

# Herding Cats: Firm Non-Compliance in China's Industrial Energy Efficiency Program

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## ABSTRACT

We study firm responses to a large-scale energy efficiency program in China, focusing on the quality of reporting and compliance outcomes. Using statistical methods to detect data manipulation in compliance reports, we find evidence that firms deliberately exaggerated performance during the first phase of the program (2006-2010), suggesting the high compliance rate was overstated. In its second phase (2011-2015), the number of firms in the program expanded by an order of magnitude, and the compliance rate decreased. We develop a simple model to show how the observed increase in non-compliance is consistent with reduced misreporting. Statistical tests find no evidence of manipulation in the second phase. Larger firms, especially those not controlled by the state, and firms in cities with relatively low growth were more likely to report non-compliance, which suggests a role for state control and local protectionism in shaping compliance decisions. Based on our findings, we offer several lessons for future program design.

**Keywords:** Energy efficiency, Command-and-control, Firm, Compliance, China

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## 1. INTRODUCTION

Initiatives to raise industrial energy efficiency are now common in many nations, but firm compliance behavior remains poorly understood. Globally, the industrial sector is responsible for 54% of energy consumption (Energy Information Agency, 2016) and multiple forms of local pollution. Over the past several decades, the shares of industrial energy use and emissions concentrated in developing and emerging countries has grown substantially (Energy Information Agency, 2016), prompting national governments to establish programs to control them. In these settings, energy efficiency measures are attractive because they are estimated to rank among the lowest-cost abatement opportunities (Intergovernmental Panel on Climate Change, 2014), and do not explicitly restrict firm output. The centrality of energy efficiency programs in the climate pledges of major developing countries such as China and India raises the importance of understanding the determinants of compliance at the firm level.

Industrial energy efficiency programs in developing countries differ from advanced industrialized countries in several ways. First, governments may perceive large tradeoffs with economic development when implementing policies designed to directly or indirectly limit energy use

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(Greenstone and Jack, 2015). Second, rapidly-growing or volatile market conditions in developing countries introduce greater uncertainty into firms' investment decisions. Structural changes in the markets in which firms operate may further create large uncertainties in demand and associated energy requirements (Fisher-Vanden, 2003). Energy efficiency upgrades typically require investing in new equipment or processes, the benefits of which are amortized over multi-year horizons, and returns are easier to predict when operating conditions are stable. Third, state implementation capacity and incentives may be underdeveloped or uneven, especially if the policy is being introduced for the first time and firms lack experience (Kostka, 2016). For instance, firms may collude with regulators, manipulate data, or renege on compliance obligations (Duflo et al., 2013; Ghanem and Zhang, 2014). Implementation may be selective depending on the relationship between state regulators and firms (Wang, 2015; Li and Chan, 2016). All of these attributes are present in the Chinese context.

We analyze the first nationwide initiative to raise energy efficiency in China: the Top 1,000 (2006-2010) / Top 10,000 (2011-2015) Firms Energy Saving Program (hereafter, T1000P and T10000P). Under the program, the government assigned firms roughly equal energy-saving targets proportional to their energy use in the base year. First, we develop a simple model to represent the firm's decision to comply with the program, as well as its propensity to exaggerate or falsify its progress. Second, we use a statistical method to evaluate the plausibility of compliance data submitted by firms, comparing the T1000P and the T10000P. Third, we evaluate the relationship between pre-existing firm characteristics and compliance outcomes, focusing on the T10000P.

Our results are consistent with the notion that if compliance incentives are strong but enforcement incentives are not, firms will exaggerate performance. From this baseline, our model projects that strengthening enforcement incentives will tend to reduce compliance rates. Based on prior literature, we hypothesize that firms that are not accountable to the state through ownership ties as well as large firms that are economically important locally, benefit less from complying and would thus be more likely to not comply. Consistent with this logic, our findings suggest that firms exaggerated performance during the T1000P, but not during the T10000P, when enforcement incentives were strengthened. Meanwhile, non-compliance increased from near zero to around 6-8%, which we interpret as evidence of more accurate reporting. In the T10000P, larger firms not controlled by the state and firms in cities with relatively slow growth were associated with lower compliance on average, consistent with smaller marginal benefits of compliance for these firms.

## 2. LITERATURE AND EMPIRICAL SETTING

### 2.1 Firm compliance with energy and environmental policy

Prior literature on energy efficiency programs focuses largely on developed economies (Allcott and Greenstone, 2012). While much of this literature focuses on individual incentives, a subset probes organizational responses to energy efficiency programs. Studies of firms (DeCanio and Watkins, 1998) and schools (Burlig et al., 2017) have shown that energy efficiency decisions depend on characteristics of the organization. Studies have tended to focus on explaining energy efficiency investments rather than compliance with policy *per se*. Location (including proximity to headquarters and similar firms, see Doshi et al., 2013), size (Benneer and Olmstead, 2008), and stakeholder pressure (Kagan et al., 2003) have been shown to affect firms' willingness to comply with, or even exceed, regulatory targets. In developed countries, studies suggest that compliance rates are generally high and data is broadly trustworthy (Shimshack, 2014), although high profile

cases of data manipulation, such as the Volkswagen emissions testing scandal in 2015, do occur. Evidence from developing countries is much more limited, but suggests that regulatory enforcement is often weak and uneven (Duflo et al., 2013; Van Rooij, 2010).

China is an important context to study the dynamics of compliance with an energy efficiency program for several reasons. First, it has a vast energy-intensive industrial sector responsible for approximately 55% of the nation's energy use (National Bureau of Statistics, 2013), equivalent to more than 10% of the global total (International Energy Agency, 2014). Second, environmental policies have been introduced for years and strengthened by the central government over time, but implementation ultimately depends on local governments and firms. Despite ever stronger policies, there is evidence of a persistent "implementation gap" (Chan et al., 1995), in which policy ambition exceeds achievement. Third, China offers an opportunity to evaluate an energy efficiency program against the backdrop of a rapidly-growing country with unique institutions. Prior work has described how most policies impose rigid targets on firms, limiting spatial and temporal flexibility in compliance responses (Kostka, 2016). The literature has also pointed to a role for local protection (Lorentzen et al., 2014) and state ownership (Hering and Poncet, 2014; Li and Chan, 2016) in shaping firm's responses to policies. In the T1000P and T10000P, for instance, target achievement was included in the government's system for evaluating the annual performance of state-owned firm leaders (Kostka, 2016), while non-state-owned firms only felt pressure indirectly through local leaders who were similarly evaluated on energy efficiency improvements in their jurisdiction. Prior studies have not explored the relationship between these characteristics and compliance in detail.

Our analysis also builds on prior studies that evaluate the T1000P and T10000P in China. Multiple studies suggest both programs were highly effective (Zhou et al., 2010; Ke et al., 2012); here, we assess the underlying quality of the data used to make these judgments. Prior studies also identify a number of implementation challenges. These include a lack of incentives for activities that were not capital improvements, e.g. capacity building (Lu et al., 2014) during the T1000P, and a lack of both transparency and oversight (Price et al., 2010). The interaction between oversight and China's cadre evaluation system may have played a critical role. In China, an important distinction between state and non-state firms lies in the evaluation of leaders. State-owned firm leaders are evaluated as part of the national cadre evaluation process, which includes a wide range of criteria, including environmental performance. In principle, the cadre evaluation system provides a strong incentive for firm leaders to perform in order to earn accolades or promotion, which affect status, reputation, and resource access. Energy-saving target achievement under the T1000P and T10000P was part of the cadre evaluation for state-owned enterprise leaders. However, strong incentives to show compliance combined with uneven or incomplete oversight of data quality may have encouraged exaggeration or falsification of environmental performance.

To summarize, all of the above studies of the T1000P/T10000P adopt a level of administrative aggregation above the firm (e.g. provinces and municipalities) or adopt survey and case study approaches that only cover a small sample of firms. Ours is the first study to examine compliance outcomes at the firm level using a new, multifaceted data set.

## **2.2 Top 1,000 and Top 10,000 Enterprises Programs: Structure and Compliance**

The T1000P was established during the Eleventh Five-Year Plan (FYP, 2006-2010) and included 1,008 industrial firms with energy consumption higher than 180,000 tons of coal-equivalent in 2004 in nine sectors (coal, textiles, paper, chemicals, petroleum and petrochemicals, building

materials, iron and steel, non-ferrous metal, and power and heat)<sup>1</sup>. Together, these firms accounted for about 30% of China's total energy use in 2005.

The program was formally launched in April 2006 with a notice from the National Development and Reform Commission (NDRC) (National Development and Reform Commission, 2006). Each firm was assigned an energy-saving target for the Eleventh FYP (2006-2010). The detailed target-setting process has not been disclosed to the public, but it is reported that the target was roughly proportional to a firm's energy use in 2004 with no consideration of firm-specific energy saving potential (Zhao et al., 2014). The target setting process was similar for the T10000P. Covered firms were required to draft a plan for changes to technology or production processes that would enable them to meet their energy-saving target (National Development and Reform Commission, 2006).

An additional four central government ministries/agencies were involved in administering the T1000P. National Energy Administration (NEA) supported policy implementation among major energy supply firms. National Bureau of Statistics (NBS) was responsible for assembling the relevant statistics for target evaluation. General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) was charged with enforcing the compulsory energy saving standard for key energy-using equipment, e.g. boilers and motors. The State-owned Assets Supervision and Administration Commission (SASAC) was responsible for incentivizing state firms to achieve the targets (National Development and Reform Commission, 2006).

Although authorities evaluated firm progress toward annual targets in 2008 and 2009, the evaluation of target achievement at the end of 2010 for the full five-year period was considered most important, especially for state-owned enterprises (SOEs) involved in the program. The performance of SOE leaders is evaluated by the government. According to program rules, failing to achieve the energy-saving target would reduce their chances of promotion. Firms reported their target progress annually to the local government, and reports were examined by government agencies at different levels as part of the evaluation process. In the first half of each year, a local (e.g. city) government was required to demonstrate firm compliance for the previous year to the provincial government. The provincial data was later summarized by the central government authorities in the NDRC. The NDRC then organized on-site inspections and examination of program documents in every province in the middle of each compliance year (National Development and Reform Commission, 2006, 2011b). The results were subsequently finalized and usually published at the end of the year. However, no formal third-party verification of energy saving was conducted, leaving room for manipulation by firms. According to the final evaluation report by the NDRC (National Development and Reform Commission, 2011a), the program delivered a reduction of about 170 million tons of coal-equivalent energy (relative to a baseline that assumed no change in energy intensity), contributing significantly to the achievement of China's target of reducing national energy intensity by 20% by 2010 relative to its 2005 level.

