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

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ABSTRACT

Studies of firm compliance with energy and environmental policy in the developing world are rare. We study the drivers of firm compliance in a large-scale Chinese energy efficiency program. We assemble a novel data set that combines detailed firm compliance reports with data on participating firm characteristics from annual industrial surveys. Using statistical methods to detect data manipulation, we find evidence that firms deliberately exaggerated performance during the first phase of the program (2006-2010). In its second phase (2011-2015), the number of firms in the program expanded by an order of magnitude and its administration relied more heavily on local governments. The compliance rate, while still high, decreased significantly. Larger firms, especially those not controlled by the state, and firms in cities with low growth were more likely to report non-compliance. We describe how firm and state capabilities to manage the program evolved over time, and point out challenges encountered when the government tried to herd more "cats." Specifically, central government architects of the program had to rely increasingly on uneven local implementation capacity, which translated into increases in non-compliance as well as increased reliance on state-connected firms to deliver energy savings. We suggest ways in which future national energy and environmental policy in China could address both of these challenges.

Keywords: Energy efficiency, command-and-control, firm, compliance, China

1. INTRODUCTION

Initiatives to raise industrial energy efficiency are now common in many nations, but the reasons why firms comply (or not) remain 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 significantly, prompting national governments to establish programs to control them. Energy efficiency is thought to rank among the least-cost abatement opportunities (Intergovernmental Panel on Climate Change, 2014), and even benefit its adopters if discounted savings exceed upfront costs (McKinsey & Company, 2013). Despite a large theoretical and applied literature on benefits of energy efficiency programs, only a few studies have systematically examined firm responses to these programs in the developing world. In particular, examining why firms comply (or not) with these programs, and the implications for improving the effectiveness of policy, is of central interest.

The settings in developing countries differ from advanced industrialized countries in that firms face higher uncertainty of survival and weak institutions limit regulators' ability to influence firm behavior. The first is reason is economic: firms face more dynamic markets with large uncertainties in

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demand. Firms have to make difficult decisions between investing in energy efficiency with existing equipment, upgrading to new and more efficient production facilities with larger capacity if demand is growing, and doing nothing if it faces low demand. The second reason is institutional: rules and norms may be insufficient to deter firms from manipulating data or reneging on compliance obligations (Duflo et al., 2013), or may lead to selective impact as a function of the relationship (such as ownership or control) between firms and the regulatory state (Wang, 2015; Li and Chan, 2016;). Given the growing link between firm behavior in developing countries and global environmental outcomes, there is enormous need to understand drivers of firm compliance in these settings.

We focus our analysis on a national energy efficiency program in China, which was implemented in two phases: the Top 1,000 (2006-2010) and Top 10,000 (2011-2015) Enterprises Energy Saving Programs (hereafter, T1000P and T10000P). In terms of firm coverage and government resources invested, the program represented the most ambitious effort to raise energy efficiency of industrial firms ever launched in China. Government resources invested in the program are difficult to estimate precisely, but account for a significant share of the total industrial energy conservation investment of about 100 billion U.S. dollars during the Twelfth Five-Year Plan (2011-2015) (Ministry of Industry and Information Technology, 2012). Under the program, firms were assigned roughly equal energy-saving targets roughly proportional to their energy use in the base year by the government (with limited room for negotiation). While the program refers frequently to energy savings, it technically targets reductions in energy intensity (or energy use indexed to the value of real output). Energy savings are defined as the gap in energy use computed using initial and final energy intensities multiplied by final year output.

In our analysis, we exploit the pre-existing heterogeneity study characteristics associated with f firms covered by the policies to study characteristics associated with compliance outcomes. Motivated by prior literature on the dynamics of policy compliance in developing countries (van Rooij, 2006; Kostka, 2016), we focus in particular on firm size (measured in terms of annual revenue), state ownership and control, and exporting status. Firm size serves as a proxy for the strength of incentives for local governments to penalize non-compliance, as policy makers rely on local industries for tax revenue. State firms are hypothesized to respond most strongly to political incentives, which vary according to the level of government that oversees them. For example, firms linked to the central government may be more likely to follow central environmental directives because compliance is one of many criteria included in annual evaluations, which determine bonuses and promotions. Exporting firms may be more willing or able to reduce negative impacts on the environment according to the "gains-from-trade hypothesis." (Frankel and Rose, 2005) We also consider characteristics of a firm's location, such as economic growth and per-capita GDP.

Our primary contribution is to assess program compliance outcomes with an energy efficiency program in China using a new and unique data set that combines compliance information with Annual Industrial Survey data on the characteristics of participating firms. First, we use a statistical method to evaluate the plausibility of compliance data submitted by firms. We find evidence that firms deliberately exaggerated performance in the first phase of the program, while we find no evidence of manipulation during the second phase of the program. Second, we assess the correlation between pre-existing firm characteristics and compliance outcomes, focusing on second phase of the program when compliance data are deemed more reliable. Larger firms not controlled by the state and firms in cities with slow growth were statistically less likely to comply. Third, we describe how firm and state capabilities to manage the program evolved over time, and point out challenges encountered when the government tried to herd more "cats." Specifically, central government architects of the program had to rely increasingly on uneven local implementation capacity, which translated into increases in non-compliance as well as disproportionate reliance on state-connected firms to deliver energy savings. Implications for future policy design, including the transition to an emissions trading system for managing CO_2 emissions in China, are explored.

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2. LITERATURE AND EMPIRICAL SETTINGS

2.1 Understanding Firm Compliance

A growing body of research empirically evaluates the effectiveness of energy and environmental policies. Much of this literature focuses on advanced industrialized countries, see review by Allcott and Greenstone (2012). Household decision-making (e.g. Allcott and Rogers, 2014 and Fowlie et al., 2015) is a primary focus, although a growing subset of this literature has looked at the responses of organizations (e.g. firms in India and schools in California, see Ryan (2015) and Burlig et al. (2017)). The literature also provides evidence that firm characteristics matter in compliance. For instance, location—including proximity to headquarters and to similar firms—as well as size are found to affect compliance with toxic chemical disclosures (Doshi et al., 2013). Bennear and Olmstead (2008) studies firm compliance with regulations requiring disclosure of violations of drinking water standards, and find reductions in both total and most severe violations among large firms.

External environment, including for example, local law enforcement capacity, civil society pressure, and relationships between government and enterprises, can also affect firm compliance (Eaton and Kostka, 2014). Kagan et al. (2003) finds that social pressures from the media and citizens can push firms to comply with regulation, and Gunningham et al. (2011) points out that strong law enforcement can increase firms' fears of being punished for violation and improve compliance.

