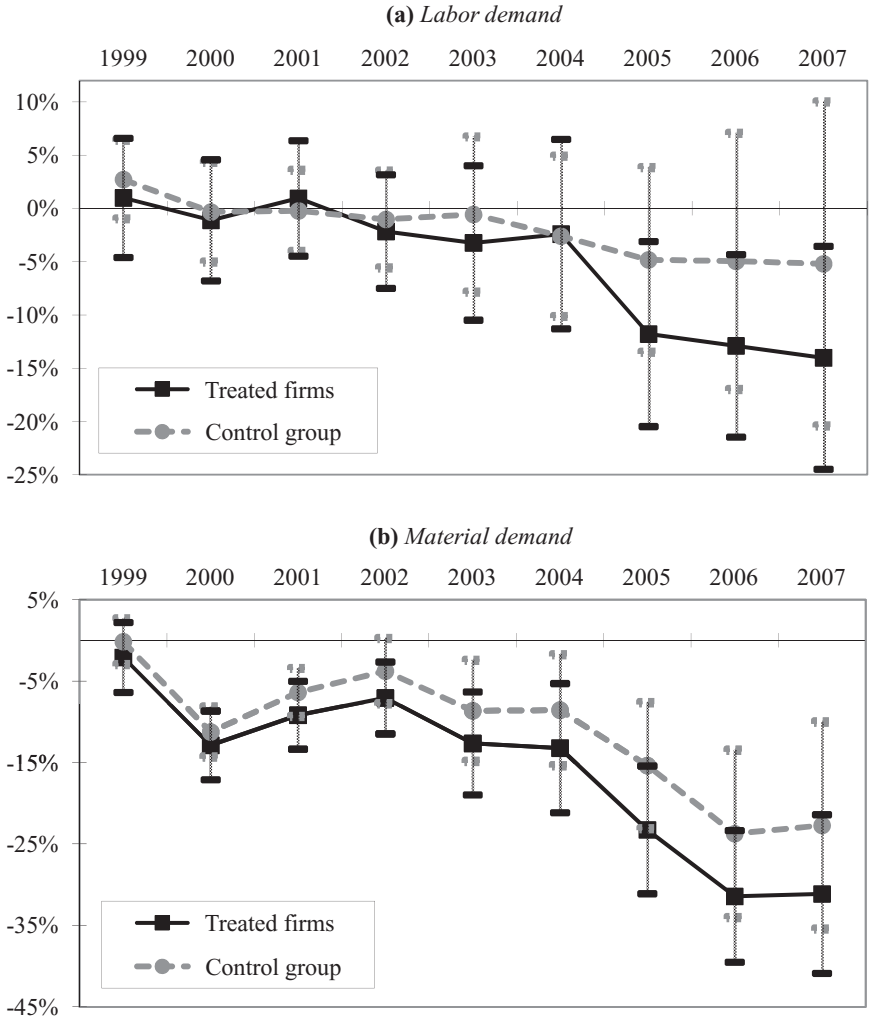

Figure 1
Evolution of Input Demand for Firms in the Treatment and Control Groups
Notes: Point estimates with 95% confidence intervals for the year dummies for both types of firms in two separate input demand equations.

The figure in panel (b) illustrates a similar evolution for material input expenditures. While the average control firm lowers its material input by 20.3 per cent between 1998 and 2007, the average restructured firm lowers it by 26.8 per cent, a 6.5 per cent additional decline. At -0.084, the log-points difference in 2007 is very similar to the estimate in the labor demand equation. Because the gap between restructured and other firms now

appears a few years earlier and the coefficients are estimated more precisely, the divergence shows up even more clearly.

The estimates in Figure 1 include firm-fixed effects, control for unobserved price differences, and instrument for output using local manufacturing activity. The full set of estimates is reported in Table A(i) in the Appendix. The last nine coefficients directly measure the differences for the two groups of firms. In the same table, we also report results without instrumenting which would be appropriate if output were predetermined. Given that all state-owned firms have output quotas to fill, that the majority of sales is covered by long-term contracts and that no firm has direct price-setting power, this is not entirely implausible. The differences are of similar magnitudes, –0.075 for labor demand and –0.094 for material input in 2007. The standard errors are a lot smaller and the differences for 2005, 2006 and 2007 are all significant at the 5% level for employment and at the 1% level for materials.

In the following tables we further investigate the effects of the reforms, but collapse the data in pre and post-reform periods. It facilitates a comparison with previous studies which also quantify the restructuring effects using a single percentage difference, see Fabrizio *et al*. [2007] and Du *et al*. [2008]. This parsimonious specification also makes it more straightforward to compare the results under a host of alternative estimation assumptions and using different sub-samples. Moreover, Bertrand *et al*. [2004] argue that collapsing the data in two periods makes the difference-in-differences estimate less likely to be overestimated due to serial correlation in the residual. Both equations, but especially labor demand, do not pass the Wooldridge [2002, p. 282–283] test for serial correlation in linear panel models.[27]

Bergh [1997] suggests that it can take several years for performance effects of a divestiture to fully materialize. Most changes in ownership type in our data set occur between 2002 and 2004. It also took time for the contemporaneous liberalization of the coal market to lead to higher input prices and lead to profitability problems. As a result, many firms might not have responded to the new industry structure right away. To allow for a delayed effect of the restructuring, we estimate the model with two alternative post-reform dummies: *POST2002* and *POST2004*.