The T1000P was expanded to the T10000P during the Twelfth FYP (2011-2015). Launched with a notice from the NDRC in December 2011 (National Development and Reform Commission, 2011b), the T10000P included 14,641 industrial firms, hundreds of transportation operators, hotels and restaurants, commercial and trade enterprises, and schools, in total 16,078 institutions. The

1. Firms initially included in the program but closed, stopped production, merged, or changed production significantly were excluded temporarily or permanently from evaluations. Therefore, the total number of firms evaluated in each year was fewer than 1,008. A similar situation existed in the T10000P. Examples of firms that were temporarily excluded from the evaluations were 山西晋能集团金光铁合金有限公司 (Shanxi Jinneng Group Jinguang Ferroalloy Co., Ltd.), 山西磊鑫电力硅镁有限公司 (Shanxi Leixin Electric Silicon and Magnesium Co., Ltd.), and 潞城市兴宝钢铁有限责任公司 (Lucheng Xingbao Steel Co., Ltd.), which were listed among firms that closed or stopped production in 2009, but reappeared in the 2010 evaluation.

coverage threshold in the T10000P was much lower, compared to the T1000P. Thresholds varied by sector/activity: the program covered industrial firms that consumed higher than 10,000 tons of coal equivalent in 2010, transportation firms that either consumed more than 10,000 tons of coal-equivalent energy in 2010, had more than 600 vehicles, or had higher than 50 million tons of throughput, and hotels, restaurants, commercial and trade enterprises, and schools that consumed more than 5,000 tons of coal-equivalent energy in 2010, or hotels and restaurants that had a business area larger than 80,000 square meters, or commercial and trade enterprises that had a business area larger than 50,000 square meters, or schools that had more than 10,000 students (National Development and Reform Commission, 2011b).

To support the expansion of the program, seven additional agencies were involved in the T10000P. Ministry of Finance (MOF) was responsible for formulating specific fiscal policies to support energy efficiency improvement. China Banking Regulatory Commission (CBRC) provided preferred loans for energy efficiency investment and withheld loans from firms that did not achieve the target. The Ministry of Industry and Information Technology (MIIT), Ministry of Transport (MOT), Ministry of Commerce (MOFCOM), and Ministry of Education (MOE) were responsible for enforcing the policy within industrial firms, transportation operators, hotels and restaurants, commercial and trade enterprises, and schools, respectively. Ministry of Housing and Urban-Rural Development (MOHURD) was charged with promoting energy efficiency improvement in buildings. Ministry of Education (MOE) was also tasked with organizing educational programs for energy saving in schools (National Development and Reform Commission, 2011b). Covered institutions in the T10000P, which accounted for more than 60% of China's total energy use in 2010, were required to achieve 250 million tons of coal-equivalent energy saving, or an estimated 920 million tons of CO<sub>2</sub> emissions mitigation in every program year (National Development and Reform Commission, 2011b).

The most notable change from the T1000P to the T10000P was expansion in the number of sectors covered and firms included. Given its broader coverage, the T10000P was designed to deliver a larger share (37%) of the total national energy saving target in the Twelfth Five-Year Plan, compared to the contribution targeted by the T1000P (25%).

### **2.3 A new data resource**

We collect firm compliance information<sup>2</sup> from annual communiques published by the NDRC for compliance years 2008, 2009, 2010, 2012, 2013, and 2014 (National Development and Reform Commission, 2009, 2010, 2011a, 2013, 2014, 2015). For the T1000P, both energy saving target and achievement information are available for all firms. For the T10000P, however, the same information is only available for non-compliant firms. Reported non-compliance rates for the T1000P were very low, but substantially increased when the program was expanded.

Among the 881 firms evaluated at the end of the T1000P in 2010, there were only 15 firms (1.7%) that did not achieve the target. According to three annual evaluations of the T10000P for compliance years 2012, 2013 and 2014,<sup>3</sup> non-compliance rates increased substantially, relative to the T1000P (9.5% in 2012, 8.4% in 2013, and 7.1% in 2014). Table 1 shows the number of non-compliant firms and total firms in each annual evaluation.

2. Firms that either did not achieve the energy saving target or failed to meet other program requirements, e.g. establishing an energy management system, are designated as non-compliant.

3. At the time of writing, only three sets of compliance reports were available for the T10000P. To our knowledge, the government did not publicly release evaluations for 2015.

**Table 1: Numbers of total firms and non-compliant firms in the two phases of the program.**

<b>Panel A: Top 1,000 Enterprises Program (Phase 1)</b>				
	Original list	Evaluation in 2008	Evaluation in 2009	Evaluation in 2010
Total firms	1,008	922	901	881
Non-compliant firms	—	36	28	15
Non-compliance rates	—	3.9%	3.1%	1.7%
<b>Panel B: Top 10,000 Enterprises Program (Phase 2)</b>				
	Original list	Evaluation in 2012	Evaluation in 2013	Evaluation in 2014
Total firms	<b>16,078</b>	14,542	14,119	13,328
Non-compliant firms	—	<b>1,377</b>	<b>1,191</b>	<b>948</b>
Non-compliance rates	—	9.5%	8.4%	7.1%

Since the T10000P only provided energy saving amounts for non-compliant firms and did not provide a full list of evaluated firms for every year, we are able to report the rate of non-compliance among included firms but have to estimate the non-compliance rate by sector (see Table 2).<sup>4</sup> Table 2 shows that non-industrial firms exhibit higher non-compliance rates than industrial firms, especially in 2012. Interestingly, transportation firms and schools, most of which are *shiyedanwei* (public institutions) or large local SOEs, showed relatively high non-compliance rates in 2012, but compliance greatly increased in 2013 and 2014. Overall, the non-compliance rate for industrial firms in the T10000P was still well above that observed in the T1000P.

**Table 2: Coverage and estimated non-compliance rates for the T10000P**

	Original list Total number	Evaluated in 2012		Evaluated in 2013		Evaluated in 2014	
		Number of non- compliant firms	Estimated non- compliance rate	Number of non- compliant firms	Estimated non- compliance rate	Number of non- compliant firms	Estimated non- compliance rate
Industrial firms	14,641	1,174	9.0%	1,038	8.2%	693	5.8%
Transportation firms	548	63	11.5%	37	6.8%	28	5.1%
Hotels and restaurants	195	14	7.2%	13	6.7%	12	6.2%
Commercial and trade firms	260	28	10.8%	29	11.2%	41	15.8%
Schools	434	88	20.3%	48	11.1%	21	4.8%

*Note:* Sectoral information is available only for the original 2011 firm list and non-compliant firms (numbers in bold in Table 1).

We match the firms using firm name and identification number with a comprehensive firm-level data set (the China Annual Industrial Survey, CAIS), which contains very detailed information on firm characteristics and financial performance on all registered firms above 5 million RMB

4. We estimate the non-compliance rate by sector by assuming that firms included in the original list but not in the evaluation in later years are all industrial firms, because many firms/institutions in the other four sectors are large *shiyedanwei* (especially schools) or large local SOEs, and the chances of closing, stopping production, merging, or experiencing a major production change are small. Here *shiyedanwei* (事业单位 in Chinese) refers to a special group of institutions in China, which are also recognized as “public institutions.” Most of them provide public goods or services, and employees are managed similarly to those in government bodies. Therefore, non-compliance rates estimated for industrial firms in 2012, 2013, and 2014 represent an upper bound on actual rates, while non-compliance rates estimated for other organizational types can be interpreted as a lower bound.



(about US \$800,000),<sup>5</sup> as these data are not provided by the NDRC. Table 3 shows the matching results. We have successfully matched almost all (1,001 out of 1,008) of the firms in the T1000P and about half of firms in the T10000P to the 2011 CAIS data.<sup>6</sup> While we cannot rule out the possibility that matched and unmatched firms differ systematically in ways that might affect compliance, the non-compliance rates based on the matched sample (8.5% in 2012, 8.0% in 2013, and 5.0% in 2014) are close to the non-compliance rate for the entire sample (9.0% in 2012, 8.2% in 2013, and 5.8% in 2014).

**Table 3: Industrial firms matched using the T1000P and T10000P data and CAIS data**

	Top 1,000 Enterprises Program				Top 10,000 Enterprises Program
	Original list	Evaluation in 2008	Evaluation in 2009	Evaluation in 2010	Original list
Industrial firms total	1,008	922	901	881	14,641
Industrial firms matched	1,001	862	840	824	7,007
Percentage matched	99.3%	93.5%	93.2%	93.5%	47.9%

Compared to the T1000P, compliance rates decreased in the T10000P across all covered industrial sub-sectors, and even among firms included in the T1000P. Therefore, non-compliance in industrial sub-sectors newly included in the T10000P does not fully account for the increase in the non-compliance rate. Of the 7,007 firms we successfully matched, 4,951 are from nine industrial sub-sectors that were covered in the T1000P, including steel, non-ferrous metal, coal mining, power, petroleum, chemical, building materials, textile and paper. Of the 412 firms included in both the T1000P and the T10000P, the non-compliance rate during the T10000P was 8.7% in 2012, 7.3% in 2013, and 5.1% in 2014, higher than the non-compliance rate observed during the earlier program.

We show the summary statistics for industrial firms successfully matched to the 2011 CAIS data in Table 4. Firms that were already included in the T1000P are older and much larger than other firms in the T10000P. These firms are much larger than other firms in the CAIS data. Firms that are covered by the T10000P are responsible for about 35% and 30% of total gross output and overseas exports, respectively, in the 2011 CAIS data.

## 2.4 Explaining Non-compliance: A simple analytical framework

What explains the increase in reported non-compliance under the expanded program? There are two possibilities. First, firms may have reduced true compliance due, for example, to an increase in abatement costs. Second, data manipulation to achieve reported compliance may have

5. The industry section of the China Statistical Yearbook is compiled based on this dataset. To our knowledge, the CAIS is the most detailed database available for China's industrial firms. The CAIS contains information about each company's identity, address, industry classification, year of incorporation, employment, hierarchical level to which the company reports (regional, provincial, or town), registration type (SOE, collective, stock-limited, private, Hong Kong/Macau/Taiwan, or foreign), and production of three main products in order of relative importance. The data set also includes information on assets, both the year-end level and the change within the year, ownership rights, contractual and actual investments, sales, profits, and exports. In addition, there are detailed records of the breakdown of contractual and actual paid-in capital among the investment sources, such as government, private investors, and/or foreign investors.

6. The imperfect match between the two data sources can be attributed to the fact that some firms included in the T10000P fell below the size cutoff for inclusion in the AIS. Inconsistent firm names or IDs, or outdated information or operating status, also precluded successful matches. Figure 4 shows that the matched sample is representative and able to approximate the full sample of the T10000P firms.