Literature on environmental compliance behavior in developing country firms is sparse. Taking China as an example, the observation that regulations on the books are not completely or uniformly implemented in firms has been referred to since the mid-1990s as the "implementation gap" (Chan et al., 1995). For example, on energy efficiency polices, Kostka and Hobbs (2012) highlights specific implementation methods that local government leaders use to strengthen formal incentives and establish effective informal norms to comply with energy efficiency mandates. Zhu and Chertow (2017) finds that firms in sectors with moderate regulatory pressure seek to enhance competitiveness by adopting energy saving technologies, while firms with survival risk or development constraints tend to implement complete technology upgrades. These papers, together with the environmental law and politics literature (van Rooij, 2006; Ran, 2009; Wang, 2013; Kostka, 2016), refer to the fact that energy and environmental directives in China offer limited compliance flexibility, imposing high costs on firms, and at times undermining compliance altogether. Some recent studies explore the effects of firm characteristics other than the often-discussed location and size factors, e.g. local influence (Lorentzen et al., 2014) and ownership (Hering and Poncet, 2014; Li and Chan, 2016), on their responses to energy and environmental policies. These papers do not observe firms' compliance behavior directly, therefore, they have to use some environmental performance proxies instead of having the compliance result as the dependent variable.

Multiple studies have found China's energy-saving programs successful and important for achieving China's national energy intensity reduction goals (Zhou et al., 2010; Ke et al., 2012). However, these studies also point to many challenges in implementation, e.g. a lack of transparency and credible monitoring (Price et al., 2010) and lack of direct financial incentives for activities that are not capital improvements, e.g. capacity building (Lu et al., 2014) during the T1000P. All of the above studies either focus on levels 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. Analysis based on a comprehensive set of firms, to our knowledge, has not been conducted, mainly because large-scale, firm-level compliance data was unavailable.

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

Starting from the Eleventh Five-Year Plan (FYP, 2006-2010), several government ministries and agencies led by the National Development and Reform Commission (NDRC) established the T1000P,

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which involved 1,008 industrial firms[1] that together accounted for about 30% of China's total energy use in 2005. Each firm was assigned an energy-saving target for the Eleventh FYP period. According to reports, 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 2005 levels. The program was expanded to the T10000P during the Twelfth FYP (2011-2015), involving 14,641 industrial firms, and hundreds of transportation operators, hotels and restaurants, commercial and trade enterprises, and schools, in total 16,078 institutions. Covered institutions, 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 about 920 million tons of CO_2 emissions mitigation in every program year (National Development and Reform Commission, 2011).

Reported compliance rates for the T1000P during the Eleventh FYP were high, but decreased when the program was expanded during the Twelfth FYP. Among the 881 firms evaluated at the end of T1000P in 2010, there were only 15 firms (1.7%) that did not achieve the target. According to three annual evaluations of the T10000P in 2012, 2013 and 2014,[2] non-compliance rates increased substantially relatively to the T1000P (9.5% in 2012, 8.4% in 2013 and 7.1% in 2014). **Table 1** shows non-compliant firms and total firms evaluated by year for each phase of the program.

The most notable change from the T1000P to the T10000P was expansion in both the sectors covered and the total number of firms included. The T1000P originally contained 1,008 industrial firms with energy use higher than 180,000 tons of coal equivalent in 2004 in nine energy-intensive industrial sectors. The T10000P originally included 14,641 industrial firms with energy use higher than 10,000 tons of coal equivalent in 2010 covering all industrial sectors as well as 1,437 other major energy using organizations, for instance, transportation firms, hotels, restaurants, commercial and trade enterprises, and schools. 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%). Interested readers can find a detailed comparison of the T1000P and T10000P[3] in Karplus et al. (2016).

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

Panel A: Top 1,000 Enterprises Program (Phase 1)				
	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%
Panel B: Top 10,000 Enterprises Program (Phase 2)				
	Original list	Evaluation in 2012	Evaluation in 2013	Evaluation in 2014
Total firms	**16078**	14,542	14,119	13,328
Non-compliant firms	-	**1,377**	**1,191**	**948**
Non-compliance rates	-	9.5%	8.4%	7.1%

[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 every year was fewer than 1,008. A similar situation existed in the T10000P. Examples of firms that were temporarily excluded from the evaluations are 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 re-appeared in the 2010 evaluation.

[2]At the time of writing, only three sets of compliance reports were available for the T10000P. In the first half of each year, the local government reported firm compliance for the previous year to the provincial government, and the provincial data was later summarized by 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. The results were then finalized and usually published at the end of the year. To our knowledge, the government did not publicly release evaluations for years after 2014.

[3]All the government documents used in this paper have been collected from the NDRC website and will be made publicly available with the publication of this paper.

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Unlike the T1000P, which published the energy saving amount for all the firms, the T10000P only provided such information for the non-compliant firms and did not provide a full list of evaluated firms every year. Therefore, we are only able to report the rate of non-compliance among included firms but have to estimate the non-compliance rate by sector in **Table 2**.[4]

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

	Original list	**Evaluated in 2012**		**Evaluated in 2013**		**Evaluated in 2014**	
	Total number	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 %	1038	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).

Table 2 shows that non-industrial firms exhibit higher non-compliance rates than industrial firms, especially in 2012. Interestingly, the transportation firms and schools, most of which are *shiyedanwei* or large local SOEs, showed relatively high non-compliance rates in 2012, but compliance greatly improved in 2013 and 2014. Overall, the non-compliance rate for industrial firms in the T10000P was still significantly higher than that of the T1000P.

We match the firms using firm name and ID 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 (about US $800,000),[5] 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.[6] While we cannot rule out the possibility that matched and unmatched firms differ systematically in ways that might affect compliance, the non-compliance

[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 as 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 significant 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, the non-compliance rates estimated for industrial firms in 2012, 2013, and 2014 are an upper bound on the actual rates, while the non-compliance rates estimated for other organizational types represent a lower bound.

[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 of Chinese industrial firms available. The CAIS contains detailed 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 or foreign investors.

[6]Potential reasons for the imperfect match include the incomplete coverage of the CAIS data due to the revenue cutoff and inconsistent firm name and ID in the two data sets. Figure 2 shows that the matched sample is representative and able to approximate the full sample of the T10000P firms.

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rates based on the matched sample (8.5% in 2012, 8.0% in 2013, and 5.0% in 2014 respectively) are close to the non-compliance rate for the entire sample (9.0% in 2012, 8.2% in 2013, and 5.8% in 2014 respectively.

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, in the T10000P we find lower compliance rates across all covered industrial sub-sectors. 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 matched, 4,951 are from the 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. In the T10000P, non-compliance even increases among the firms previously included in the T1000P. Of the 412 firms included in both the T1000P and the T10000P, the non-compliance rate was 8.7% in 2012, 7.3% in 2013, and 5.1% in 2014.

We show the summary statistics of industrial firms successfully matched to the 2011 CAIS data in **Table 4**. Firms 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 exports in the 2011 CAIS data, respectively.