Table II reports the estimates of the labor and material input equations using the same estimator as before. The full set of time-varying restructuring effects in (4) (and similarly in (5)) is replaced with a single $\lambda_P \cdot \text{STATE}_{0i} \cdot \text{POST}_t$ interaction term that switches from zero to one in the

[27] The material equation easily passes the Breusch–Godfrey test for serial correlation which assumes homoskedastic errors, but even this test still suggests a (mild) problem for the employment equation: the p-value of rejecting the null hypothesis of no serial correlation is 0.152.

TABLE II
INPUT DEMAND EQUATIONS PRIOR TO AND FOLLOWING RESTRUCTURING

Dependent variable: *(N = 10,792)*	ln(EMPLOYMENT)		ln(MATERIAL)	
ln(REVENUE)	0.181	0.189	0.893	0.892
	(0.220)	(0.216)	(0.133)***	(0.132)***
ln(WAGE)	–0.260	–0.262		
	(0.051)***	(0.050)***		
$STATE_0$*POST2002	–0.042		–0.040	
	(0.027)		(0.018)**	
$STATE_0$*POST2004		–0.072		–0.051
		(0.035)**		(0.020)***
Weak identification test:				
Kleibergen-Paap Wald F-stat.	88.162	88.162	88.171	88.171
Stock-Yogo critical values (10% maximal IV size)	19.93	19.93	19.93	19.93
Overidentification test:				
Hansen J Statistic	0.405	0.416	0.119	0.138
Chi-sq(1) p-value	0.525	0.519	0.730	0.710

Notes: IV-FE regression that includes firm and year fixed effects and controls for price heterogeneity (interaction terms of fixed assets, fraction of state-owned capital, and provincial dummies). Revenue is instrumented with manufacturing output and employment in a firm's 6-digit region (diqu). Standard errors are clustered at firm level. ***, **, * denote significance at 1%, 5%, and 10% level.

post-reform period for treated firms. Note that we still include a full set of (uninteracted) time effects α_τ to control for changes that affect all firms, such as changes in technology, the business cycle and the market environment.

The coefficients on firm-level revenue and wages are estimated consistent with expectations. The revenue coefficient in the material input equation, which includes both fuel and nonfuel expenditures, is a direct estimate of the output elasticity of materials. It is estimated close to unity, as expected, and in between the coefficients for the separate fuel and nonfuel expenditure equations in Du *et al*. [2008].

Taking the production function at face value, the revenue coefficient in the labor equation equals $(\nu - \rho)/(\nu - \nu\rho)$. It will be positive but less than one if returns to scale are increasing. This is what we expected, as many firms in the sample are likely to operate below minimum efficient scale (OECD [2010]), but the coefficient is not significantly different from zero when we instrument for revenue. Given the limited changes in generation capacity between consecutive years and stable long-term contracts to deliver electricity, firms do not have a lot of opportunities or incentives to respond to short-term productivity fluctuations. It makes identifying the revenue coefficient difficult, but also limits the potential endogeneity problem. Note that Fabrizio *et al*. [2007] and Du *et al*. [2008] also obtained insignificant coefficient estimates for output.[28] In contrast with those two

[28] Results in Table A.i in the Appendix show a very precisely estimated coefficient on revenue in the labor equation if we do not instrument, but this estimate is only consistent if revenue is predetermined.

studies, we do find a negative and significant coefficient on the wage rate. The absolute value of the wage coefficient equals the elasticity of substitution $1/(1-\rho)$. The 0.26 estimate suggest substitution between labor and capital is quite low, which is intuitive for electricity generation.

The last coefficient in each column—the interaction between the restructuring and the post-reform dummies—measures the gap in input demand for treated and control firms in the post-reform period. The negative coefficients indicate a relative efficiency gain for former state-owned firms. Using the two alternative reform periods, they are estimated to experience an additional reduction of 4.1 or 7.0 per cent in labor use and a reduction of 3.9 or 5.0 per cent in expenditures on material (including fuel). The higher effects for both input factors in the limited 2004–2007 period are significant at the 5% and 1% level.

V(ii). *Verifying Robustness*

In Table III we report the results of several robustness checks to verify the sensitivity of the estimated restructuring effects to various assumptions.