**Table 4: Summary statistics for industrial firms matched to the 2011 CAIS data.**

	Top 1,000 Enterprises Program		New Entrants in the Top 10,000 Enterprises Program		Other firms in the CAIS database	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Age (years)	23.4	21.9	11.5	25.9	8.3	8.5
Gross output (billion yuan)	12.0	26.7	1.5	5.3	0.1	1.1
Share in the total gross output (%)		12.2		22.9		64.9
Share of firms with overseas exports (%)		39.3		29.0		27.0
Share in total exports (%)		2.8		27.6		69.6
Number of firms		435		6,572		220,516

fallen, with the change in true compliance ambiguous. Our empirical setting allows us to measure data falsification in both phases of the program. In the first phase, compliance incentives were strong but enforcement incentives were relatively weak; in the second phase, program documents suggest that enforcement incentives were strengthened.

To study how the combination of compliance and enforcement incentives affects a firm's compliance decision, we construct a simple analytical framework motivated by Kleven et al. (2011)'s model for tax evasion. We consider a risk-neutral, price-taking firm  $i$  maximizing its profit  $\pi_i$ . The firm produces a homogeneous product with price  $p$ . The production cost  $c_i$  depends on its output level  $x_i$  and its investment in energy efficiency  $I_i^e$ , where  $\frac{\partial c_i}{\partial x_i} > 0$ ,  $\frac{\partial^2 c_i}{\partial x_i^2} > 0$ ,  $\frac{\partial c_i}{\partial I_i^e} < 0$  and  $\frac{\partial^2 c_i}{\partial I_i^{e2}} > 0$ .

To simplify the discussion, we assume the production cost is only related to the energy efficiency investment in the current period, therefore we confine our model to a static setting. The firm faces an energy efficiency target and the chance of missing the target is  $p_i^N(I_i^e)$ , which decreases with the level of the energy efficiency investment  $I_i^e$  ( $\frac{\partial p_i^N}{\partial I_i^e} < 0$  and  $\frac{\partial^2 p_i^N}{\partial I_i^{e2}} > 0$ ). We further assume that beyond a sufficiently large energy efficiency investment  $\bar{I}_i^e$ , the target will be met with certainty ( $p_i^N(\bar{I}_i^e) = 0$ ). If the target is not met, the firm faces a loss  $c_i^N$ . The punishment could involve costs to the firm, e.g. ineligibility for low bank lending rates,<sup>7</sup> or non-monetary punishment, e.g. through the cadre management system for state-owned firms only, or loss of reputation. The firm also decides whether or not to invest in manipulation activities ( $I_i^m$ ). If the firm engages in manipulation ( $I_i^m > 0$ ), the probability of being caught by the government is  $p_i^M(I_i^m)$ , which is a decreasing function of the manipulation investment  $I_i^m$  ( $\frac{\partial p_i^M}{\partial I_i^m} < 0$  and  $\frac{\partial^2 p_i^M}{\partial I_i^{m2}} > 0$ ). We assume  $p_i^M(I_i^m) > \underline{p}_i^M$ , meaning there is always at least a chance  $\underline{p}_i^M$  of being caught no matter how large the manipulation investment is. The firm faces a loss  $c_i^M$  if it is caught. Similar to the cost of the pure non-compliance loss,  $c_i^N$ , this loss is firm-specific. The firm always has an outside option of not participating in production with  $\pi_i = 0$ .

The firm first decides whether or not to engage in manipulation and then maximizes its profit. If it does not engage in manipulation, its profit function can be written as

$$\pi_i(x_i, I_i^e) = px_i - c(x_i, I_i^e) - I_i^e - p_i^N(I_i^e)c_i^N.$$

7. We do not observe direct monetary fines imposed on firms for non-compliance in the T1000P and T10000P.



If it engages in manipulation, its profit function can be written as

$$\pi_i^M(x_i, I_i^e, I_i^m) = px_i - c(x_i, I_i^e) - I_i^e - I_i^m - p_i^M(I_i^m) p_i^N(I_i^e) c_i^N - p_i^M(I_i^m) c_i^M.$$

We generate several predictions from the model above.

**Proposition 1:** The firm will not engage in manipulation if the penalty for manipulation is sufficiently high.

**Proof:** If the firm engages in manipulation,  $\pi_i^M(x_i, I_i^e, I_i^m) < px_i - c_i(x_i, I_i^e) - \underline{p}_i^M * \bar{c}_i^M$ , and we can show that  $\pi_i^M(x_i, I_i^e, I_i^m) < 0$  if  $\underline{p}_i^M * \bar{c}_i^M > \bar{\pi}_i^e$  where  $\bar{\pi}_i^e$  is the maximum of  $px_i - c_i(x_i, I_i^e)$ , in other words, the firm would rather stop production than engage in manipulation.

For example, a sufficiently high monetary fine or losing access to bank loans, or a high intrinsic disincentive (e.g. demotion of cadres in a state-owned firm) could deter manipulation. Thus, we would expect the strengthening of enforcement incentives in the second phase of the program to reduce the willingness of non-compliant firms to manipulate data to achieve compliance.

**Corollary 1:** The firm will not engage in manipulation if the penalty for non-compliance is zero.

**Proof:** This result can be easily seen by setting  $c_i^N = 0$ . For a given combination of  $x_i^*, I_i^{e*}, I_i^{m*}$  that maximizes  $\pi_i^M = px_i^* - c_i(x_i^*, I_i^{e*}) - I_i^{e*} - I_i^{m*} - p_i^M(I_i^{m*}) c_i^M$  when the firm engages in manipulation, profit will be higher when the firm does not engage in manipulation ( $\pi_i = px_i^* - c(x_i^*, I_i^{e*}) - I_i^{e*}$ ).

**Corollary 2:** The firm will not engage in manipulation if its optimal private energy efficiency investment is sufficient to achieve the target with certainty.

**Proof:** We first assume the firm engages in manipulation activities, so the first-order conditions are:

$$p = \frac{\partial c_i}{\partial x_i},$$

$$-\frac{\partial c_i}{\partial I_i^e} - 1 - p_i^M(I_i^m) c_i^N \frac{\partial p_i^N}{\partial I_i^e} = 0, \text{ and}$$

$$-1 - p_i^N(I_i^e) c_i^N \frac{\partial p_i^M}{\partial I_i^m} - \frac{\partial p_i^M}{\partial I_i^m} c_i^M = 0.$$

Suppose there exist values of  $x_i^*, I_i^{e*}, I_i^{m*}$  that satisfy the above conditions and maximize  $\pi_i^M$ . If the economic energy efficiency investment is sufficient to achieve the target with certainty, and  $p_i^N(I_i^{e*}) = 0$ . The profit function  $\pi_i^M$  can be again written as  $px_i^* - c(x_i^*, I_i^{e*}) - I_i^{e*} - I_i^{m*} - p_i^M(I_i^{m*}) c_i^M$ . Following similar logic to Corollary 1, choosing not to engage in manipulation will generate higher profit.

**Proposition 2:** With a sufficiently large loss associated with being caught manipulating data ( $c_i^M > \bar{c}_i^M$ ), a non-trivial loss associated with non-compliance ( $c_i^N > 0$ ), and a privately optimal energy efficiency investment that falls short of target achievement

( $|\frac{\partial c_i}{\partial I_i^e}| < 1$ ), the firm will not engage in manipulation and has a positive probability of missing the target ( $p_i^N$ ). The probability is negatively correlated with the penalty for

non-compliance ( $c_i^N$ ) and positively correlated with the return to its energy efficiency investment at the equilibrium  $\left( \left| \frac{\partial c_i}{\partial I_i^e} \right| \right)$ .

**Proof:** Using Corollary 1 and 2 and Proposition 1, the conditions suggest that the firm will not engage in manipulation and there is an interior solution. One of first-order conditions for maximizing  $\pi_i$  is:

$$-\frac{\partial c_i}{\partial I_i^e} - 1 - c_i^N * \frac{\partial p_i^N}{\partial I_i^e} = 0$$

We can easily see that  $\frac{\partial p_i^N}{\partial I_i^e}$  (with a negative value) is positively correlated with  $c_i^N$  and negatively correlated with  $\left| \frac{\partial c_i}{\partial I_i^e} \right|$ . Since  $\frac{\partial p_i^N}{\partial I_i^e} < 0$  and  $\frac{\partial^2 p_i^N}{\partial I_i^{e2}} > 0$ ,  $p_i^N$  is negatively correlated with  $\frac{\partial p_i^N}{\partial I_i^e}$ , so it is negatively correlated with  $c_i^N$  and positively correlated with  $\left| \frac{\partial c_i}{\partial I_i^e} \right|$ . Therefore, the non-compliance rate is negatively correlated with the non-compliance penalty and positively correlated with the return to energy efficiency investment at the equilibrium.

The return to energy efficiency investment is usually hard to observe, and may be endogenous to firm characteristics. In our quantitative analysis, we therefore focus on the role of the non-compliance penalty in explaining the non-compliance rate. This proposition suggests that non-compliance rates are likely to be highest among large non-state-owned firms because (a) larger firms would be less harmed, as they are in a better position to negotiate with the local government, and (b) intrinsic (cadre-evaluation) incentives are lower, relative to state-owned firms.

To summarize, the model predicts that stronger enforcement incentives (e.g., raising the penalty for manipulation) should reduce its occurrence. For a given level of data manipulation and non-compliance penalties, large, non-state-owned firms would be less likely to comply. In the next section, we take these predictions to the data. We first examine compliance outcomes for evidence of manipulation, and then ask which firm characteristics are associated with non-compliance.