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 that have export (%)	39.3		29.0		27.0	
Share in the total export (%)	2.8		27.6		69.6	
Number of firms	435		6,572		220,516	

2.3 Possible explanations for increasing non-compliance

The increase in non-compliance under the expanded program presents an empirical puzzle. Some explanations include changes common to all firms—for example, lower energy prices (in particular, for coal, as the price plunged due to oversupply in the face of slowing demand growth since 2012) and a more limited remaining pool of energy efficiency improvements. Another potential explanation is that data manipulation in favor of target achievement was much more prevalent during the T1000P compared to the T10000P. Therefore, we first examine and compare reported compliance behavior of firms to understand whether or not compliance behavior changed substantially with the expansion of the program.

Manipulation in the reporting of environmental data in China is a well-documented phe-

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nomenon. Previous studies either find huge a disparity in reported values for the same energy statistics (Guan et al., 2012), and discover data manipulation in air quality data by observing "bunching" of the PM_{10} numbers below the "Blue Sky Day" threshold (Chen et al., 2013; Ghanem and Zhang, 2014) using statistical approaches. This "bunching" behavior just below the compliance threshold defined by a policy is also observed in other developing countries (Duflo et al., 2013). Specifically for energy conservation, Kostka (2016) has anecdotally documented data falsification and other strategic behavior (for example, one locality reported energy savings from companies that had already declared bankruptcy) as unintended consequences of the command-and-control policy, which reflects the reality of "command without (or with limited) control."

3. ANALYSIS

3.1 Are compliance reports credible?

We apply a statistical method adopted in Chen et al. (2013) to study the credibility of firm compliance reporting. Specifically, we analyze whether or not firms' self-reported energy saving in 2010 is "bunched" above the target under the T1000P.[7] 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 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, energy savings are difficult to co-optimize with output to a high degree of precision.

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

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:

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

where n is the total number of observations, and

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

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 significant discontinuity in the neighborhood of 100% shown in the right panel of

[7] 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, therefore we implement a similar discontinuity test for this subset of firms later on. We find no evidence of manipulation.

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Figure 1: Probability distribution and the BDT for energy saving achievement in percentage of firms under the T1000P (bin size: 2.5%)

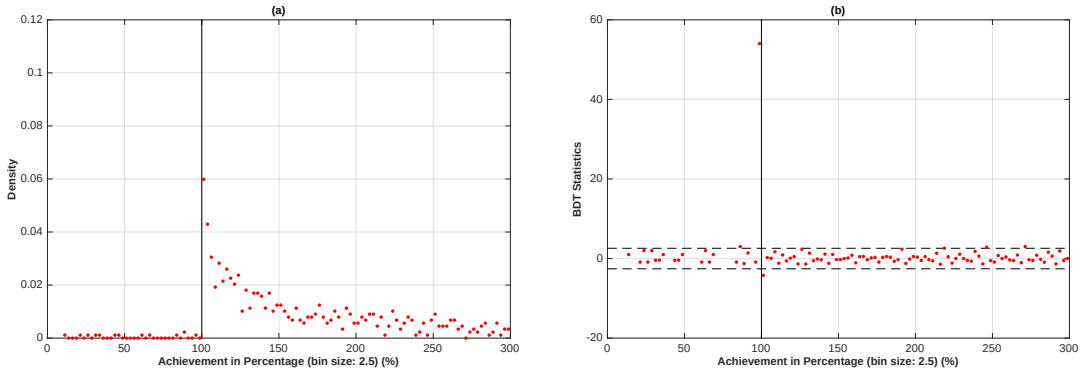

Figure 1. Dashed lines indicate critical values with a confidence level of 99%. The results are still robust if we increase the bin size to 5% as shown in **Figure A1**.

We do not find evidence of data manipulation during the second phase of the program. Though 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[8] for these non-compliant firms. There should be fewer firms just below the threshold among the non-compliant firms if firms' reported energy savings are "bunched" just above the threshold. From **Figure A2, A3** and **A4**, we do not observe any discontinuity around these potential thresholds. Though we cannot rule out the possibility of energy saving exaggeration by the T10000P firms (Zhao et al., 2016), falsification of target achievement seems unlikely.

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. Our data set contains unusually rich qualitative detail on why firms failed to comply with the T10000P, which help us understand how these incremental costs could affect compliance. 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**.

Firm 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 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 CPC, which has a higher political rank than NDRC, did not provide complete evaluation materials in 2012. This non-compliance behavior was still made public, an indication of the commitment to transparency 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 during the

[8] We assume the threshold for compliance, 完成 - completed, is 40% for 2012, 60% for 2013 and 80% for 2014.

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program. 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. Reasons 3 to 7 similarly illustrate how unanticipated operational conditions 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 translate into economies of scale that increase non-linearly with output. Targets mandate linear decreases in energy intensity, which are 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 not have correctly 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 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. Though 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 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.

Our survey of self-reported reasons for non-compliance yields several interesting findings. That firms generally comply with environmental policy is a widespread assumption, yet 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 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.

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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 not provide complete data	245	Firms refused or failed to completely submit the self-checking report, energy data, or any other materials required by the evaluation.
2	Ceased production, merge, product portfolios change, or new buildings	179	Those were firms that faced bankruptcy or stopped a significant 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, therefore the energy saving linked to production was limited. Lower production level could increase the unit energy consumption of the product as more frequent starts and stops reduce efficiency of operation.
4	Uncertain energy use per unit of production	26	Some firms had production process with fluctuating energy use, especially for some transportation firms.
5	Product price decrease	5	Decreasing product price could bring down the output in value term of a firm with same input use, therefore energy consumption per unit of output in value term increased.
6	Lower heating value fuels	5	Fuels with a lower heating value than 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	Lack of 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. Details about the non-compliance cases can be found in Karplus et al. (2016).

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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. We are interested in the extent to which these two approaches tell the same—or different—stories. We recognized that our analysis is not causal, given that firms' characteristics are interlinked and not randomly assigned.

Here we ask which firm characteristics and types of external environment are associated with non-compliance in the T10000P. The results reveal the intrinsic heterogeneity in incentives among firms and identify "hotspots" that should be a focus of any effort to improve compliance.

Firm size, profitability, ownership status, and export status. These factors 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. Given that energy saving targets were imposed and enforced differentially by provinces, and reflected differences in production technology by industry, we include province and industry dummies in our regression.

Rates of non-compliance vary widely across provinces. 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,[9] 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.[10] 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,[11] 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**. 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, and profit rate (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, 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 enterprises associated with the central government and a much greater variety associated with local governments.

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. Though SOEs under central and local supervision, which are obligated by the government to report energy saving as part of annual cadre evaluations,

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

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

[11] 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.

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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, i.e. log revenue, with SOE dummies, and find the coefficient of the size variable still significant and positive, but the coefficients of interaction terms are significant and negative. Therefore, it is the non-SOEs that are associated with increasing non-compliance as their size increases. This finding is perhaps not surprising. Large, non-state firms are not subject to the direct control of the government and may have the power to capture the local regulator, especially if they account for a significant share of local economic activity.

