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Scaling Compliance with Coverage? Firm-level Performance in China's Industrial Energy Conservation Program

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Abstract: Industrial energy conservation programs in China form a cornerstone of China's energy and environmental management efforts, engaging thousands of major energy-using enterprises, and targeting hundreds of million tons of annual coal-equivalent energy savings during the Eleventh and Twelfth Five-Year Plans (2006 to 2015). An important question in China and other developing countries is to understand how compliance systems develop and perform, especially in settings where regulators have limited prior experience and resources to support evaluation and enforcement. We use detailed, newly-released compliance reports, combined with industrial census data on participating firms, to identify the drivers of compliance at the firm level. We find evidence consistent with manipulation of reported compliance data during the Eleventh Five-Year Plan (2006–2010), but not during the expanded program under the Twelfth Five-Year Plan (2011–2015). We show that the non-compliance rate increased with the expansion of the program, and publicly-reported reasons for non-compliance vary widely. We find that firms that are large, and new program entrants, as well as firms in cities with low growth exhibit higher non-compliance rates after program expansion. Our findings demonstrate that although expanding coverage increases potential energy savings, regulators must grapple with increased heterogeneity in firms' internal energy-saving opportunities and capabilities as well as in the degree of external accountability to regulators. Introducing a market for energy saving or CO_2 emissions may help to solve the problem of uneven abatement costs, but differences in the strength of accountability relationships could undermine performance.

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1. Introduction

Limiting the energy and environmental footprint of industrial firms in rapidly emerging nations is a high-stakes governance challenge. Despite the large projected benefits, enforcement of environmental policies remains uneven. In many parts of the world, government programs assign cleanup targets to industrial firms responsible for generating pollution, engaging various levels of the administrative hierarchy in design and implementation. Given the prevalence of these programs, there is a need to understand how policy originates within and is enforced by the governing organization, what determines enterprise-level compliance, and whether or not changes to policy design could improve outcomes.

A recent effort to make detailed firm-level compliance data available for a flagship industrial energy saving initiative in China offers a unique opportunity to study these governance questions. Compared to other nations, China's large and diverse industrial sector makes the country a leading source of energy use, air pollution, and climate-warming greenhouse gases. In terms of coverage and government resources invested, the initiative's two installments—known as the Top 1,000 and Top 10,000 Enterprises Energy-Saving Programs—were the most ambitious efforts to raise the efficiency of industrial firms ever launched in China. Initiated by the central government, the program engaged cadres across all levels of government in the administration of the program. Funds were made available to participating firms to raise energy efficiency through adoption of technology and process changes, contingent on detailed plans for achieving energy saving targets. 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 12th Five-Year Plan (Ministry of Industry and Information Technology, 2012).

China's energy conservation programs are part of a multi-layered effort to increase oversight of the energy system and environmental protection. The Top 1,000 and Top 10,000 Enterprises Programs were designed to support the implementation of mandatory energy-intensity targets at the national and provincial levels. As designed, the Top 1,000 Enterprises Program was expected to deliver 10% to 25% of China's national energy-saving target for the Eleventh Five-Year Plan period (Price *et al.*, 2010), and was later estimated to have delivered much more. The total energy saving achieved by the Top 10,000 Enterprises Program has not been announced at the time of writing, but the energy saving in the first four years (2011–2014) has already surpassed the targeted five-year energy saving.

While participation in both programs was essentially voluntary (e.g. there were no financial penalties for non-compliance), in practice a firm's ownership status determined the strength and channels of accountability. For state-owned enterprises, energy saving achievements were included in cadre performance evaluations, part of an extensive range of criteria used to assess the performance of government officials and SOE leaders. Non-state firms were not subject to such evaluations. In many respects, given the widespread reliance on the personnel evaluation system in enforcing a broad range of policies, studying firm responses to China's energy conservation programs provides insight into China's environmental policy enforcement and the origins of an "implementation gap" that has been documented since the 1990s (Chan *et al.*, 1995).