### 3. ANALYSIS

#### 3.1 Are compliance reports credible?

As discussed above, firms may engage in manipulation if data quality monitoring is weak and the penalty for manipulation is not sufficiently high. We apply a statistical method described in Chen et al. (2013) to study the credibility of firm compliance reporting during the T1000P, when the program was first initiated and systems for reporting, monitoring, and verifying firms' self-reported data were not well established. Specifically, we first analyze whether or not firms' self-reported energy saving in 2010 is "bunched" above the target in the T1000P.<sup>8</sup> We calculate each firm's energy saving achievement in percentage terms ( $A$ ) by dividing its cumulative reported energy saving during the program by its energy saving target. If firms falsify data by revising upward their actual energy saving number, we expect  $A$  to show a discontinuity around 100%, with a disproportionate number of firms reporting savings just above their target. This discontinuity does not conclusively

8. We can only perform this analysis for the T1000P as it provides the energy saving amount by firm in addition to their achievement status. For the three evaluations in the T10000P, only achievement status (not achieved—未完成 in Chinese, almost achieved—基本完成 in Chinese, achieved—完成 in Chinese, over-achieved—超额完成 in Chinese) is reported, and only for central SOEs. The energy saving amount is only provided for non-compliant firms, and therefore we implement a similar discontinuity test for this subset of non-compliant firms later on. We find no evidence of manipulation.

prove data manipulation occurred. However, in practice an accurate hit is almost impossible as the firm's estimate of energy saving is affected both by total output and energy intensity changes. For example, the energy saving in year  $T$  for a firm,  $S_T$ , is calculated using production data from the current year  $Y_T$  times the energy intensity difference between the current year  $T$  ( $I_T$ ) and the last year  $T-1$  ( $I_{T-1}$ ). Therefore, it is difficult for a firm to simultaneously target energy savings and output with a high degree of precision.

$$S_T = Y_T (I_{T-1} - I_T) \quad (1)$$

The left panel of Figure 1 shows the probability distribution of  $A$  with a bin width of 2.5% for the T1000P. The frequency spikes at the bin for 100-102.5%, where 100% is the cut-off for achievement. We then implement the Burgstahler and Dichev test (BDT) (Burgstahler and Dichev, 1997) to obtain a more quantitative measure of the sharpness of the discontinuity. For any bin ( $j$ ) excluding the first and last, the BDT statistics are computed by comparing the bin's observed probability densities ( $\hat{p}_j$ ) with the average of the neighboring probability density ( $\hat{p}_{j-1}$  and  $\hat{p}_{j+1}$ ), quantifying any deviation from a standard normal distribution as follows:

$$BDT_j = \frac{\frac{\hat{p}_{j-1} + \hat{p}_{j+1}}{2} - \hat{p}_j}{\sqrt{\text{var}\left(\frac{\hat{p}_{j-1} + \hat{p}_{j+1}}{2} - \hat{p}_j\right)}} \quad (2)$$

where  $n$  is the total number of observations, and the variance is given as

$$\text{var}\left(\frac{\hat{p}_{j-1} + \hat{p}_{j+1}}{2} - \hat{p}_j\right) = \frac{1}{n} \hat{p}_j (1 - \hat{p}_j) + \frac{1}{4n} (\hat{p}_{j-1} + \hat{p}_{j+1}) (1 - \hat{p}_{j-1} - \hat{p}_{j+1}) + \frac{1}{n} \hat{p}_j (\hat{p}_{j-1} + \hat{p}_{j+1}). \quad (3)$$

As discussed in Takeuchi (1997), the test is more powerful if the sample size is larger (e.g. more than 500) and the bin width is narrower. With a sample size of around 1,000 observations, our test has sufficient power to detect discontinuities.

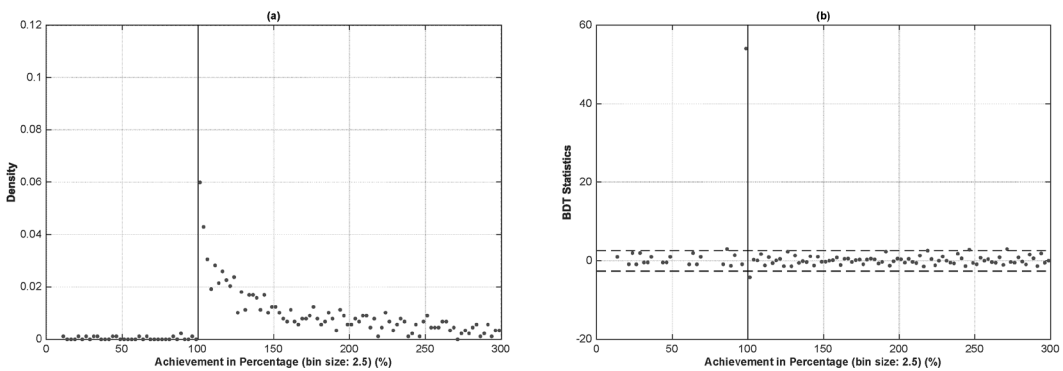
We find a statistically-significant discontinuity in the neighborhood of 100% shown in the right panel of Figure 1. Dashed lines indicate critical values with a confidence level of 99%.<sup>9</sup>

We do not find evidence of data manipulation during the second phase of the program. Although cumulative energy saving data during the Twelfth FYP are only available for the non-compliant firms in 2012, 2013 and 2014, we use the BDT test to check if there is a discontinuity close to the compliance threshold<sup>10</sup> for these non-compliant firms. We expect fewer firms to appear just below the threshold among the non-compliant firms, if firms' reported energy savings are "bunched" just above the threshold, similar to the manipulation behavior documented in Ghanem and Zhang (2014). In Figure A2, A3 and A4, we do not observe any discontinuity around these potential thresholds, which is consistent with the prediction of the model that manipulation should decrease as the expected penalty for manipulation increases. Although absence of evidence is not evidence of absence and we cannot rule out the possibility of energy saving exaggeration by the T10000P firms (Zhao et al., 2016), the increased regularity of data monitoring and the energy management require-

9. There are also three marginally significant outliers around 90 percent, 245 percent, and 275 percent in Figure 1b. We offer two possible explanations. First, observations around these intervals are sparse, increasing the chance of outliers. None of these outliers can be observed when the interval is wider in Figure A1. A second reason for the outlier around the 90 percent mark is that firms that have achieved energy savings just below their targets may manipulate their savings slightly upward to achieve the target, creating a lower density in the 90% to 100% interval. We discuss this possibility in detail in the follow-up statistical test on non-compliant firms in the T10000P.

10. The threshold for compliance, 完成—completed, is 40% for 2012, 60% for 2013 and 80% for 2014, respectively.

**Figure 1: Probability distribution and the Burgstahler and Dichev test for energy saving achievement in percentage terms of firms in the T1000P (bin size: 2.5%)**



ment in the T10000P (National Development and Reform Commission, 2011b) and firm familiarity with energy saving opportunities may have strengthened compliance incentives. Therefore, in the regression analysis we run later to explore firm characteristics associated with non-compliance in the T10000P, we assume manipulation behavior has been effectively deterred.

### 3.2 Firm non-compliance during the T10000P

To the extent that energy saving programs interfere with daily operations or impose costs, we might expect firms to resist or fall short of compliance obligations. The economics literature has long emphasized the direct costs of abatement, and more recently has focused on ancillary costs, such as information acquisition costs, administrative costs, and behavioral factors (Gillingham and Palmer, 2014; Ryan, 2015). However, there is only limited evidence of the origins of any incremental costs in the literature. We assembled a data set of firms' reasons for non-compliance under the T10000P, which they reported to provincial governments and which were later published in annual communiques by the NDRC (National Development and Reform Commission, 2013, 2014, 2015). Several provinces began to supply this information in 2012, and the number of reporting provinces increased over time. Over the years of our sample, there are in total 803 records for non-compliant firms. We categorize them in Table 5.

A firm's unwillingness to comply with the evaluation (Reason 1) was the most frequently reported reason for non-compliance. This reason suggests limits to the program's administrative reach. Firms that are local economic giants may have had strong bargaining power (Lorentzen et al., 2014) and thus an ability to resist inspections. Many organizations failed to submit complete evaluation materials. For example, we find that the Party School of the Central Committee of the Communist Party of China, which has a higher political rank than the NDRC, did not provide complete evaluation materials in 2012. This non-compliance behavior was still made public by the NDRC.

Reasons provided suggest that the difficulty of achieving the target depends on a firm's production characteristics, which in some cases changed significantly and unexpectedly from year to year. The second most common reason given for non-compliance (Reason 2) was that firms closed, stopped production, merged, changed production, or constructed new facilities, rendering the original target difficult to meet.<sup>11</sup> Reasons 3 to 7 similarly illustrate how unanticipated operational con-

11. Whether specific firms should be accounted as firms that "close, stop, merge, or change production" or not was a discretionary decision by provincial governments. Therefore, some firms that might be qualified to be exempted from the T10000P were still recognized as non-compliant in some provinces.

ditions negatively affected compliance—Reason 3 suggests that firms with low levels of production found it difficult to achieve the target, even though their production was very efficient. Indeed, fixed energy requirements and increased stop-start frequency at low levels of production imply economies of scale that increase non-linearly with output. Targets mandate linear decreases in energy intensity, which may be more difficult to achieve if underlying production levels decrease. Conversely, some firms may have been able to achieve the target by expanding production with only minor technical improvements (Zhao et al., 2016).

Some reasons suggest that guidelines for calculating energy savings were not uniformly applied. For instance, some firms claimed that changes in the market price paid for output affected target stringency (Reason 5), however, firms were supposed to have applied a constant price in the calculation. Other non-compliant firms may have incorrectly adjusted energy use to reflect energy content (Reason 6), for instance, when switching to less expensive fuels with lower heating value.

Approximately 34 firms indicated that they were already highly efficient, with limited room for improvement (Reason 8). Firms' historical energy use played a dominant role in the target-setting process, probably with some (limited) provincial or firm-specific adjustments based on estimated energy saving potential (Zhao et al., 2014). Therefore, firms that are already at the energy efficiency frontier may still face very stringent targets. Although the idea of "benchmarking" was introduced in the document, those firms that reported that they were already energy efficient were still judged as non-compliers.

Reasons 9 and 10 suggest that firms newly entering the program could fail solely on the basis of weak internal energy management capabilities, for instance, an underdeveloped energy management system, even if they fully achieved their target.

Some firms failed to achieve annual targets because they were planning large, one-time energy efficiency upgrades that would occur only later in the compliance period (Reason 11). To prevent firms from coming under great pressure to achieve the bulk of their energy saving target at the "Eleventh Hour" (as occurred in the case of power rationing implemented by some provinces at the end of the Eleventh FYP to achieve compliance with provincial energy intensity targets), the Twelfth FYP emphasized the importance of meeting annual targets. However, this requirement limited firm's temporal flexibility to undertake the required upgrades. In some cases, energy saving due to a single technology upgrade could exceed the target required for the entire five years.

To summarize, our survey of self-reported reasons for non-compliance yields several interesting findings. We find a high level of unwillingness to cooperate with authorities implementing the program (the most prevalent reason for non-compliance). We also find evidence that uncertainty in production conditions and weak capabilities to perform energy management functions justified a large share of non-compliant cases. These are reasons that might be more prevalent in developing countries where economies are rapidly evolving, economic growth is top priority, and energy and environmental management systems are being implemented for the first time.

### **3.3 Firm Characteristics Associated with Non-compliance**

To complement the qualitative exploration of self-reported reasons for non-compliance, we perform a regression-based assessment of the relationship between firm characteristics and compliance outcomes in the T10000P. We are interested in the extent to which these two approaches tell the same—or different—stories. We recognize that our analysis is not causal, given that firms' characteristics are interlinked and not randomly assigned.

Firm size, profitability, ownership status, and export status are common control variables used in previous literature (e.g. Bajo et al., 2009 and Doshi et al., 2013), but could plausibly have

direct effects on compliance behavior, to the extent that these groups affect the strength of accountability relationships with provincial and national government regulators. For example, firms that are less profitable may be more likely to miss the target because of low production levels or unstable or limited funds for energy saving investment. We also explicitly test the prediction from Proposition 2, which is that large non-SOEs would have a higher non-compliance rate.