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 rates 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, it is very common for them to rely on the firm's accountant, who knows very little about energy, to report energy use, resulting in substantial misreporting (Kostka, 2016). Finally, firms that were involved in the T1000P show slightly lower non-compliance rates, as they may have a well-established energy management system and take the energy 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 export in the gross output in various specifications. We do not find a significant effect of any of these export-related variables in any of those regressions. Therefore, we believe the export status of the firms has no impact on the compliance behavior.

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

	(1)	(2)	(3)	(4)	(5)
Log (main business revenue)	0.07*	0.08*	0.08*	0.10**	0.17***
	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
Profit rate		-0.31	-0.33	-0.34	-0.31
		(0.39)	(0.38)	(0.39)	(0.37)
Central SOE			-0.05	-0.04	2.18***
			(0.18)	(0.18)	(0.59)
Local SOE			-0.12	-0.11	0.82**
			(0.11)	(0.11)	(0.29)
Top 1,000 enterprise				-0.20	-0.11
				(0.16)	(0.16)
Log (main business revenue) * Central SOE					-0.31***
					(0.08)
Log (main business revenue) * Local SOE					-0.16**
					(0.05)
Province fixed effects	*YES*	*YES*	*YES*	*YES*	*YES*
Sector fixed effects	*YES*	*YES*	*YES*	*YES*	*YES*
Year fixed effects	*YES*	*YES*	*YES*	*YES*	*YES*
Number of years	3	3	3	3	3
Number of observations	19974	19974	19974	19974	19974

Note: Standard errors are clustered at the province and sector level.

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

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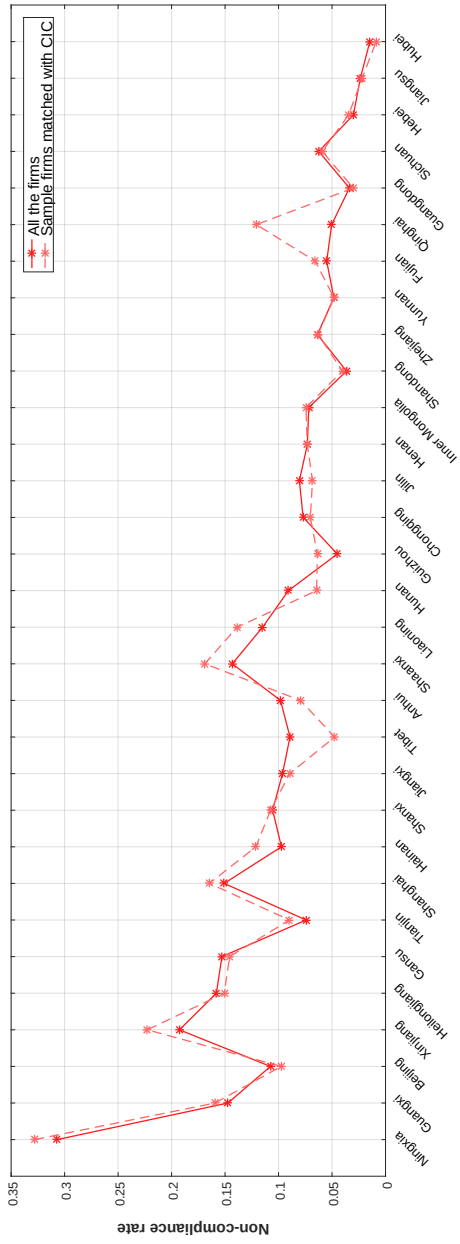

Figure 2: Non-compliance rate by province for all the firms and firms matched with CAIS data in 2012, 2013 and 2014.

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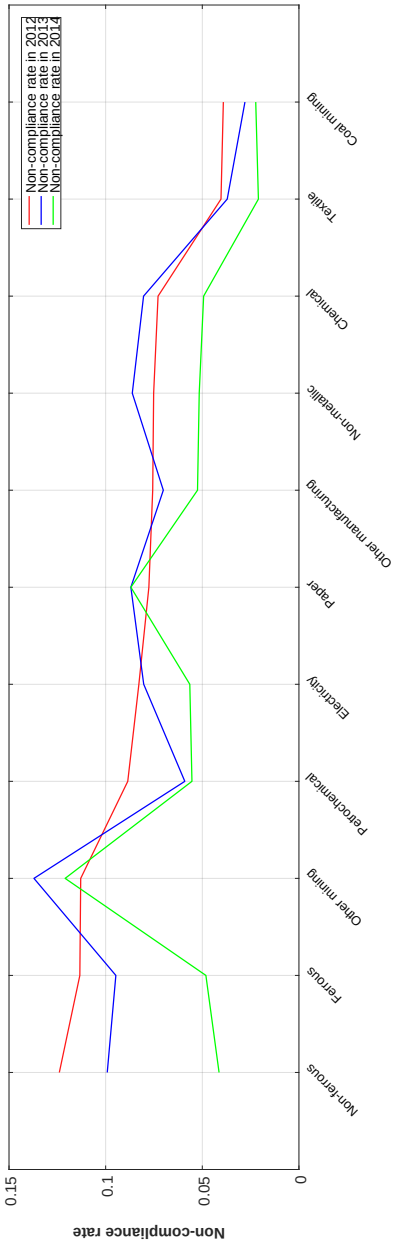

Figure 3: Non-compliance rate by sector for firms matched with CAIS data in 2012, 2013 and 2014.

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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 mitigation cost 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 make lower the costs of reducing energy intensity. **Table 7** shows the regression results.

Table 7: Factors including local economic indicators predicting non-compliance with the T10000P

	(1)	(2)	(3)	(4)
Log (main business revenue)	0.10*	0.09*	0.10*	0.18***
	(0.04)	(0.04)	(0.04)	(0.04)
Profit rate	-0.43	-0.43	-0.43	-0.38
	(0.32)	(0.32)	(0.32)	(0.31)
Central SOE	-0.03	-0.01	-0.01	2.69***
	(0.19)	(0.19)	(0.19)	(0.59)
Local SOE	-0.10	-0.09	-0.09	1.01**
	(0.12)	(0.12)	(0.12)	(0.31)
Top 1,000 enterprises	-0.22	-0.23	-0.24	-0.12
	(0.17)	(0.17)	(0.17)	(0.17)
Log (main business revenue) * Central SOE				-0.38***
				(0.08)
Log (main business revenue) * Local SOE				-0.19***
				(0.05)
Per-capita GDP	-0.01		-0.01	-0.01
	(0.02)		(0.02)	(0.02)
GDP growth rate		-0.03***	-0.03***	-0.03***
		(0.01)	(0.01)	(0.01)
Province fixed effects	*YES*	*YES*	*YES*	*YES*
Sector fixed effects	*YES*	*YES*	*YES*	*YES*
Year fixed effects	*YES*	*YES*	*YES*	*YES*
Number of years	3	3	3	3
Number of observations	17657	17657	17657	17657

Note: Standard errors are clustered at the province and sector level.