Here we evaluate China's energy-saving programs on multiple dimensions. Section 2 describes the Top 1,000 and Top 10,000 Enterprises Programs and summarizes firm compliance behavior. Section 3 examines the relationship between pre-existing firm characteristics and policy compliance and identifies predictors of non-compliance behavior. Section 4 discusses the challenges of moving from command-and-control to market-based approaches for energy saving and emissions reduction. Section 5 concludes.

2. Energy Saving Programs in the Context of China's Environmental Policy

The determinants of environmental policy compliance among China's firms has been widely studied. Multiple studies conduct detailed reviews of one or both energy conservation programs (Zhou *et al.*, 2010; Price *et al.*, 2010; Ke *et al.*, 2012; Lu *et al.*, 2014) and find them effective and important for achieving China's national energy intensity reduction goals. These studies belong to a broad and rich literature aimed at explaining variation in the enforcement of China's energy and environmental policy, which includes Kostka and Hobbs (2012) for energy efficiency, Santalco (2012) for renewable energy, Schreifels *et al.* (2012) for sulfur dioxide, and Golding (2011) for water. These papers, together with the environmental law and politics literatures (van Rooij, 2006; Wang, 2013; Kostka, 2016; Ran, 2009), offer insights into the determinants of policy outcomes in China based on interviews, case studies, and provincial or municipal level data.

These studies have pointed to the important role of political campaigns (van Rooij, 2006), command-and-control instruments such as binding environmental targets as well as their unintended consequences (e.g. data falsification and other strategic behavior) in implementation (Kostka, 2016), and the dual role of cadre incentives and the engagement of civil society (Wang, 2013) in strengthening enforcement behavior among local officials. However, we still know little about what sways the behavior of polluters themselves, and under what conditions firms—in this case, large energy us-

ers—do or do not comply with targets. Evidence of how firms respond to voluntary programs such as the Top 1,000 and Top 10,000 Enterprises Programs has, to our knowledge, not been studied in the previous literature.

The fact that the NDRC has made publicly available very detailed firm compliance records for the Top 1,000 and Top 10,000 Enterprises Programs has made the present inquiry possible. This level of transparency on policy compliance is rare in China. Using these data we are able to analyze firm compliance behavior by matching observations with firm-level information from China's industrial census (National Bureau of Statistics, 2003–2011). We find that firms that are large, new program entrants, and firms in cities with low growth tend to fail to comply. We find evidence that the non-compliance rate increases with the expansion of the program, both as a result of reduced deliberate misreporting of compliance data and an increase in the effective stringency of energy saving targets, a function of increasing marginal energy saving cost and target inflexibility. Our findings extend a large literature focused on firm compliance behavior largely in developed countries (see for example Doshi *et al.* (2013) on environmental information disclosure in the U.S., Potoski and Prakash (2005) on environmental regulatory initiatives in the U.S., Bajo *et al.* (2009) on insider trading in Italy, and Gunningham *et al.* (2004) on the voluntary odor control system installation in paper mills in several developed countries). As a developing country with uneven contract enforcement and substantial state ownership of industry, China offers an important case for comparison.

2.1 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) implemented the "Top 1,000 Enterprises Program", which involved 1,008 industrial firms[1], accounting 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 into the "Top 10,000 Enterprises Program" 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 650 million tons of CO_2 emissions mitigation each year (National Development and Reform Commission, 2011).

Reported compliance rates for the Top 1,000 Enterprises Program during the Eleventh FYP were very high, but decreased in the expanded version of the program during the Twelfth FYP. Among the 881 firms evaluated at the end of the Eleventh Five-Year Plan in 2010, there were only 15 firms (1.7%) that did not achieve the target. According to three annual evaluations of the "Top 10,000 Enterprises Programs" in 2012, 2013 and 2014[2], non-compliance rates increased substantially (9.5% in 2012, 8.4% in 2013 and 7.1% in 2014).