TABLE III
VERIFYING THE ROBUSTNESS OF THE RESTRUCTURING EFFECT ESTIMATES

	ln(EMPLOYMENT)	ln(MATERIAL)
Dependent variable:	Coefficients on $STATE_0$*POST2004	
Benchmark estimates	–0.072	–0.051
	(0.035)**	(0.020)***
Alternatives for omitted price bias:		
—Not controlling for omitted prices	–0.079	–0.043
	(0.032)**	(0.017)**
—Excluding state-ownership from price controls	–0.076	–0.050
	(0.035)**	(0.020)**
Alternatives for revenue endogeneity		
—Single instrument for revenue (manufacturing output in region)	–0.070	–0.078
	(0.042)*	(0.029)***
—Additional instruments for revenue (provincial temp. & elec. demand)	–0.062	–0.033
	(0.033)*	(0.022)
—Estimate in first differences with twice lagged revenue as instrument	–0.099	–0.045
	(0.041)**	(0.025)*
—Lagged revenue as proxy	–0.067	–0.039
	(0.028)**	(0.029)
Randomized inference		
—10(109)	–0.074	–0.044
	(0.039)*	(0.023)*
—20(55)	–0.077	–0.045
	(0.042)*	(0.022)**
—50(22)	–0.076	–0.045
	(0.041)*	(0.024)*
Mahalanobis matching	–0.076	–0.041
	(0.034)**	(0.021)**

Note: Each statistic is estimated by a separate IV-FE regression with the same controls as in Table II and changes in the estimation strategy as indicated. ***, **, * denote significance at 1%, 5%, and 10% level. Standard errors are clustered at firm level.

The benchmark results using the *POST2004* dummy are repeated in the top row.

Not controlling for the omitted price bias leads to a slightly stronger effect on employment, but a weaker effect on material expenditure. These opposing changes are intuitive because only the electricity price is omitted from the first equation, while the second equation misses both the electricity and coal prices which have opposite effects and the coal price is likely to vary more. In light of our earlier discussion of the likely bias, the changes in the estimates when controls are included suggest that prices increased more rapidly for treated than for control firms. This is consistent with a declining share of input needs satisfied with subsidized coal and a declining share of output sold at below market rates. Excluding the share of state-ownership from the set of price controls, as it might be correlated with the restructuring dummy, has only a very small effect on the point estimates.

The next set of results in Table III relies on alternative approaches to control for the endogeneity of revenue in the two input demand equations. We first report estimates using only regional manufacturing output as instrument, which has the stronger correlation with firm-level electricity revenue.[29] It leads to a higher point estimate for the restructuring effect in the material demand equation, at –0.078, but also raises the standard errors in both equations. Adding two additional instruments that vary only at the province-year level, average temperature of the provincial capital and total electricity demand, lowers both restructuring estimates, but the changes are not significant.

Using twice lagged revenue as an instrument for the equation in first differences raises the estimated effect for employment. Using lagged revenue as a proxy for current revenue lowers the point estimates for both effects slightly, but raises the estimation precision for the effect on employment. Given that our data set is far from balanced, we lose a nonnegligible share of observations with the last two estimators. While the point estimates depend somewhat on the exact identification assumption, the signs and general magnitudes of the effects are preserved.

To investigate concerns about serial correlation of the residuals, we implement the randomization inference method suggested by Bertrand *et al*. [2004]. This is a group jacknife approach, where the FE-IV regression is first estimated on half of the firms in the sample. In the following regressions, we randomly replace ten of the firms with ten randomly drawn firms from the half of the sample that was not used initially. We can repeat this procedure 109 times and obtain as many different estimates for the restructuring effects. A similar analysis is performed replacing twenty or fifty firms at a time, which allows 55 and 22 regressions respectively.

[29] The two instruments pass the weak instruments and overidentification tests, reported at the bottom of Table II.

In Table III we report the average and standard deviation for the coefficient of interest across all estimates. The modest changes suggest that autocorrelation is not a serious issue once we limit the comparison to the periods preceding and following the reforms. The asymptotic approximation to the standard errors even seems surprisingly accurate. The average point estimate on the restructuring effect is at most reduced by one eighth and it always remains significant at least at the 10% level.

The difference-in-differences approach controls for unobservable differences across firms that are constant over time. The summary statistics illustrated that the treated state-owned firms differ from other firms in a number of observable ways and one might be concerned that the probability of restructuring is related to observable characteristics as well. By including these characteristics in the regressions, we already controlled for differences in performance potential, but we can additionally control for nonrandom selection into treatment. The treatment evaluation literature has developed several approaches, see Imbens and Wooldridge [2009] for an overview, and we implement one straightforward matching estimator.

To make sure that treated firms are benchmarked to comparable control firms, we adjust for the imbalance in their covariates as follows. We first match each treated firm to its nearest neighbor in covariate space using the Mahalanobis distance metric. We then estimate the input demand equations on the restricted sample of matched firms. This has the advantage that the regression does not need to fit firms in the control group with covariates that are very different from those observed for treated firms. On the restricted sample of matched firms, the second stage regression produces very similar estimates on the $\text{STATE}_{0i}{\cdot}\text{POST2004}_t$ interaction terms.