We do not find that the development level of the city where the firm is located has a significant impact on compliance behavior. However, we find that firms in cities with higher GDP growth rate have a higher compliance rate. Output increases proportionally with energy savings, as shown in Equation (1). This finding is consistent with the existence of fixed energy requirements associated with firm operations, which implies decreasing energy intensity as output increases. Observed effects remain consistent in sign and magnitude across all specifications.

4. MOVING FROM COMMAND-AND-CONTROL TO MARKET-BASED POLICY: OPPORTUNITY AND TRADEOFFS

China has announced that it will launch a national emissions trading system starting in late 2017. This system will target CO_2 associated with fossil energy use, largely replacing a major function of the Top 10,000 Enterprises Program. Indeed, emissions trading has been advanced as an answer to

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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 inherent in moving from a command-and-control to market-based approach.

4.1 Advantages of Greater Flexibility in an ETS

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,*[12] *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. Trading in the context of an ETS would be much more straightforward.

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 find that only Jiangsu Province had officially launched energy saving trading in 2015.[13] Moreover, no official guidelines were provided for the accounting of allowances bought under the T10000P, increasing the risks that purchases allowances will not be counted toward compliance obligations and ultimately limiting firms' participation in large-scale energy saving trading programs.

4.2 Administrative Advantages of a Command-and-Control 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 were found to overfulfill 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 the provinces have passed their aggregate targets (40%, 60%, and 80% respectively). In 2013, about half (15) of the provinces had already achieved their cumulative

[12] 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 T1000P.

[13] 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 of "energy saving capacity."

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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 significantly 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.

This mechanism is borne out in the data. 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[14] is higher than the rates achieved by all the 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.

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 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. Local 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 enterprises, which for over 10,000 firms is no doubt a very challenging task that requires significant investment in monitoring infrastructure and personnel training.

4.3 Lessons for Future Policy Design

The Top 1,000 and 10,000 Enterprises Program provides an important common basis for future energy and CO_2 emissions reduction policies, regardless of whether command-and-control or market-based. First, the large scale of the program has successfully drawn the attention of company executives, without which employees would feel little pressure to undertake energy savings. The transparency of compliance status further places pressure on firms.

Second, the program to some extent facilitated the financing of retrofits designed to raise energy efficiency. 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 involving hundreds of firms within the province. For instance, Shanxi People's Government launched the "Shanxi 1,000 Firms Program" that involves 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 are now established and are being improved. We find no evidence that firms falsified target achievement during the T10000P, in contrast to the T1000P. NDRC's public release of the program's compliance documents is essential to facilitate program evaluation and improvement.[15] Previous studies have found that higher public participation, transparency of results, and easier access to information improve the outcomes of environmental policies (Scruggs, 2003; Lipscy, 2011).

A national ETS for CO_2 could potentially complicate, and not easily coexist with, a follow-on program to the T10000P in the Thirteenth FYP. The incompatibility of the T10000P with an ETS was affirmed in interviews we conducted with T10000P firms in a pilot ETS province. There are seven

[14] We only have the detailed achievement status information at the firm level for central SOEs.

[15] 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).

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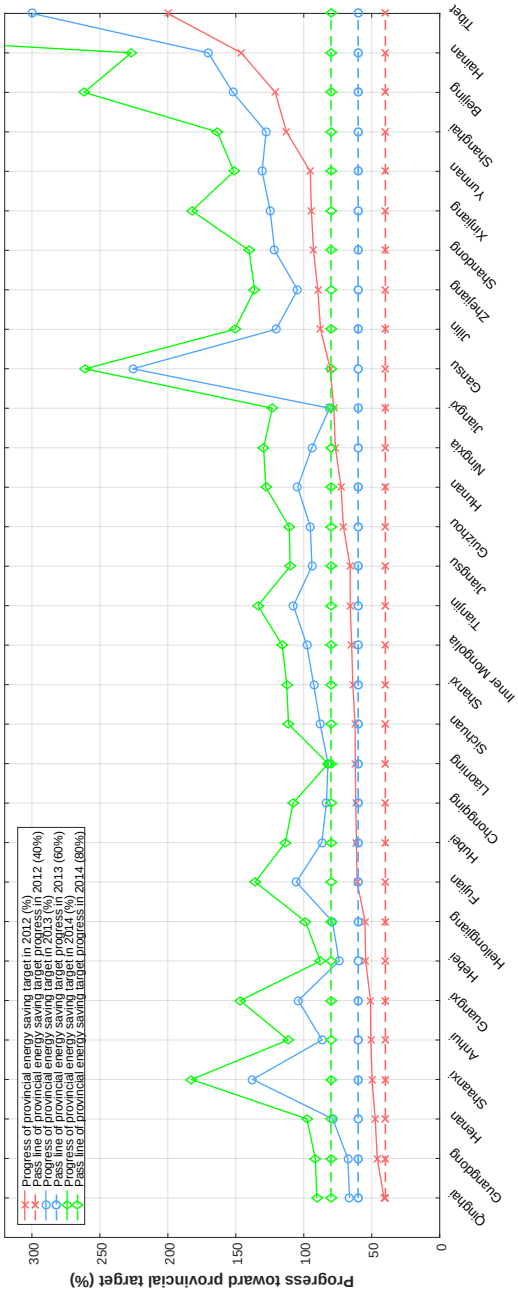

Figure 4: Overall energy saving achievement rate at the provincial level in 2012, 2013 and 2014.

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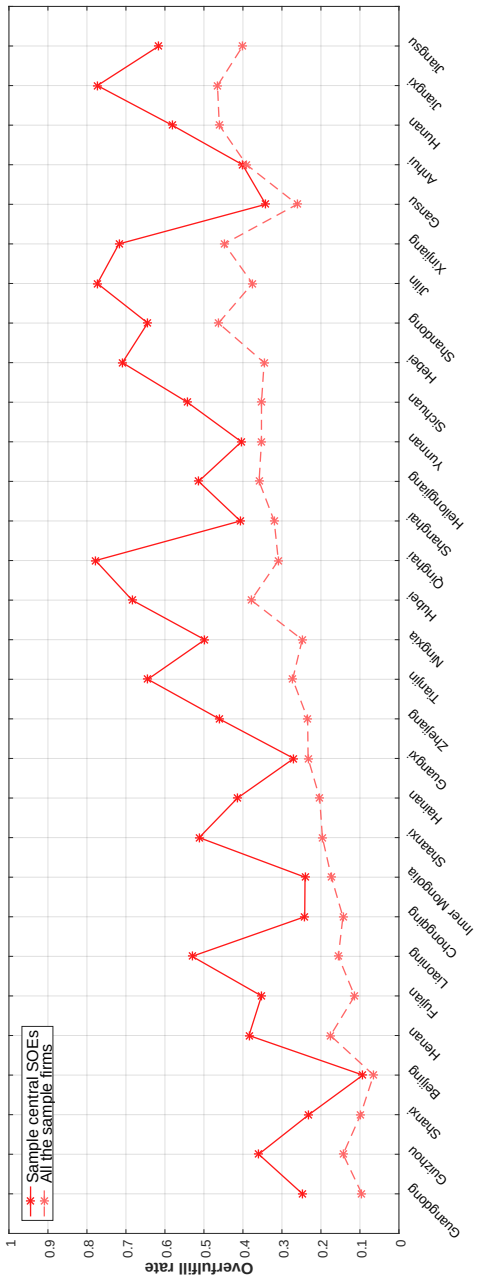

Figure 5: Rate by which central SOEs and all firms exceeded their energy saving targets in 2012, 2013 and 2014.