2.2 Expanding coverage, growing non-compliance

The most notable change from the Top 1,000 Enterprises Program to the Top 10,000 Enterprises Program was that the coverage became much broader, in terms of both sectors covered and total firms included. The Top 1,000 Enterprises Program originally contained 1,008 industrial firms with energy use higher than 180,000 tons of coal equivalent in 2004 representing nine energy-intensive industrial sectors. The Top 10,000 Enterprises Program 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 users, such as transportation firms, hotels, restaurants, commercial and trade enterprises, and schools. Given its broader coverage, the Top 10,000 Enterprises Program targeted a higher share (37%) of total national energy saving in the Five-Year Plan than the Top 1,000 Enterprises Program (25%). **Table A1** provides a comparison of the Top 1,000 Enterprises and Top 10,000 En-

1 Firms initially included in the program that 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 during the Twelfth FYP. 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 reports were available for the "Top 10,000 Enterprises Programs". 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 NDRC. NDRC then organized on-site checks and document examination in each province in the middle of the year. The results were then finalized and usually published at the end of the year.

Table 1. Numbers of total firms and non-compliant firms covered by the two programs.

	Top 1,000 Enterprises Program				Top 10,000 Enterprises Program			
	Orig. list	Evaluation			Orig. list	Evaluation		
		2008	2009	2010		2012	2013	2014
Total firms	1,008	922	901	881	**16,078**	14,542	14,119	13,328
Non-compliant firms	-	36	28	15	-	**1,377**	**1,191**	**948**
Non-compliant rates	-	3.9%	3.1%	1.7%	-	9.5%	8.4%	7.1%

terprises Programs[3]. In **Table 1**, we show non-compliant firms and total firms evaluated by year for each program.

Annual compliance reports for the Top 10,000 Enterprises Program only include non-compliant firms as well as all SOEs, but contain no information on firms that prematurely exit the program. We are therefore only able to provide non-compliance information by sector for firms included in the original list and for non-compliant firms included in annual reports in **Table 2**.[4]

Table 2 shows that non-industrial firms have 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 fairly high non-compliance rates in 2012, but compliance greatly improved in 2013 and 2014. In general, these organizations seem to respond to the program. Overall, the non-compliance rate for industrial firms in the Top 10,000 Enterprises Programs is still significantly higher than that of the Top 1,000 Enterprises Program.

Since detailed sector information for industrial firms under the Top 10,000 Enterprises Program is not available, and the compliance reports provide no financial data, we match the firms using firm names and ID with a comprehensive firm-level data set (the China Industrial Census, CIC) that contains very detailed corporate finance information on all registered firms above 5 million RMB (about US $800,000)[5]. **Table 3** shows the matching results.

Expanding sector coverage does not fully account for the increase in the non-compliance rate. Among all the industrial firms in the Top 10,000 Enterprises Program, 6,945 firms were successfully matched to the 2011 CIC data. Of the 6,945 firms matched, 4,951 are from the sectors that were covered in the Top 1,000 Enterprises Program. Non-compliance rate among these firms, assuming all these firms did not prematurely exit the program in the following years, are 8.5% in 2012, 8.0% in 2013, and 5.0% in 2014 respectively, slightly lower than the overall non-compliance rate for all industrial firms.

We further match the merged data set above with the Top 1,000 Enterprises Program data, and find that among the 6,945 firms, 412 firms were included in the Top 1,000 Enterprises Program. The non-compliance rate for these firms is 8.7% in 2012, 7.3% in 2013, and 5.1% in 2014 respectively, suggesting that even for the same group of firms, compliance has become more difficult under the Top 10,000 Enterprises Program. **Table 4** shows the summary statistics of industrial firms successfully matched to the 2011 CIC data.

2.3 Possible explanations for non-compliance

Many reasons could explain the higher non-compliance rate in the Top 10,000 Enterprises Program. For example, fewer inexpensive energy saving technologies, lower energy prices (in particular, for coal, as the price plunged due to oversupply in the face of slowing demand

3 All the government documents used in this paper have been collected from the NDRC website and will be made publicly available after this paper is published.