The results turn out to be more sensitive to one final robustness check: the definition of restructured firms. In Table IV we report restructuring effects estimated using three alternatives definitions. While the benchmark definition suggests positive and significant productivity effects of restructuring, the evidence is weaker using the alternative definitions. For expenditure on materials the coefficients are still estimated negatively using both alternatives, but for Big 5 subsidiaries, the effect is only significant at the 10% level, and for firms with majority state-ownership of capital the effect is not significant. For labor demand, the effect is reduced to one third for firms where the state is majority shareholder, while employment is even estimated to increase (in relative terms) in Big 5 subsidiaries.

It turns out that the sets of firms identified as treated using the three alternative definitions are rather different. Only half of the Big 5 subsidiaries were classified as state-owned in 2002 and only slightly more had the state as majority investor. Several of them had already transformed to shareholder companies before 2002 and some were even listed on the stock exchange. Most of the restructuring of these units might already have

TABLE IV
ALTERNATIVE DEFINITIONS OF RESTRUCTURED FIRMS

Dependent variable:	ln(EMPLOYMENT)	ln(MATERIAL)	No. of Treated	No. of Controls
	Coefficients on $STATE_0$*POST2004		(in 2002)	
(a) Using the full sample of firms				
Benchmark estimates	–0.072	–0.051	369	654
(State-owned in 2002)	(0.035)**	(0.020)***	(36.1%)	
Big 5 subsidiary	0.077	–0.032	228	795
	(0.029)***	(0.018)*	(22.3%)	
Majority state-ownership of	–0.038	–0.011	447	576
capital in 2002	(0.033)	(0.020)	(43.7%)	
(b) Using the same set of control firms in each case:				
Benchmark estimates	–0.068	–0.028	369	436
(State-owned in 2002)	(0.050)	(0.031)	(45.8%)	
Big 5 subsidiary	0.056	–0.039	228	436
	(0.032)*	(0.019)**	(34.3%)	
Majority state-ownership of	–0.060	–0.011	447	436
capital in 2002	(0.045)	(0.025)	(50.6%)	

Note: Each statistic is estimated by a separate IV-FE regression with the same controls as in Table II, but defining the $STATE_0$ restructuring dummy in three different ways. Results in panel (a) use the full sample, results in panel (b) only include firms in the control group that are not considered treated using any of the three defintions. ***, **, * denote significance at 1%, 5%, and 10% level. Standard errors are clustered at firm level.

taken place before 2002. At the time of their ownership changes, they often underwent internal restructuring, introduced corporate governance changes, and sometimes started foreign partnerships.

Big 5 subsidiaries tend to be the larger firms in the industry. While they make up less than one quarter of all firms, they represent more than half of the firms in the top quarter by revenue. Moreover, their employment to revenue ratio is less than two thirds of the sample average, while the same ratio is one half above the average using the other two definitions for restructured firms. It is not surprising that these firms did not reduce their workforce aggressively after 2002. Moreover, while revenue growth in restructured firms lags the sample average after 2002 using all three definitions, the difference is a lot smaller for Big 5 subsidiaries than for formerly state-owned firms.

A further problem with the comparison for different definitions in panel (a) is that the control group also changes. In the second panel of Table IV we report results for the same regressions, but include only firms in the control group that are not considered treated according to any of the three definitions. The estimate of labor productivity gains is still largest using the first definition, but the differences are not as large now. For Big 5 subsidiaries, material expenditure declined by 3.8% more than for control firms, the largest of the three point estimates for the materials equation. None of the three material productivity estimates are now significantly different from each other.

The evolution of input use in firms with majority state-ownership suggests improved productivity in the post-reform period, but the point estimates are smaller than in the benchmark case and never significant. Firms with majority state ownership, but not classified as state-owned are found to behave differently. The presence of other owners seems to have already changed these firms' operations prior to the 2002 reform. In spite of a high ownership share, the state appears to act differently in companies that are not formally classified as state-owned.[30]

V(iii). *Heterogeneity of Restructuring Effects*

The sensitivity of the estimates to alternative definitions of restructuring leads us to investigate whether effects might be heterogeneous across other dimensions as well. Since the start of the Chinese economic reforms in 1978, the coastal provinces in the East have developed a lot more rapidly than the rest of the country. Previous work for the manufacturing sector suggests that productivity levels and growth rates tend to be higher for smaller, often privately owned firms, and for new entrants which have concentrated in the East (Brandt *et al.* [2012]).

To investigate whether such performance differences also apply to the power sector, we estimate the input equations on sub-samples, splitting the original sample in two by location, firm size, or age. The West, Central, and East regions are defined following the official classification of provinces in China's Statistical Yearbook. The old-young and small-large divisions are relative to the median firm in terms of fixed assets and date of creation. The cut-off points are a capital stock of 137.5 million RMB and a start-up year of 1993. Because we assign firms in the first year that we observe them and they vary in the number of years they remain active, the total number of observations in the two groups differs slightly.