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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 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 have to reduce energy use by themselves rather than buy allowances from the ETS, even if it is cheaper. If this were to occur on a large scale, it would 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," 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.

Our paper provides a novel, if somewhat unsettling, perspective on the high compliance rates observed during the first phase of the T1000P. Results from the second phase of the program were more encouraging, in that they do not show evidence of data manipulation. The increase in non-compliance, however, points to limits to program effectiveness and to the possibility of increased and uneven net costs associated with firm compliance. The quantitative results show that firm compliance, while in general high, decreased sharply after the program expanded in 2011. Larger firms, especially larger non-state firms, and firms in cities with low growth tended to fail to comply. This finding speaks to the literature that emphasizes the importance of understanding incentives of policy compliance for heterogeneous firms and reflecting them in the focus and stringency of verification efforts (Friesen, 2003) as firms' self-reported compliance could not be taken at the face value. We also describe the challenge that the government faced when the program was expanded but its capacity was constrained, causing policymakers to increasingly rely on state-connected firms to deliver energy savings. Taken together, our findings provide detailed and textured insights into the firm and locational factors associated with non-compliance and limitations of command-and-control policies. Considering these factors will help to obtain more plausible estimates of policy impact on Chinese firms, as well as point to gaps that will need to be closed to improve policy design and implementation. While state-owned firms are major energy users, policy performance may increasingly depend on whether or not the reach of regulation can be extended to all energy-intensive firms, including the many large energy users that lack strong central state ties.

Our findings from China may apply more broadly in developing country settings. First, we find evidence that it is the combination of firm and regulatory capabilities, and not each in isolation, that are required for a policy to work well. Second, transparency and trustworthiness of data is more important than receiving reports of 100% compliance in these settings. Although the T1000P achieved near-perfect compliance, statistical tests reveal the possibility that data was exaggerated or falsified. The transparent reporting during the T10000P, complete with detailed rationales for non-compliance, is likely to be much more important to the program's legitimacy and durability. Third, our findings highlight distinct opportunities—associated with increasing abatement flexibility—of a national ETS, as well as administrative challenges. Success of the national ETS will require clearly establishing a legal basis with penalties for non-compliance (which may not exist currently at the local levels), and refraining from using government channels of influence that have proven effective in soliciting compliance under command-and-control programs.

6. APPENDIX

Figure A1 shows that the 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

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percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2012, 2013 and 2014.

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REFERENCES

Allcott, H., Greenstone, M., 2012. Is there an energy efficiency gap? Journal of Economic Perspectives 26, 3–28.

Allcott, H., Rogers, T., 2014. The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation. American Economic Review 104, 3003–3037.

Bajo, E., Bigelli, M., Hillier, D., Petracci, B., 2009. The determinants of regulatory compliance: An analysis of insider trading disclosures in Italy. Jounrnal of Business Ethics 90, 331–343.

Bennear, L.S., Olmstead, S.M., 2008. The impacts of the 'right to know': Information disclosure and the violation of drinking water standards. Journal of Environmental Economics and Management 56, 117–130.

Burgstahler, D., Dichev, I.D., 1997. Earnings management to avoid earnings decreases and losses. Journal of Accounting and Economics 24, 99–126.

Burlig, F., Knittel, C., Rapson, D., Reguant, M., Wolfram, C., 2017. Machine learning from schools about energy efficiency. Mimeo.

Chan, H.S., Wong, K.K., Cheung, K.C., Lo, J.M.K., 1995. The implementation gap in environmental management in China. Public Administration Review 55, 333–340.

Chen, Y., Jin, G.Z., Kumar, N., Shi, G., 2013. Gaming in air pollution data? Lessons from China. NBER Working Paper No. 18729.

Doshi, A.R., Dowell, G.W.S., Toffel, M.W., 2013. How firms respond to mandatory information disclosure. Strategic Management Journal 34, 1209–1231.

Duflo, E., Greenstone, M., Pande, R., Ryan, N., 2013. Truth-telling by third-party auditors and the response of polluting firms: Experimental evidence from India. Quarterly Journal of Economics 128, 1499–1545.

Eaton, S., Kostka, G., 2014. Authoritarian environmentalism undermined? Local leaders' time horizons and environmental policy implementation in China. The China Quarterly 218, 359–380.

Energy Information Agency, 2016. International Energy Outlook 2016. Chapter 7. Industrial Sector Energy Consumption.

Fowlie, M., Greenstone, M., Wolfram, C., 2015. Do energy efficiency investments deliver? Evidence from the weatherization assistance program. NBER Working Paper No. 21331.

Frankel, J.A., Rose, A.K., 2005. Is trade good or bad for the environment? sorting out the causality. The Review of Economics and Statistics 87, 85–91.

Friesen, L., 2003. Targeting enforcement to improve compliance with environmental regulations. Journal of Environmental Economics and Management 46, 72–85.

Ghanem, D., Zhang, J., 2014. 'Effortless perfection': Do Chinese cities manipulate air pollution data? Journal of Environmental Economicsand Management 68, 203–225.

Gillingham, K., Palmer, K., 2014. Bridging the energy efficiency gap: Policy insights from economic theory and empirical evidence. Review of Environmental Economics and Policy 8, 18–38.

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Government of Shanxi Province, 2008. Inform on Statistics and Monitoring and Evaluation Implementation Plan of Energy Conservation in Shanxi.

Guan et al., 2012. The gigatonne gap in China's carbon dioxide inventories. Nature Climate Change 2, 672–675.

Gunningham, N., Kagan, R.A., Thornton, D., 2011. Fear, duty, and regulatory compliance: Lessons from three research projects, in: Parker, C., Nielsen, V.L. (Eds.), Explaining Compliance: Business Responses to Regulation. Edward Elgar Publishing, Cheltenham, U.K.

Hering, L., Poncet, S., 2014. Environmental policy and exports: Evidence from Chinese cities. Journal of Environmental Economics and Management 68, 296–318.

Intergovernmental Panel on Climate Change, 2014. Climate Change 2014: Mitigation of Climate Change. The Fifth Assessment Report (AR5), Working Group III.