Rates of non-compliance vary widely across provinces, suggesting fundamental differences in energy use and intensity across provinces (Zhang and Broadstock, 2016). In Figure 2, we rank provinces according to their non-compliance rate (share of non-compliant firms to total firms) in 2012 from high to low. Dashed lines show the non-compliance rate of firms that are matched with CAIS, which is a subset of all the firms reported by the NDRC. Though there are minor discrepancies between the two rates, in general they fit pretty well,<sup>12</sup> suggesting that the data set matched with the CAIS is representative and able to approximate the full data set. The range of non-compliance rates across provinces and years varies widely, especially in 2012 with the highest rate above 0.5 and lowest rate of 0.<sup>13</sup> Less developed provinces with high energy intensity (e.g. Ningxia, Xinjiang, Shanxi, and Shaanxi) reported high non-compliance rates. However, surprisingly provinces with the highest development levels and low energy intensity (e.g. Beijing, Tianjin and Shanghai) also reported high non-compliance rates, suggesting firms' targets are stringent, or that the local government is very strict in the evaluation. Compliance rates also vary across sectors,<sup>14</sup> but exhibit a much narrower range and higher consistency over the three years when compared to cross-provincial variation, as shown in Figure 3.

We run a logit regression to analyze factors associated with non-compliance, with coefficients shown in Table 6.<sup>15</sup> The dependent variable is a binary variable for non-compliance. The value of the dependent variable is one if a firm is non-compliant and zero if a firm is compliant. We use the log of main business revenue (in million yuan) as a proxy for firm size,<sup>16</sup> and profit share of revenue (total profit divided by main business revenue) as a proxy for size-normalized profitability. Shareholding status (state, non-state) and authority level (central, provincial, prefectural, county) variables are used to define dummies for ownership,<sup>17</sup> and another dummy is included to distinguish whether the firm was included in the T1000P or not. Oversight of each state enterprise is associated with a different layer within China's multi-tiered government, with the largest, so-called strategic

12. Pearson's correlations are 0.9, 0.8, and 0.7 for 2012, 2013, and 2014 respectively.

13. We doubt the accuracy of Hubei's zero non-compliance rate in 2012 as 33 firms are reported non-compliant in 2013.

14. We categorize firms into eleven sectors. Nine sectors are industries listed in the T10000P, and the other two sectors are other mining industries and other manufacturing industries besides those nine sectors.

15. In the regression, we include all firms that are successfully matched between the CAIS data and compliance data. However, as discussed in the last section, firms that close, stop, merge, or change production may be exempted from evaluation. The decision to consider a firm as having "closed, stopped, merged, or changed production" was at the discretion of the provincial government. Therefore, some firms that might qualify for an exemption were recognized as non-compliant in some provinces. We run a robustness check of our regression with these firms excluded from the sample, and the result does not change in magnitude or sign. We cannot exclude the possibility that some firms strategically reported that they "closed, stopped, merged, or changed production" to avoid inclusion in the evaluation, and might have appeared in our sample of compliant firms. However, any resulting error is expected to be very small, as we focus on the predictors of observed non-compliance.

16. Other variables, e.g. total employees and total assets, can also be used as proxies for firm size. Our main results stay robust when including them both in the regression.

17. The omitted group includes both domestic private and foreign firms. Our rationale for grouping these firm types is that state-owned firms are expected to feel substantially greater pressure to comply with domestic policy, relative to private or foreign firms. Adding a foreign firm dummy and interaction term generates insignificant coefficients and does not change the main results.



**Table 5: Self-reported reasons for non-compliance in the T10000P.**

No.	Reasons	Number of firms	Description
1	Did not cooperate with the evaluation or did not provide complete data	245	Firms refused or failed to completely submit the self-monitoring report, energy data, or any other materials required for the evaluation.
2	Ceased production, merged, product portfolios changed, or new buildings	179	Firms faced bankruptcy or stopped a substantial part of or entire production temporarily or permanently, merged with other firms, or added energy-intensive products to their portfolios. Energy saving targets of schools were linked to the number of students, therefore constructing new buildings made targets harder to achieve if the number of students was unchanged.
3	Low or unstable production	161	Production level was lower than expected, and therefore the energy savings linked to production was limited. A lower production level could increase the unit energy consumption of the product as more frequent starts and stops reduce the efficiency of operation.
4	Uncertain energy use per unit of production	26	Some firms had a production process with fluctuating energy efficiency, especially for some transportation firms.
5	Product price decrease	5	Decreasing product price could bring down the output in value terms for a firm with the same input use, and therefore energy consumption per unit of output in value terms increased.
6	Lower heating value fuels	5	Fuels with a lower heating value than those previously used could lead to an increase in reported energy use if firms did not measure the heating value change to correctly convert the energy use to coal equivalent units.
7	Ongoing construction project	5	Energy use increased due to new projects under construction.
8	Little room to improve energy efficiency	34	Firms were very efficient already, with little room to improve.
9	Limited capacity in firms newly included in the program	28	Firms newly included in the evaluation might not have accurate historical data or an energy management system, or lack capacity to achieve energy saving or complete the evaluation.
10	Poor energy management	12	Firms had very low energy management scores.
11	Ongoing or planned technology upgrading	11	Firms were implementing technology upgrades, or had plans to enhance energy efficiency in later years during the Twelfth FYP.
	Other "reasons"	98	Reasons are not relevant or cannot be justified. For example, firms changed their names, or firms claimed insufficient funds to invest in energy efficiency.

*Note:* Some firms had more than one reason for non-compliance, therefore the numbers do not add up to 803.

enterprises associated with the central government and a much greater variety associated with local governments. All independent variables<sup>18</sup> are acquired from the 2011 CAIS data as we do not have access to CAIS data for later years.<sup>19</sup> We include province-year and sector-year fixed effects in all specifications to control for unobserved factors that are constant within a province or a sector in different years, e.g. target-setting differences across provinces or different rates of technological advance across sectors. There is much unobserved information that would ideally be included in our regression but is unavailable, e.g. a firm's marginal return to energy efficiency investments and the

18. Although the CAIS data includes additional variables for some years that could plausibly be associated with compliance, most are not available for the year 2011. For example, although R&D expenditures in early years and year-to-year variation in revenue can be calculated by merging data for 2009 through 2011, the sample size is reduced to one-third of the original data due to incomplete firm coverage in these years (Brandt et al., 2014). When we include R&D expenditures and variation in revenue in a regression using this smaller sample, we find no statistically-significant associations between these variables and compliance.

19. We perform a cross-sectional analysis as we have access to only one year of industrial survey data for firms during the T10000P. Using data on firm characteristics that predates observations of compliance reduces the concern that our regressors are endogenous to firm compliance outcomes.

Figure 2: Non-compliance rate by province for all the firms and firms matched with CAIS data in 2012, 2013 and 2014.

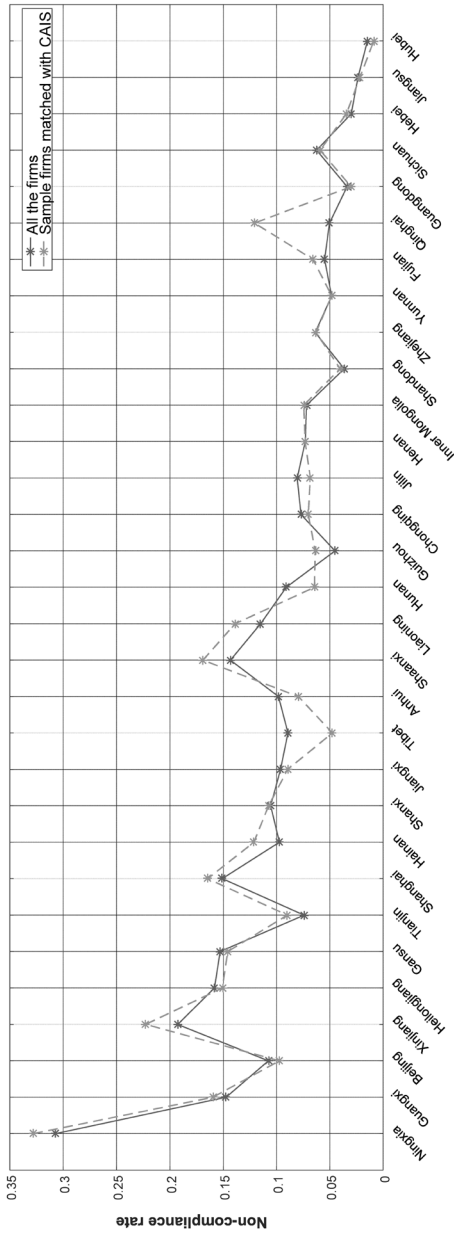
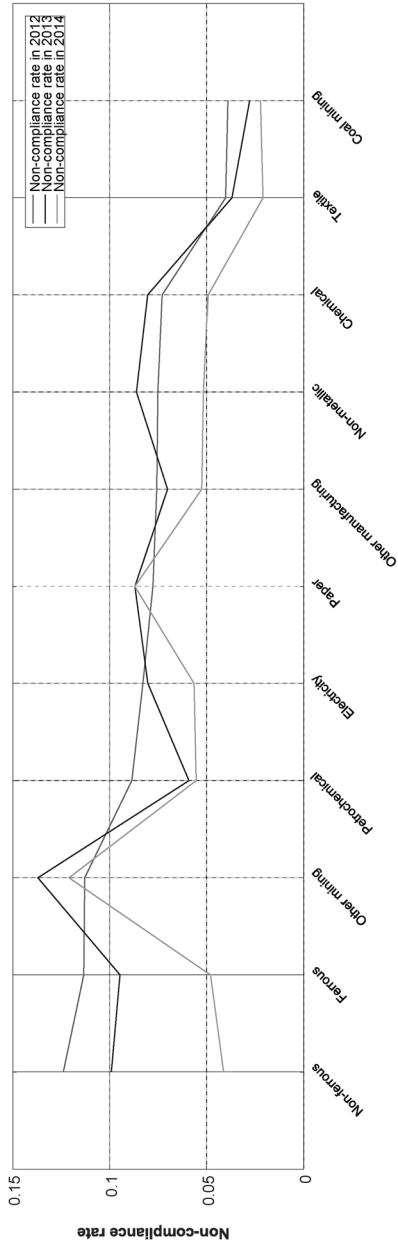


Figure 3: Non-compliance rate by sector for firms matched with CAIS data in 2012, 2013 and 2014.



amount of state energy efficiency subsidies. We do not include these intermediate variables, as we are concerned that they may be endogenous to firm characteristics and compliance.

We find that larger firms are more likely to be non-compliant. This finding is consistent with the hypothesis tested in Lorentzen et al. (2014) that industrial giants may be shielded from the pressure to implement environment standards. SOEs under central and local supervision are obligated by the government to report energy saving as part of annual cadre evaluations, and exhibit a slightly lower non-compliance rate compared to the non-state owned firms.