We report the FE-IV estimates on each of the sub-sample in Table V. We expected that firms located in the East, young firms, and also large firms, given the relatively high minimum efficient scale in electricity generation, would already have reached a higher efficiency level initially, irrespective of ownership type. Therefore, the largest potential for efficiency gains from restructuring and the largest coefficients (in absolute value) on the $STATE_{0i} \cdot POST2004$ interaction term are expected for firms in the West/Central, firms that are old, and small. This is exactly what we find for labor efficiency. The gains are positive (point estimates are negative) in five of the six samples and the effect is estimated stronger for firms in the West or

[30] The vast majority of firms classified as state-owned have the state as majority investor (308 out of 369, or 83.5%). The 139 companies with state-majority ownership but not registered as state-owned firms are responsible for the differences between the first and third regressions.

TABLE V
HETEROGENEOUS RESTRUCTURING EFFECTS

Dependent Variable:	ln(EMPLOYMENT)		ln(MATERIAL)	
(a) By location	West/Central	East	West/Central	East
ln(REVENUE)	–0.318	0.312	0.797	1.024
	(0.745)	(0.219)	(0.325)**	(0.158)***
ln(WAGE)	–0.135	–0.309		
	(0.143)	(0.054)***		
$STATE_0$*POST2004	–0.112	–0.067	–0.027	–0.058
	(0.084)	(0.056)	(0.034)	(0.037)
No. of observations	4,776	5,664	4,776	5,664
(b) By age	Old firms	Young firms	Old firms	Young firms
ln(REVENUE)	–0.206	0.379	1.592	0.714
	(0.896)	(0.308)	(0.804)**	(0.225)***
ln(WAGE)	–0.166	–0.335		
	(0.135)	(0.069)***		
$STATE_0$*POST2004	–0.090	0.041	–0.029	–0.045
	(0.050)*	(0.048)	(0.042)	(0.027)
No. of observations	5,235	5,205	5,235	5,205
(c) By size	Small firms	Large firms	Small firms	Large firms
ln(REVENUE)	–0.030	0.456	0.745	0.849
	(0.294)	(0.277)*	(0.244)***	(0.143)***
ln(WAGE)	–0.181	–0.343		
	(0.076)**	(0.055)***		
$STATE_0$*POST2004	–0.102	–0.019	–0.016	–0.060
	(0.049)**	(0.051)	(0.027)	(0.026)**
No. of observations	4,946	5,494	4,946	5,494

Note: Each statistic comes from a separate IV-FE regression with the same controls as in Table II on half of the sample which is split according to median firm size, location or median age. ***, **, * denote significance at 1%, 5%, and 10% level. Standard errors are clustered at firm level.

Central regions than in the East (a –0.045 difference), for firms that are old (a –0.131 difference), and small (a –0.083 difference). The last two differences are even statistically significant.

In contrast, the relative strength of restructuring effects for material efficiency always shows the reverse pattern: it is stronger for East, young, and large firms, although the difference is only statistically significant for the small-large firm comparison. It does suggest that the actions needed to improve material efficiency are different from actions that improve labor efficiency.

Union activity and general worker resistance have to be overcome to eliminate excess employment. It is intuitive that this is easier in small firms. In old firms the higher probability of future exit, due to bankruptcy or technological obsolescence, might be sufficient to overcome resistance to change and some employees might willingly look for more secure employment. Older firms in China also have a historical burden of forced excess employment which gives them a lot of scope for improvement. Higher restructuring effects for firms that were initially performing worse should

lead to convergence in operational efficiency, which is an expected outcome from greater market pressure.[31]

Improving material (fuel) efficiency requires firms to operate their plants more efficiently. In the East, the rapid growth of electricity demand from manufacturing is putting greater pressure on the power system to increase output. The greater importance of market prices for coal, as plants are further from the important coal mining areas in the West, could also play a role. At the same time, the higher level of economic development in the East might have facilitated the deployment of more advanced technologies as well as more experienced management. These factors are likely to work similarly for larger firms, where some of the gains might also come from a more efficient deployment of the portfolio of plants.

VI. IMPLICATIONS

In this section we answer three questions to put the estimated restructuring effects in context. What do the point estimates imply? Which additional effects are not captured by the estimates? Are there still efficiency differences among new entrants by ownership type?

The estimates have direct implications for the aggregate resource use of the power sector. Fossil fuel fired, mainly coal fired units remain extremely important in China. By the end of the sample period in 2007, they accounted for 77.4% of total installed electricity generation capacity of 718 GW and even 83.3% of total electricity generation of 3,264 TWh.[32] In 2002, the group of treated firms accounted for at least 39.5% of all thermal electricity generation, based on the revenue statistics in our data set. If the input gap between them and the control firms had remained constant rather than declining by 7 per cent for employment and 5 per cent for material use, 22,100 additional workers would have been employed in the electricity generation sector in 2007, workers not available for other fast-growing segments of the economy. Coal consumption would have been approximately 27.4 million tonnes higher.