Kagan, R.A., Gunningham, N., Thornton, D., 2003. Explaining corporate environmental performance: How does regulation matter? Law and Society Review 37, 51–90.

Karplus, V.J., Shen, X., Zhang, D., 2016. Scaling compliance with coverage? Firm-level performance in China's Industrial Energy Conservation Program. MIT Joint Program on the Science and Policy of Global Change Report 303.

Ke et al., 2012. China's industrial energy consumption trends and impacts of the Top-1000 Enterprises Energy-Saving Program and the Ten Key Energy-Saving Projects. Energy Policy 50, 562–569.

Kostka, G., 2016. Command without control: The case of China's environmental target system. Regulation and Governance 10, 58–74.

Kostka, G., Hobbs, W., 2012. Local energy efficiency policy implementation in China: Bridging the gap between national priorities and local interests. The China Quarterly 211, 765–785.

Li, X., Chan, C.G.W., 2016. Who pollutes? Ownership type and environmental performance of Chinese firms. Journal of Contemporary China 25, 248–263.

Lipscy, P.Y., 2011. Efficiency clientelism. Paper Presented at the Princeton Conference on Environmental Politics.

Lorentzen, P., Landry, P., Yasuda, J., 2014. Undermining authoritarian innovation: The power of China's industrial giants. The Journal of Politics 76, 182–194.

Lu et al., 2014. Energy assessments under the Top 10,000 Program – a case study for a steel mill in China. ECEEE Industrial Summer Study Proceedings.

McKinsey & Company, 2013. Pathways to a Low-carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve.

Ministry of Industry and Information Technology, 2012. The twelfth five-year plan for industrial energy conservation. Beijing, China.

National Development and Reform Commission, 2011. Inform on the implementation plan of the Top 10,000 Firms Energy Saving and Emissions Reduction Program. Beijing, China.

Price, L., Wang, X., Yun, J., 2010. The challenge of reducing energy consumption of the Top-1000 largest industrial enterprises in China. Energy Policy 38, 6485–6498.

Ran, R., 2009. Environmental Politics at Local Levels in China: Explaining Policy Implementation Gap and Assessing the Implications. PhD thesis, University of Duisburg-Essen.

van Rooij, B., 2006. Implementation of Chinese environmental law: Regular enforcement and political campaigns. Development and Change 37, 57–74.

Ryan, N., 2015. Is there an energy-efficiency gap? Experimental evidence from Indian manufacturing plants. Mimeo.

Scruggs, L., 2003. Sustaining Abundance: Environmental Performance in Industrial Democracies. Cambridge Press.

Takeuchi, Y., 1997. On a statistical method to detect discontinuity in the distribution function of reported earnings. Mathematics and Computers in Simulation 64, 103–111.

Wang, A., 2013. The search for sustainable legitimacy: Environmental law and bureaucracy in China. Harvard Environmental Law Review 37, 365–440.

Wang, Y., 2015. Politically connected polluters under smog. Business and Politics 17, 97–124.

Zhang, D., Karplus, V.J., Zhang, X., 2014. Emissions Trading in China: Progress and Prospects. Energy Policy 75, 9–16.

Zhao, X., Li, H., Wu, L., Qi, Y., 2014. Implementation of energy-saving policies in China: How local governments assisted industrial enterprises in achieving energy-saving targets. Energy Policy 66, 170–184.

Zhao, X., Li, H., Wu, L., Qi, Y., 2016. Enterprise-level amount of energy saved targets in China: Weaknesses and a way forward. Journal of Cleaner Production 129, 75–87.

Zhou, N., Levine, M., Price, L., 2010. Overview of current energy efficiency policies in China. Energy Policy 38, 6439–452.

Zhu, J., Chertow, M.R., 2017. Business strategy under institutional constraints: Evidence from China's energy efficiency regulations. Ecological Economics 135, 10–21.

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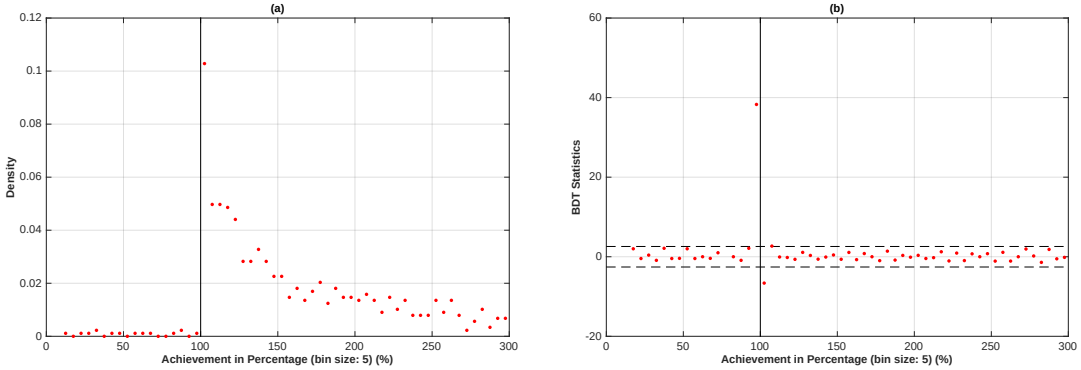

Figure A1: Probability distribution and the BDT for energy saving achievement in percentage of firms under the T1000P (bin size: 5%)