In a specification shown in column (5) of Table 6, we interact the size proxy, log revenue, with SOE dummies, and find the coefficient of the size variable still significant and positive, but the coefficients of the interaction terms are significant and negative. Therefore, it is the non-SOEs that are associated with increasing non-compliance as their size increases. The result is consistent with the prediction from Proposition 2. Large, non-state firms are not subject to the direct control of the government and their business contributes significantly to local tax revenue (Lorentzen et al., 2014). Therefore, they face relatively lower pressure from the local government, and thus would be expected to reduce non-compliance to a lesser degree than SOEs (e.g. because leaders in non-state-owned firms are not subject to the cadre evaluations that are applied to SOE leaders) or smaller firms (e.g. larger firms would be less harmed by the possibility of losing access to bank loans, as they are in a better position to negotiate with the local government), reducing the probability of achieving the target. Central SOEs, especially the larger ones, face more pressure from the central government to achieve the targets, which can be seen from the fact that the interaction effect that brings down the non-compliance rate with increasing size is larger for central SOEs. These firms are also usually better managed and have an “energy office” (or at minimum an “energy manager”) in charge of tracking and improving energy efficiency, while other firms may not have a specific person responsible for energy management. For example, prior research suggests that these firms often rely on the firm’s accountant, who knows very little about energy, to report energy use, resulting in substantial misreporting (Kostka, 2016).

Finally, firms included in the T1000P show slightly lower non-compliance rates in the T10000P, as they may have a well-established energy management system and take the energy

**Table 6: Factors predicting non-compliance with the T10000P.**

	(1)	(2)	(3)	(4)	(5)
Log (main business revenue)	0.07	0.08*	0.09*	0.10*	0.17***
(million yuan)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
Profit share of revenue		-0.32	-0.34	-0.34	-0.31
		(0.32)	(0.32)	(0.32)	(0.32)
Central SOE			-0.05	-0.03	2.22***
			(0.17)	(0.17)	(0.63)
Local SOE			-0.13	-0.11	0.86*
			(0.14)	(0.14)	(0.37)
Top 1,000 enterprise				-0.21	-0.11
				(0.13)	(0.13)
Log (main business revenue) * Central SOE					-0.32***
					(0.08)
Log (main business revenue) * Local SOE					-0.17*
					(0.07)
Province-year fixed effects	YES	YES	YES	YES	YES
Sector-year fixed effects	YES	YES	YES	YES	YES
Number of years	3	3	3	3	3
Number of observations	19399	19399	19399	19399	19399

Note: Standard errors are clustered at the province level. \*P < 0.10, \*\*P < 0.05, \*\*\*P < 0.01.

saving targets more seriously. Though not significant, we find firms with higher profitability are more likely to fail to achieve the target. In regressions that we do not show here, we also add an export dummy (equal to unity if the firm exports overseas, and zero otherwise) and share of overseas exports in gross output in additional specifications. We do not find a significant effect of any of these export-related variables in any of those regressions. Therefore, our findings suggest that the exporting status of a firm had no impact on its compliance behavior. In Table A1, we use the values from the 2006 CAIS data for the same independent variables in all regressions discussed above and find the results remain strongly robust (both significance and direction) when compared to Table 6.

Macroeconomic and institutional characteristics also seem to matter, consistent with findings from the non-compliance self-reports above. We include per-capita GDP at the prefecture city level (in 10,000 yuan) and GDP growth rate in percentage terms from 2012 to 2014 in the regression. Cities with higher per-capita GDP may feel increased policy stringency as the local cadres put more weight on environmental performance, however, firms in those cities may have more difficulty achieving the target as they should be cleaner and the marginal cost of energy efficiency improvements is higher. Similarly, the expected effect of GDP growth rate is also ambiguous. Cities with higher growth rates may emphasize economic development more, and have higher tolerance for non-compliance, but firms in those cities may find it easier to achieve the target because—as previously explained—expanding production can lower the required energy intensity reduction. Table 7 shows the regression results.

**Table 7: Factors predicting T1000P non-compliance (dependent variable).**

	(1)	(2)	(3)	(4)
Log (main business revenue) (million yuan)	0.10*	0.09*	0.10*	0.18***
Profit share of revenue	(0.04)	(0.04)	(0.04)	(0.05)
Central SOE	-0.45	-0.44	-0.44	-0.40
	(0.26)	(0.26)	(0.26)	(0.27)
Local SOE	-0.04	-0.02	-0.02	2.74***
	(0.18)	(0.18)	(0.18)	(0.58)
Top 1,000 enterprises	-0.09	-0.09	-0.09	1.07**
	(0.14)	(0.14)	(0.14)	(0.35)
Log (main business revenue) * Central SOE	-0.23	-0.24	-0.24	-0.13
	(0.14)	(0.14)	(0.14)	(0.14)
Log (main business revenue) * Local SOE				-0.39***
				(0.07)
Per-capita GDP	-0.00		-0.01	-0.00
	(0.03)		(0.03)	(0.03)
GDP growth rate		-0.03***	-0.03***	-0.03***
		(0.01)	(0.01)	(0.01)
Province-year fixed effects	YES	YES	YES	YES
Sector-year fixed effects	YES	YES	YES	YES
Number of years	3	3	3	3
Number of observations	17188	17188	17188	17188

Note: Standard errors are clustered at the province level. \*P < 0.10, \*\*P < 0.05, \*\*\*P < 0.01.

We do not find that the development level of the city where the firm is located had a major impact on compliance behavior. However, we find that firms in cities with higher GDP growth rate have a higher compliance rate. This may reflect the fact that firms in these cities are realizing energy savings as they grow the scale of their operations. Observed effects remain consistent in sign and magnitude across all specifications.

#### 4. FROM COMMAND-AND-CONTROL TO MARKET-BASED POLICIES

Reducing energy intensity via command-and-control, firm-specific targets as in the case of the T1000P and T10000P imposes uneven costs on firms. In contrast, market-based policies are more flexible, and in theory result in abatement at a lower marginal cost that is equalized across firms. Against this backdrop, China has announced that it will launch a national emissions trading system starting in late 2019. This system will target CO<sub>2</sub> associated with fossil energy use, partly replacing a major function of the T10000P in the long term. Indeed, emissions trading has been advanced as an answer to concerns plaguing the command-and-control approach, including importantly a lack of flexibility to undertake reductions where they cost least. Based on the analysis above, we discuss some of the tradeoffs in moving from a command-and-control to market-based approach in the Chinese setting.

##### 4.1 The case for an ETS: Greater flexibility

Several years into the T10000P, it became clear that some firms, especially those that were already very energy efficient, faced great difficulty in achieving an energy saving target largely based on total energy use, but ignoring marginal abatement costs. This situation is illustrated by the following statement from the Datang Jixi Thermal Power Company in 2013:

*“The company’s two 125 MW generation units are already the most energy efficient ones compared to other units with similar type in China. There is no room to improve the energy efficiency, therefore the energy saving target is not achieved. In order not to add a negative impact on Jixi City’s Twelfth FYP energy saving target, Datang Heilongjiang Power Company has negotiated with Datang Jixi No. 2 Thermal Power Company,<sup>20</sup> and signed an agreement regarding the target sharing of the energy saving target during the Twelfth FYP. Datang Jixi No. 2 Thermal Power Company will carry the 22,000 tons of coal equivalent energy saving target for Datang Jixi Thermal Power Company. This case has been reported to the Jixi Development and Reform Commission for approval.”*

This case of spontaneous energy saving trading implies that the two companies faced highly uneven marginal abatement costs, to the point that they engaged in trading on their own initiative. Many existing studies have also found highly heterogeneous cost in energy saving across sectors and provinces in China and an effective ETS would have the potential to equalize the marginal abatement cost and reduce welfare loss (Wei et al., 2013; Zhang et al., 2013). However, the effectiveness of the ETS will not be fully exploited without a liquid emissions permit market, low transaction costs, and allowance trading desks. A functional ETS will require continuous efforts to overcome the low liquidity problems that existed in China’s pilot CO<sub>2</sub> markets and pilot SO<sub>2</sub> markets (Hart and Ma, 2014).

Temporal flexibility is also important, given that changes to production technology or practices that substantially reduce energy consumption may take several years to implement fully. By requiring firms to achieve an annual energy saving target, firms may fall in and out of compliance from year to year as they pursue least-cost opportunities for achieving their total energy-saving target. This suggests the merits of allowing firms to bank allowances under an ETS.

Recognizing the advantages of greater flexibility, architects of the T10000P endorsed the necessity of the energy saving trading scheme in the original implementation plan. However, we

20. Jixi City is a city in Heilongjiang Province, and Datang Heilongjiang Power Company is the parent company of both Datang Jixi Thermal Power Company and Datang Jixi No. 2 Thermal Power Company. Datang Jixi No. 2 Thermal Power Company is also in the T10000P.

find that only Jiangsu Province officially launched energy saving trading in 2015.<sup>21</sup> Moreover, no official guidelines were provided for the accounting of allowances bought under the T10000P, increasing the risk that purchased allowances would not be counted toward compliance obligations and ultimately limiting firms' participation in large-scale energy saving trading programs.

#### 4.2 The need to evolve institutions alongside policy

Moving to a market system such as an ETS could, however, undermine well-defined administrative mechanisms for achieving compliance, which relies on the strong relationship between the government and large, often state-owned enterprises. Many of these enterprises overfulfilled their targets by a large margin. Figure 4 shows the overall energy saving achievement rate at the provincial level, defined as the total energy savings achieved by all the firms in the province divided by the aggregated energy saving target at the provincial level, ranked from the lowest to highest. In each of the three years covered by our data set, all provinces passed their aggregate targets (40%, 60%, and 80% respectively). In 2013, about half (15) of the provinces had already achieved their cumulative energy-saving targets for the five years of the program. This total increased to 25 provinces by the end of 2014. This suggests that many firms overfulfilled their energy saving target, because of either inexpensive energy saving opportunities or great support/pressure from the government. In other words, in order to achieve its centrally-mandated provincial target, the provincial government does not necessarily push every firm to achieve its individual target. It can instead lean on a number of key firms to overfulfill the target, raising the total energy saved in the province as a whole.<sup>22</sup>

The non-compliance and target achievement data provide some support for this mechanism. Beijing and Shanghai have the highest provincial target achievement rates. However, they also have high firm non-compliance rates at the same time. This strategy reflects a potentially rational calculation by the provincial government: as energy intensity reduction at the provincial level is the primary index that enters the performance evaluation, it might be much easier to reduce energy use by leaning hard on fewer firms, especially on SOEs with direct government reporting links. This is confirmed by the fact that the extent to which energy saving targets were exceeded by central SOEs<sup>23</sup> is higher than the rates achieved by all firms across all provinces shown in Figure 5. Government enforcement pressure may be less effective if these firms have the opportunity to purchase reduction credits from outside their own boundaries.