The impact on pollution is also nonnegligible. Aggregate statistics for the industry suggest lower levels of pollution per kWh of electricity: a 33% decline in dust emissions per kWh from 2002 to 2006 and 26% lower SO_2 emissions by 2007 (OECD [2010]). The estimated reduction in coal consumption translates directly into lower CO_2 emissions. The above estimate suggests a reduction of approximately 78 million tonnes of CO_2 emissions each year, more than the total for North Korea, the 43rd largest emitter in the world, or 1.4 per cent of total U.S. emissions.

[31] We also report the estimated revenue coefficients in Table V. Only for the firms that we expected to perform better initially, those in the East, young, and large firms, are they estimated in line with theory and with reasonable standard errors.

[32] These statistics are from China Electricity Council: *http://www.cec.org.cn/tongjixinxibu*

Aggregate statistics on the coal intensity for the sector show a decline between 2002 and 2006 of 4.2 per cent, from 383 to 367 g/kWh. This is remarkably similar to our estimate of a 5.0 per cent improvement in material productivity. The two estimates are not entirely comparable as two opposing factors that influence the aggregate did not contribute to the identification of our estimate. On one hand, greater efficiency of new plants which use more advanced technology and tend to operate at a more efficient scale improves the aggregate coal intensity. On the other hand, an increased share of coal-fired plants in total electricity generation increases aggregate coal use per kWh.

Entry of new and more efficient firms does not contribute to the identification of our restructuring effect as each firm is implicitly compared to its own past performance by including firm-fixed effects. This is potentially a large omission as stronger competition should improve the quality of entering firms as better performance is required for survival. It also accelerates the replacement of older, less productive units with more modern and efficient units. Yet another omitted effect is the noticeable decline in input use by the group of control firms. This is especially large for material expenditures, see Figure 1. To some extent it might simply capture changes in (relative) prices for electricity and coal, but part of the decline is likely to be an indirect effect of the 2002 restructuring and the more competitive market environment it generated.

Given these additional factors, our estimates should be considered a conservative estimate of the restructuring benefits. The continued increase in China's electricity consumption, by a further 38% between 2007 and 2011 for a cumulative increase of 164% since the start of the reform, further magnifies the effect of the efficiency gain.

The estimated efficiency gains imply more rapid improvements in labor and material productivity for continuing firms that were state-owned in 2002 than for IPP's. At the same time, thermal generation capacity increased rapidly: more than doubling from 266 GW at the onset of the reforms to 556 GW at the end of the sample period in 2007. Using the estimated input demand equations, we can compare remaining discrepancies in efficiency among active firms at the end of our sample period and even look at new entrants. The firm-level residuals provide estimates for adjusted labor and material input use, correcting for revenue, wage, and unobserved price differences. We subtract time effects that affect all firms, but leave the firm-fixed and the restructuring effects in the residuals.

Table VI contains the raw input-output ratios as well as the adjusted input use statistics calculated from the estimated residuals. In the first panel, we compare state-owned firms in 2002, the treated firms in our analysis, with the control group of IPP's. The simple input-output ratios indicate that treated firms use markedly more workers. In logarithms the difference in material use is not statistically significant, but in levels it is (see

TABLE VI
PRODUCTIVITY DIFFERENCE IN THE CROSS-SECTION OF FIRMS

	State-owned firms mean	IPPs mean	Difference in means (st. error)
(a) All active firms in 2002			
ln(Employment/Revenue)	–5.035	–5.780	0.745 (0.085)***
ln(Material/Revenue)	–0.347	–0.350	0.003 (0.027)
Employment use (adjusted)	4.717	4.145	0.572 (0.071)***
Material use (adjusted)	0.706	0.672	0.035 (0.021)*
Number of observations	369	654	
(b) New entrants (after the reforms) in 2007			
ln(Employment/Revenue)	–7.338	–6.728	–0.611 (0.194)***
ln(Material/Revenue)	–0.369	–0.329	–0.040 (0.046)
Employment use (adjusted)	3.907	3.721	0.187 (0.099)*
Material use (adjusted)	0.402	0.442	–0.040 (0.049)
Number of observations	56	329	
(c) Firms classified as treated (state-owned in 2002) in 2005			
ln(Employment/Revenue)	–5.702	–5.828	0.126 (0.192)
ln(Material/Revenue)	–0.344	–0.393	0.049 (0.064)
Employment use (adjusted)	4.864	4.489	0.375 (0.142)***
Material use (adjusted)	0.596	0.479	0.118 (0.047)***
Number of observations	183	61	

Note: ***, **, * indicates significance at 1%, 5%, or 10% level.