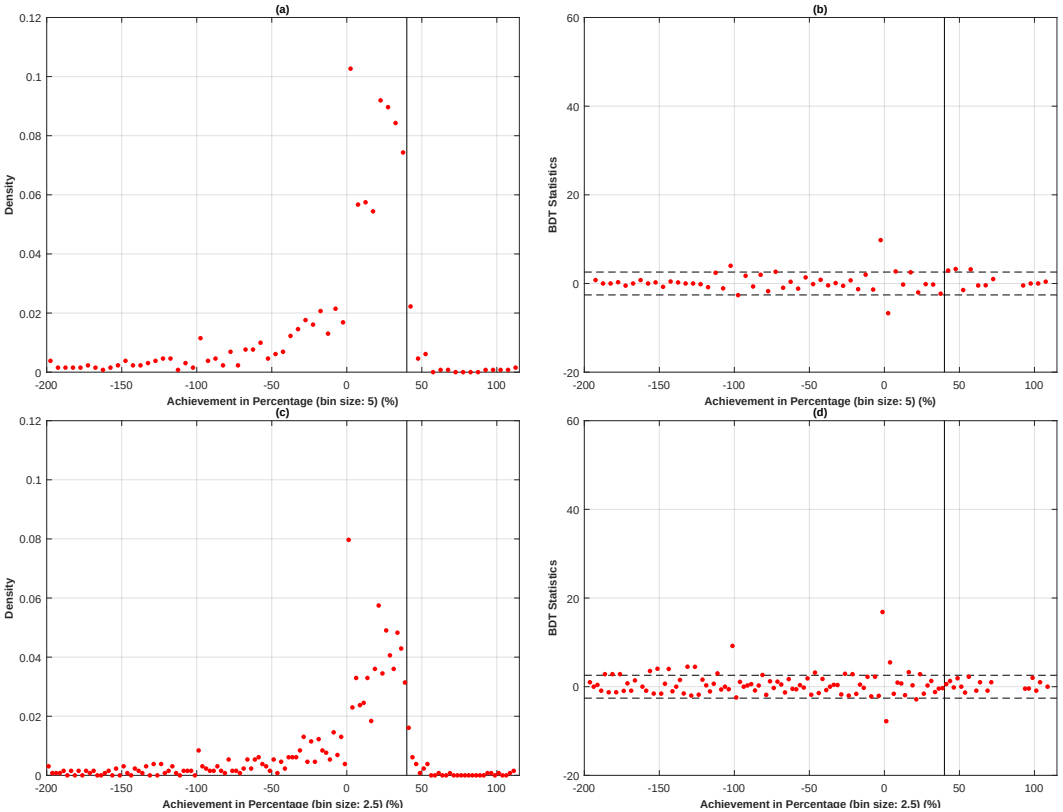

Figure A2: Probability distribution and the BDT for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2012.

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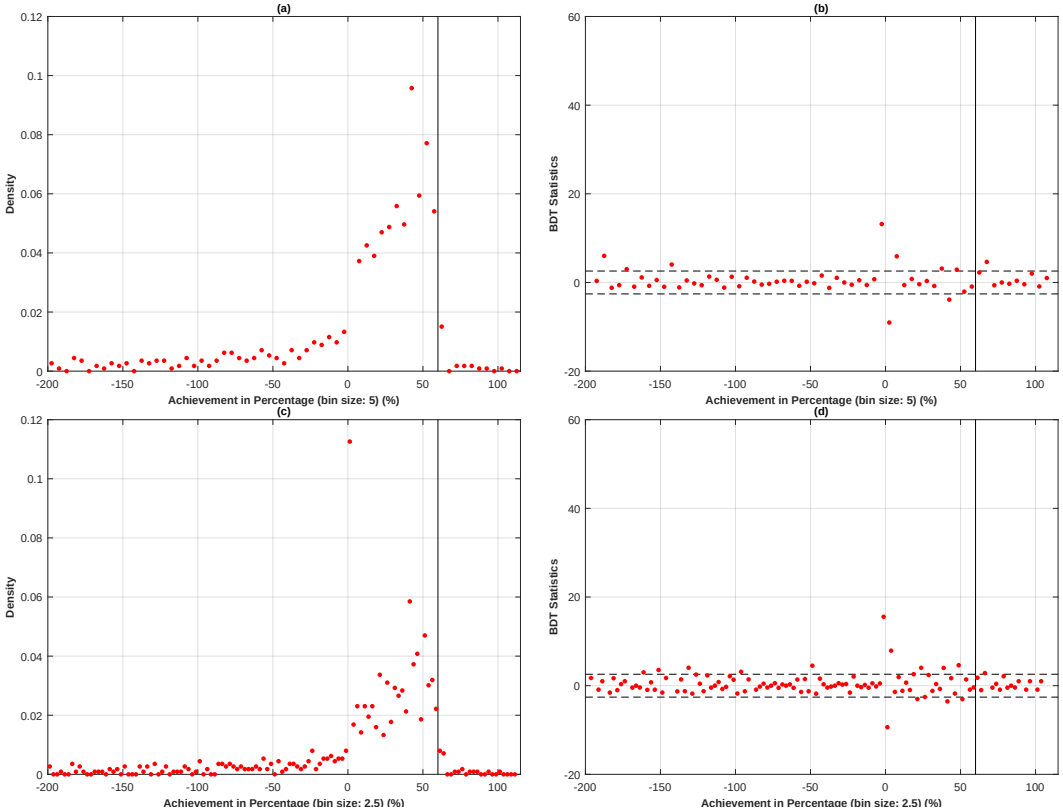

Figure A3: Probability distribution and the BDT for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2013.

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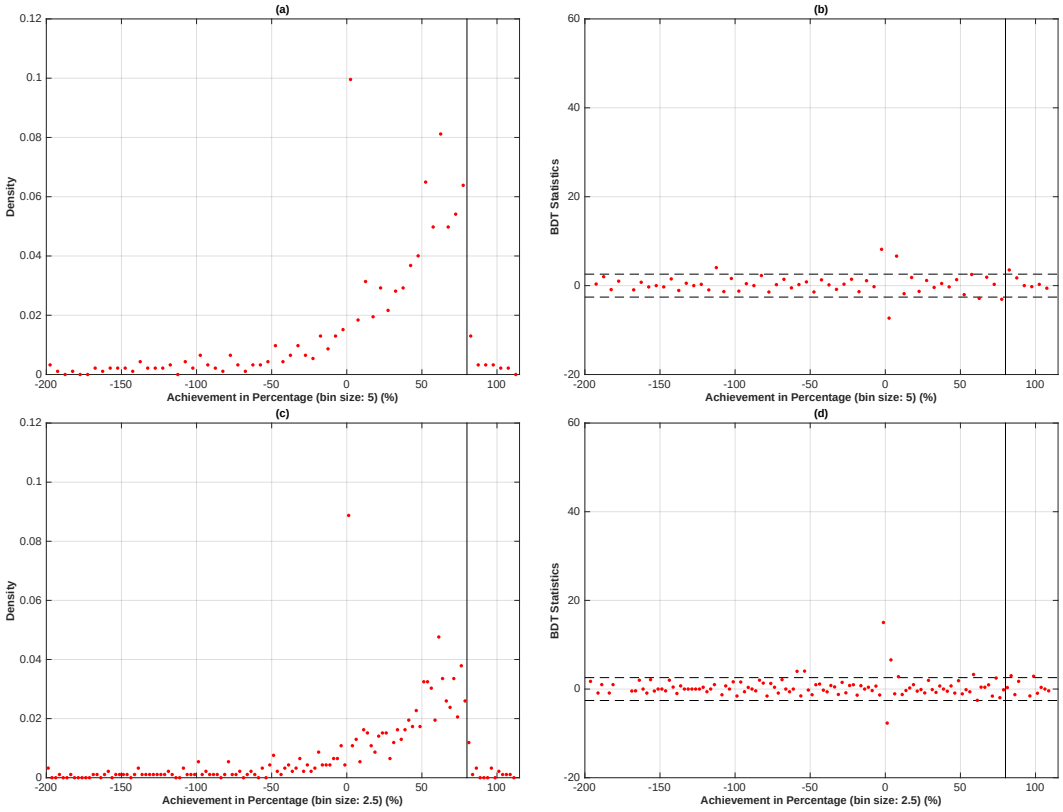

Figure A4: Probability distribution and the BDT for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2014.

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