In theory, with the introduction of the ETS, the government could still facilitate reliance on SOEs by requiring more abatement and providing additional subsidies. However, requiring SOEs to abate more is not feasible under the current allocation rule set by the NDRC, because the allowance allocation is to be solely based on the firm's benchmark emissions intensity or historical emissions without differentially treating SOEs (Pizer and Zhang, 2018). Additional abatement targets and/or subsidies would thus have to be arranged separately from the ETS. As a result, the success of the national ETS may depend on whether or not it can elicit true compliance from large non-SOEs that will be part of the future system.

21. In Jiangsu Province, energy saving trading is not limited to only the T10000P enterprises. Besides incentivizing energy saving, one purpose of the policy is to allow firms in energy-intensive sectors that are restricted from expanding production capacity to add new installations after buying allowances for "energy saving capacity."

22. We note that the over-fulfillment of targets may reflect the influence of other policies beyond the T10000P that supported energy saving. These complementary policies are likely highly heterogeneous across provinces. Due to data availability, we are not able to explicitly include these policies in our firm-level analysis. However, this should not affect our regression results because the province-year fixed effects capture heterogeneity at the provincial level.

23. We only have the detailed achievement status information at the firm level for central SOEs.



Figure 4: Overall energy saving achievement rate at the provincial level in 2012, 2013 and 2014, relative to program targets.

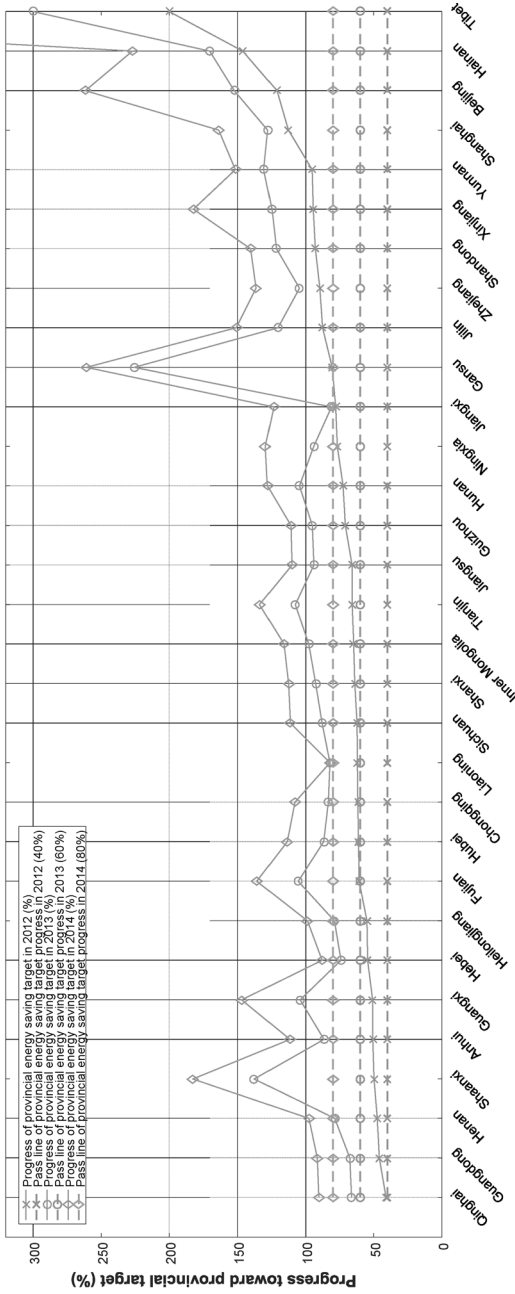
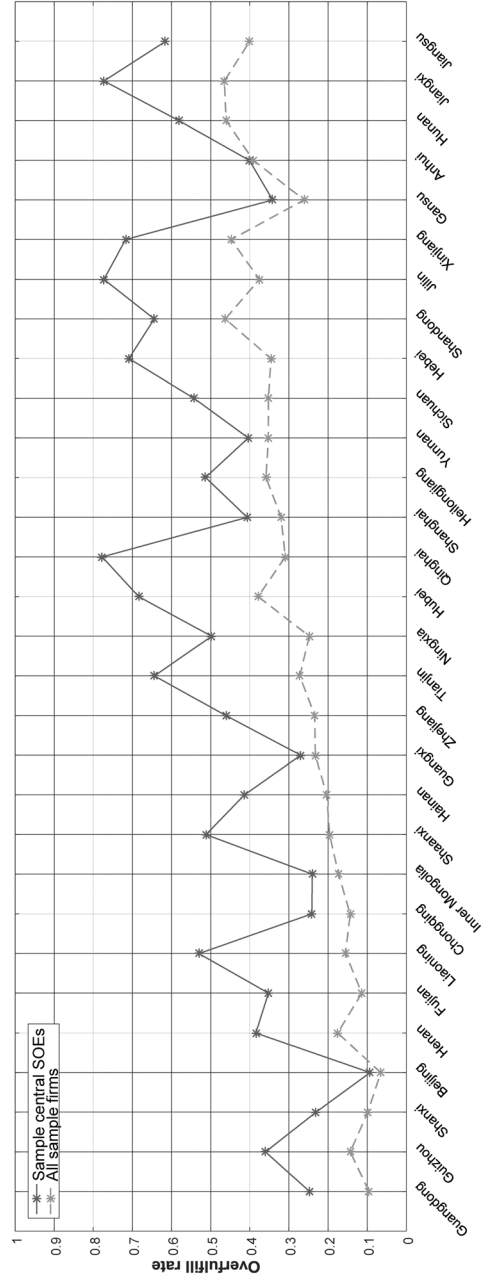


Figure 5: Rate by which central SOEs and all firms exceeded their energy saving targets in 2012, 2013 and 2014.



Longer term, relying on a limited pool of enterprises carries its own challenges for energy governance. The (over-)reliance on these firms also reveals the limited capacity of the local government to supervise and motivate a large number of firms to save energy, especially after the program was greatly expanded during the Twelfth FYP. Provincial and city governments may face strong incentives to rubber stamp without scrutinizing self-reported firm-level energy saving, as they do not want to miss their targets. At the central level, there is no detail available on the scrutiny applied to the energy saving data (i.e. no inspection reports or audits are published) for participating firms. Given that the T10000P involved over 14,000 entities, this is no doubt a very challenging task that requires substantial investment in monitoring infrastructure and personnel training.

### **4.3 Lessons for Future Policy Design**

The T1000P and T10000P provide an important common basis for future energy and CO<sub>2</sub> emissions reduction policies, regardless of whether they are command-and-control or market-based. First, it represents a major effort to evaluate and reduce energy intensity in a large, internally diverse developing country, and firm responses (whether real or fabricated) suggest that the program did not go unnoticed. The transparency of compliance data is also unusual, and may have placed additional compliance pressure on firms.

Second, the program appears to have lowered the barriers for firms to engage in energy saving, for instance, by taking advantage of energy retrofit programs available to all firms. Beyond the aid of the central government, many provincial governments initiated their own energy-saving programs that set firm-specific targets and provided financial aid to hundreds of firms within the province. For instance, Shanxi People's Government launched the "Shanxi 1,000 Firms Program" that involved more Shanxi firms, including those firms under the national T1000P during the Eleventh FYP (Government of Shanxi Province, 2008).

Third, data collection and transparency mechanisms required for program effectiveness were established and are being improved. We do not find evidence that firms falsified target achievement during the T10000P, in contrast to the T1000P. NDRC's public release of the program's compliance documents will facilitate program evaluation and improvement.<sup>24</sup> Previous studies have found that higher public participation, transparency of results, and easier access to information can improve the outcomes of environmental policies (Scruggs, 2003; Lipsy, 2011).

A national ETS for CO<sub>2</sub> could potentially complicate, and not easily coexist with, a follow-on program to the T10000P in the Thirteenth FYP and beyond. There are seven provincial administrative regions that have launched ETS pilots during the Twelfth FYP (Zhang et al., 2014), and most ETS pilots apply a lower annual energy consumption threshold to determine firm participation. Therefore, most T10000P firms in these pilot provinces are assigned both energy saving targets and emissions allowances. Therefore, to achieve the energy saving target for the T10000P, some firms had to reduce energy use within firm boundaries rather than buy allowances from the ETS, even if it would have been cheaper. If this were to occur on a large scale, it could undermine the effectiveness of an ETS.

## **5. CONCLUSION**

Those who are familiar with Chinese central-local relations and environmental governance often quote the famous Chinese proverb that "the mountains are high and the emperor is far away,"

24. We also note some minor inconsistencies and errors in these documents (limited to firms in some provinces, see the Appendix of Karplus et al. (2016) for details).

but finding strong evidence of local firms shirking central directives is usually not easy. The detailed records released for the T1000P and T10000P provide us with a unique opportunity to study data quality and drivers of non-compliance in a major national energy efficiency program in China. By presenting this new data set as a resource for the research community, and applying it to examine the integrity of reporting and antecedents of non-compliance in firms, our analysis lends new insight into the dynamics of policy implementation in a large, developing economy.

Our findings are consistent with a role for attributes that distinguish developing country efforts to control energy use—sharp tradeoffs with economic growth, volatile market conditions, and limited government and firm accountability—in shaping outcomes under the T1000P and T10000P. Our analytical framework considers these elements from the perspective of a firm decision-maker, which allows us to identify conditions that could explain the high initial compliance rate and the subsequent increase in non-compliance. In the first phase of the program, we find evidence of falsified and/or exaggerated reporting. This observation is novel and casts a shadow on prior claims that the T1000P exceeded its target by almost a 50% margin (National Development and Reform Commission, 2011a). Any perceived benefit to firms (in the form of reduced private energy costs) must therefore have been insufficient, or too uncertain, to uniformly incentivize firms to comply. Meanwhile, weak MRV capabilities meant that the costs of falsifying compliance were low, while the reputational cost of missing targets was high, especially for the primarily state-owned enterprises participating in the program.

In the second phase of the program, we find no evidence of falsification, but we observe an increase in non-compliance. Results from the second phase of the program do not show evidence of data manipulation. The increase in non-compliance, however, suggests that under the expanded program, non-compliance became an attractive alternative to either achieving or falsifying target progress. Heightened scrutiny of firm reporting may have raised the cost of falsification, which is consistent with the reduced compliance rates observed in the subset of (mainly state-owned) firms in the first phase. However, expanding the program to include many “cats” that lacked strong accountability to the central state may also explain the increase. Our empirical results show that larger firms, especially larger non-state firms, and firms in cities with low growth tended to fail to comply. For these non-state-owned firms, the costs of incremental compliance may have been particularly high, while reputational costs of non-compliance were likely lower than for state-owned firms.