Table I). Adjusting for observable differences using the estimated factor demands, the comparison reveals significantly higher input use for treated firms. The difference is a lot higher for employment than for material expenditures, 0.572 versus 0.035, but note that average expenditures on materials is eight times higher than on wages.

The comparison in the next panel for firms that entered after the start of reforms shows a markedly different situation. Not only did the share of state-owned firms decline to 14.5 per cent of new entrants compared to 36.1 per cent of active firms in 2002, they even used fewer workers and less material per unit of revenue than other firms. After adjusting for observable differences, state-owned firms still employ an excess of workers, but the gap with IPP's has declined from 0.572 in 2002 to only 0.187 for newly entered state-owned firms. Their material productivity is not significantly different from IPP's.

Finally, the results in panel (c) of Table VI compare input efficiency between two groups of restructured firms, distinguishing between firms that

remained state-owned and those that changed ownership status. We already know from the benchmark estimates that these firms improved more rapidly than others, but we now find further differences within this group. In 2005, three years after the reforms started, adjusted employment and material use are respectively 31.2 and 11.1 per cent lower for firms that privatized (point estimates of 0.375 and 0.118). These firms are converging even more rapidly to the original group of IPP's. Both differences are estimated very precisely.[33]

VII. CONCLUSIONS

We have investigated the impact of regulatory reforms and the vertical unbundling of the dominant integrated firm in China in 2002 on the performance of electricity generation companies. The difference-in-differences method used by Fabrizio *et al*. [2007] to estimate labor and material input efficiency in the United States underlies the analysis, but we modified it to account for specific features of the Chinese situation.

Our data set allows the inclusion of firm-fixed effects to help control for output endogeneity and missing information on input and output prices. Regional variation in the evolution of manufacturing activity provides instruments to break the potential correlation between productivity shocks and output levels. Institutional details on the operation of the electricity and the power coal markets is exploited to construct a flexible proxy for price differentials. Detailed information on firm-type and ownership is exploited to identify which firms can be considered directly affected by the reforms. We investigate the robustness of the results with respect to all these issues.

The results strongly indicate a positive impact on both labor and material input efficiency. We find that it did take a few years for the effects to materialize, which explains the weaker evidence in Du *et al*. [2008] who only had data until 2004. The benchmark estimates suggest that the average firm that was state-owned in 2002 reduced employment by 7 per cent more than the control firms and material input by an additional 5 per cent. The magnitudes of these reform-related input reductions are plausible in light of the estimated reductions in factor use experienced by all firms between 2002 and 2007, respectively 5 and 20 per cent for employment and materials.

Firms that are expected to be less productive initially—those located in the West or Central regions, older, and smaller firms—show stronger improvements in labor productivity, but weaker change in material productivity. One possible explanation is that competitive pressure is sufficient

[33] We show the comparison in 2005 because at the end of the sample period in 2007 an additional 43 restructured firms had exited. The adjusted input difference in 2007 is similar for employment (0.311***), but lower for material input (0.036).

to reduce excessive employment, but technological and/or managerial innovations are needed to improve material (fuel) efficiency. Restructuring effects are less pronounced when they are identified from a broader group of firms with majority state-ownership of equity, rather than from the official state versus non-state categorization. Subsidiaries of the Big 5 generation firms that were created from the breakup of the State Power Company, which include many firms of mixed ownership type, on average did not experience a comparable decline in employment.

Looking towards the future, SERC has indicated that it still plans to liberalize wholesale electricity prices. This would provide firms with additional incentives to maximize profits and minimize costs. Improved deployment of existing capacity could even generate efficiency gains that go beyond single plants or firms. The addition of renewable and nuclear generation capacity in recent years increases the potential benefits of the reforms further, as more coal-fired plants will become marginal producers and responsive to market forces.[34]

Early experiments with competitive wholesale markets in two regions in 2004 and 2005 revealed a number of bottlenecks before efficient dispatching became feasible. Transmission firms had to divest their generation assets, generators had to become residual claimants on their profits, and market distortions due to subsidized coal had to be reduced. Progress has been made in each of these areas. Key remaining impediments for the next phase in the reform process are the need for stronger rule of law and the establishment of a strong and independent regulator. These are political constraints and their resolution will fall to the new leadership to be installed at the end of 2012.

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[34] The famous Three Gorges Dam hydroelectric project alone represented almost 5% of total thermal capacity in 2007. Nuclear capacity is scheduled to rise from 12 GW in 2010 to 24 GW in 2020, with another 25 GW of extra capacity in preparation. Wind capacity has increased slowly to 6 GW, but is becoming more of a priority for the future.

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APPENDIX

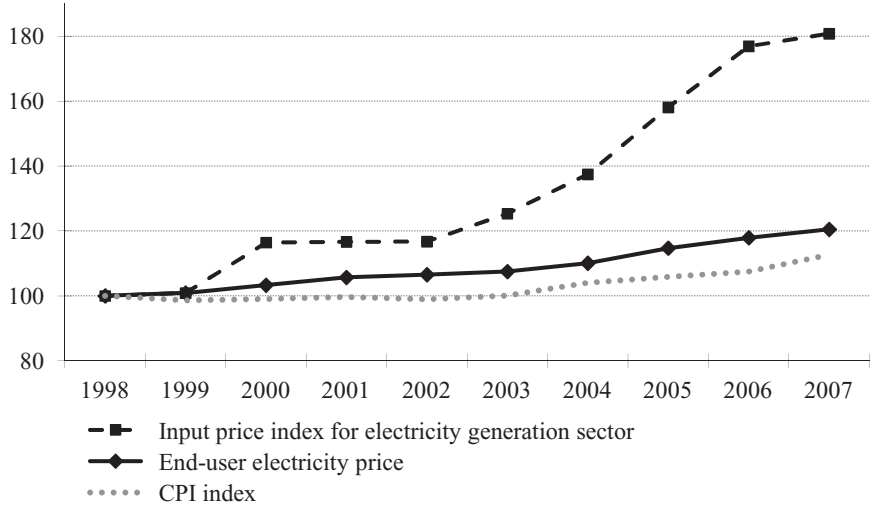

Figure A.1
Price Indices for Electricity, Fuel and General Consumer Prices
Source: National Bureau of Statistics, *http://www.stats.gov.cn*

TABLE A.1
INPUT DEMAND EQUATIONS WITH TIME-VARYING RESTRUCTURING EFFECTS

Dependent Variable:	ln(EMPLOYMENT)		ln(MATERIAL)	
	FE—basic	FE—IV	FE—basic	FE—IV
ln(REVENUE)	0.237 (0.008)***	0.186 (0.194)	0.878 (0.006)***	0.901 (0.123)***
ln(WAGE)	–0.271 (0.008)***	–0.262 (0.035)***		
YEAR1999	0.026 (0.018)	0.027 (0.019)	–0.001 (0.014)	–0.002 (0.014)
YEAR2000	0.000 (0.019)	–0.003 (0.024)	–0.113 (0.014)***	–0.112 (0.016)***
YEAR2001	–0.003 (0.020)	–0.002 (0.019)	–0.063 (0.015)***	–0.064 (0.015)***
YEAR2002	–0.014 (0.020)	–0.010 (0.023)	–0.035 (0.015)**	–0.038 (0.020)*
YEAR2003	–0.015 (0.020)	–0.006 (0.037)	–0.081 (0.015)***	–0.086 (0.032)***
YEAR2004	–0.036 (0.020)*	–0.026 (0.038)	–0.079 (0.015)***	–0.086 (0.035)**
YEAR2005	–0.060 (0.021)***	–0.048 (0.044)	–0.147 (0.016)***	–0.154 (0.039)***
YEAR2006	–0.067 (0.022)***	–0.050 (0.061)	–0.228 (0.016)***	–0.237 (0.052)***
YEAR2007	–0.073 (0.023)***	–0.052 (0.078)	–0.216 (0.017)***	–0.227 (0.065)***
RS*YEAR1999	–0.018 (0.028)	–0.017 (0.029)	–0.023 (0.021)	–0.019 (0.022)
RS*YEAR2000	–0.012 (0.028)	–0.008 (0.029)	–0.020 (0.022)	–0.016 (0.022)
RS*YEAR2001	0.012 (0.027)	0.012 (0.028)	–0.032 (0.021)	–0.028 (0.021)
RS*YEAR2002	–0.007 (0.027)	–0.011 (0.027)	–0.038 (0.020)*	–0.033 (0.023)
RS*YEAR2003	–0.027 (0.028)	–0.027 (0.037)	–0.043 (0.021)**	–0.040 (0.032)
RS*YEAR2004	0.001 (0.030)	0.002 (0.045)	–0.050 (0.023)**	–0.047 (0.040)
RS*YEAR2005	–0.068 (0.031)**	–0.070 (0.044)	–0.083 (0.023)***	–0.079 (0.040)**
RS*YEAR2006	–0.068 (0.032)**	–0.079 (0.044)*	–0.082 (0.024)***	–0.077 (0.041)*
RS*YEAR2007	–0.075 (0.033)**	–0.088 (0.053)*	–0.094 (0.025)***	–0.084 (0.050)*
Observations	10,831	10,792	10,831	10,792

Notes: Labor demand and material input demand estimated using year- and firm-fixed effects (FE-basic) and additionally instrumenting log(REVENUE) with total manufacturing output and employment in a firm's region (FE-IV). The following controls for unobserved prices are included, but not reported: interaction terms of fixed assets, fraction of state-owned capital, and provincial dummies. Standard errors in parenthesis are clustered at the firm level. ***, **, * denotes significance at the 1%, 5%, and 10% level.