Our findings point to two recommendations for China's future energy and climate policies. First, compliance flexibility may play an important role in deterring both falsification and non-compliance by reducing the compliance cost relative to the firm's outside option. High rates of non-compliance suggest high compliance costs for some firms. The inflexibility of command-and-control policies may become more salient over time, as firms exhaust low-cost abatement opportunities and must turn to higher marginal cost reductions. Moving to a flexible compliance mechanism such as an energy-saving or emissions trading system could help to reduce costs.

Second, the magnitude of any gains will depend on systems to support on-the-ground implementation, to ensure that the cost of falsification is higher than the cost of both true compliance and non-compliance. Regardless of the policy approach chosen, building an effective monitoring, reporting, and verification (MRV) system from the outset will be important for any policy to succeed. This will be especially needed in settings where the government is resource constrained and rule of law is weak. As our empirical results suggest, in these settings policymakers may increasingly rely on state-owned firms to support implementation. If China introduces an emissions trading system, any gains will be offset if only a subset of state-owned firms comply. Therefore, building a comprehensive accountability mechanism that extends to all firms will be important, and its existence and functionality should not be taken for granted.

Some of our findings in China may apply broadly in developing country settings. First, incentives for accurate reporting are as important as incentives for compliance. Firms in developing country settings may face higher costs of compliance associated with acquiring information on how to report correctly and motivating managers to implement these procedures. High compliance costs increase the motivation for firms to cheat. Therefore, our second lesson is that data quality should not be taken for granted. Although the T1000P achieved near-perfect compliance, statistical tests suggest that data were exaggerated or falsified. The more transparent reporting during the T10000P, complete with detailed rationales for non-compliance, may play an important role in the program's legitimacy and durability, and pave the way for market-based programs (Karplus and Zhang, 2017). Third, our findings suggest that moving to a national ETS will present both opportunities and challenges. While it carries the potential to reduce the burden on firms with high marginal abatement costs, to be effective an ETS would still have to supersede government channels of influence that have incentivized compliance under command-and-control programs and require strong data quality management capabilities.

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APPENDIX

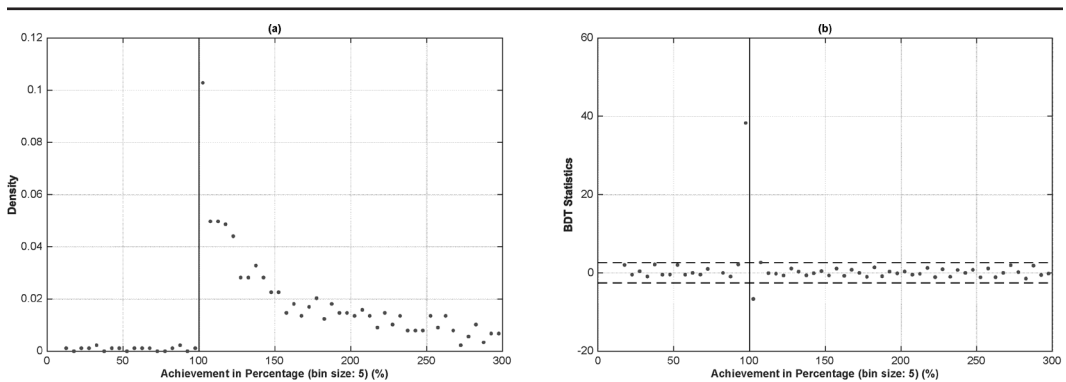
Table A1 shows the results of a robustness check for factors predicting non-compliance with the T10000P using the 2006 CAIS data. Figure A1 shows that the finding of a discontinuity in the neighborhood of 100% with the bin size of 5% is robust. Figure A2, A3 and A4 show probability distribution and the BDT for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2012, 2013 and 2014.

**Table A1: Factors predicting non-compliance with the T10000P using the 2006 CAIS data.**

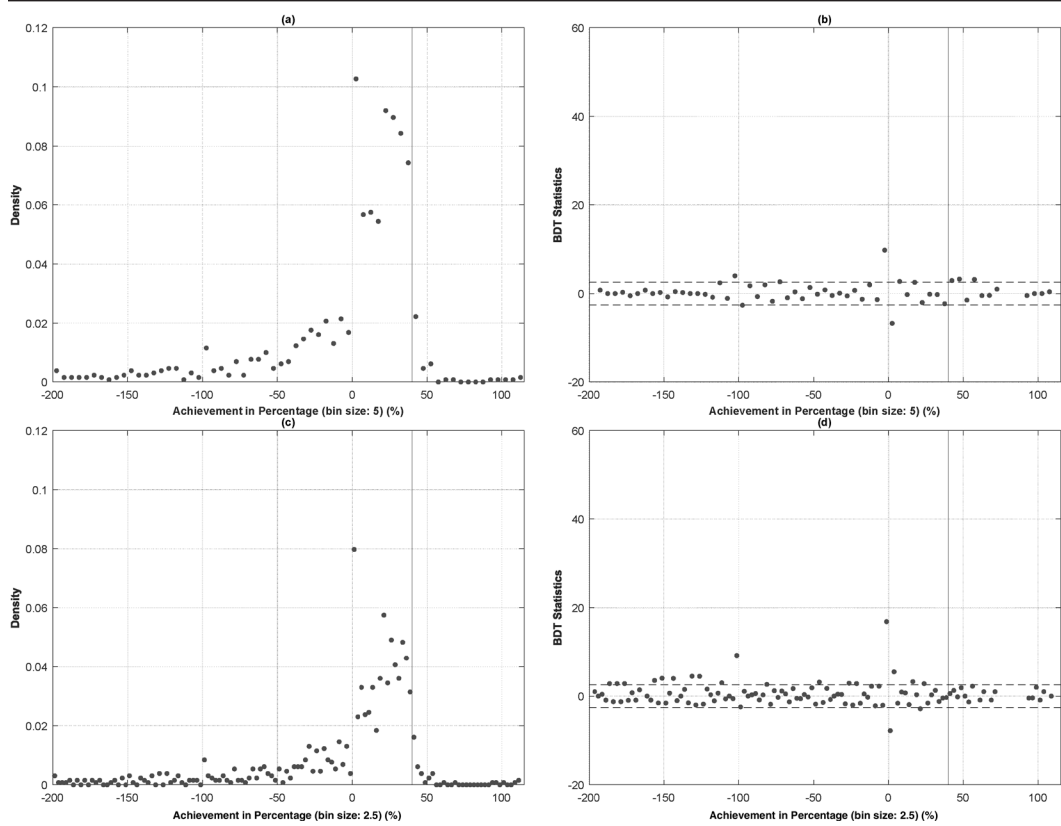
	(1)	(2)	(3)	(4)	(5)
Log (main business revenue)	0.07*	0.06	0.07*	0.08*	0.14***
(million yuan)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
Profit share of revenue		0.56	0.54	0.54	0.53
		(0.38)	(0.39)	(0.39)	(0.39)
Central SOE			-0.15	-0.12	1.13*
			(0.17)	(0.17)	(0.54)
Local SOE			-0.08	-0.06	0.69*
			(0.08)	(0.08)	(0.34)
Top 1,000 enterprise				-0.28*	-0.21
				(0.11)	(0.11)
Log (main business revenue) * Central SOE					-0.19**
					(0.06)
Log (main business revenue) * Local SOE					-0.14*
					(0.06)
Province-year fixed effects	YES	YES	YES	YES	YES
Sector-year fixed effects	YES	YES	YES	YES	YES
Number of years	3	3	3	3	3
Number of observations	25966	25966	25966	25966	25966

Note: Standard errors are clustered at the province level.

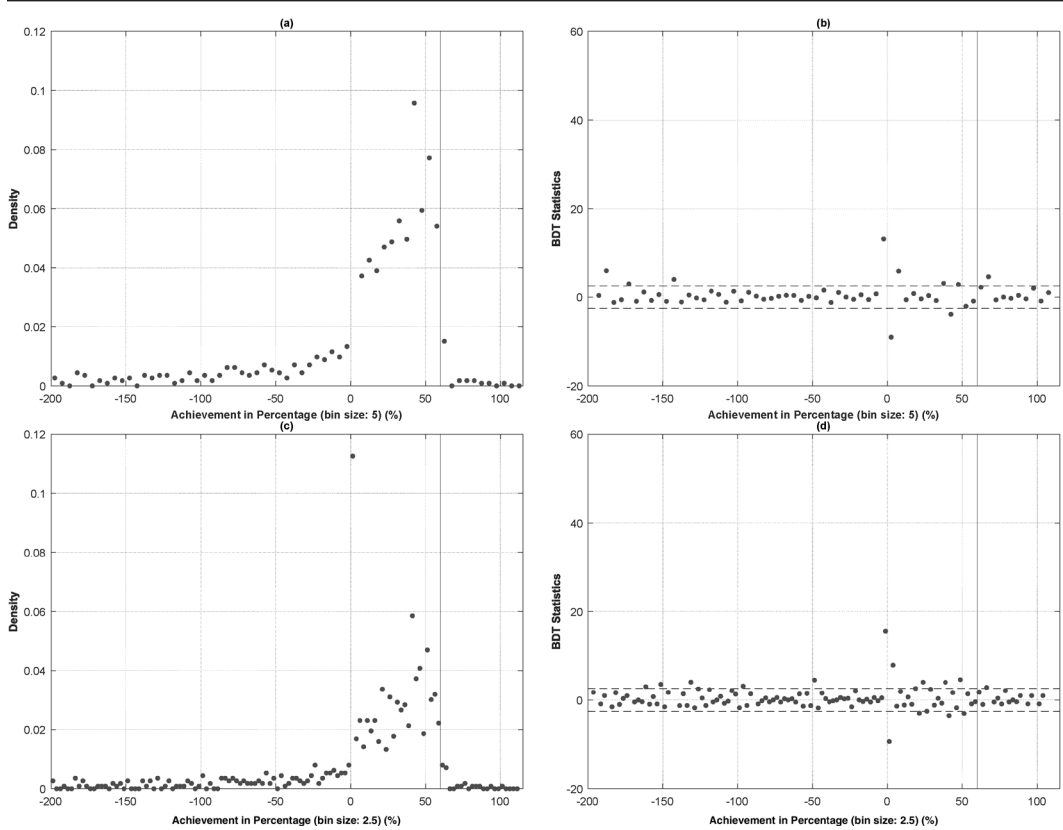
**Figure A1: Probability distribution and the BDT statistic for energy saving achievement in percentage of firms under the T1000P (bin size: 5%)**



**Figure A2: Probability distribution and the BDT statistics for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2012.**



**Figure A3: Probability distribution and the BDT statistics for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2013.**



**Figure A4: Probability distribution and the BDT statistics for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2014.**