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 noncompliance 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. The numbers of firms that did not achieve their target in "hotels and restaurants" and "commercial and trade" sectors remained almost unchanged over the three years, which suggests our assumption may be justified.

5 The industry section of the China Statistical Yearbook is compiled based on this dataset. To our knowledge, the CIC is the most detailed database of Chinese industrial firms available. The CIC 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.

Table 2. Coverage and estimated non-compliance rates for the Top 10,000 Enterprises Program.

	Orig. list	Evaluated in 2012		Evaluated in 2013		Evaluated in 2014	
	Total Firms	Non-Compliant Firms	Non-Compliance Rate (Estimated)	Non-Compliant Firms	Non-Compliance Rate (Estimated)	Non-Compliant Firms	Non-Compliance Rate (Estimated)
Industrial	14,641	1,174	9.0%	1038	8.2%	693	5.8%
Transportation	548	63	11.5%	37	6.8%	28	5.1%
Hotels & Restaurants	195	14	7.2%	13	6.7%	12	6.2%
Commercial & Trade	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 list and non-compliant firms (numbers in bold in **Table 1**).

Table 3. Industrial firms matched using the Top 1,000 and 10,0000 Enterprises Programs data and industrial census data.

	Top 1,000 Enterprises				Top 10,000 Enterprises
	Orig. list	**2008 Evaluation**	**2009 Evaluation**	**2010 Evaluation**	**Original list**
Industrial firms total	1,008	922	901	881	14,641
Industrial firms matched	1,001[6]	862	840	824	6,945
Percentage matched	99.3%	93.5%	93.2%	93.5%	47.4%

Table 4. Summary statistics of industrial firms matched to the 2011 CIC data.

	Top 1,000 Enterprises Program		New Entrants in the Top 10,000 Enterprises Program	
Number of firms	**412**		**6533**	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
Revenue (billion yuan)	6.5	14.5	1.0	5.0
Assets (billion yuan)	3.7	9.3	0.5	2.1
Employees (thousands)	8.7	20.5	1.3	3.9
Age (years)	22.5	19.7	11.4	26.1

growth since 2012), and tighter scrutiny over self-reported performance information could help to explain the observed decrease in compliance. Another potential explanation is that data manipulation in favor of target achievement was much more prevalent during the Top 1,000 Enterprises Program compared to the Top 10,000 Enterprises Program. We examine and compare reported compliance behavior of firms to understand whether or not compliance behavior changed substantially with the expansion of the program, focusing on the behavior in the neighborhood of the target.

Manipulation in the reporting of environmental data in China is a well-documented phenomenon. 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 PM10 numbers below the "Blue Sky Day" threshold (Chen *et al.*, 2013; Ghanem and Zhang, 2014) using statistical approaches. The "bunching" behavior just below the compliance threshold defined by a policy is also observed in other developing countries (Duflo *et al.*, 2013).

In this study, we apply a statistical method from Chen *et al.* (2013) to analyze whether or not firms' energy saving data is "bunched" above the target under the Top 1,000 Enterprises Program[7]. We calculate each firm's energy sav-

6 We are able to match all the firms in the original list of the Top 1,000 Firms Enterprises with unique firm ID with the CIC data. However, some participating firms have the same firm ID but different firm names, either because distinct organizations may belong to the same firm, or due to input error. This duplication is discussed further in Section 4.

7 We can only perform this analysis for the Top 1,000 Enterprises Program as it provides the energy saving amount by firm in addition to their achievement status. For the three evaluations in the Top 10,000 Enterprises Program, only achievement status – 未完成 (not achieved), 基本完成 (almost achieved, 完成 (achieved), or 超额完成 (over-achieved) – is available for central SOEs. The energy saving level is only provided for non-compliant firms, therefore we implement a similar discontinuity test for this subset of firms later on.

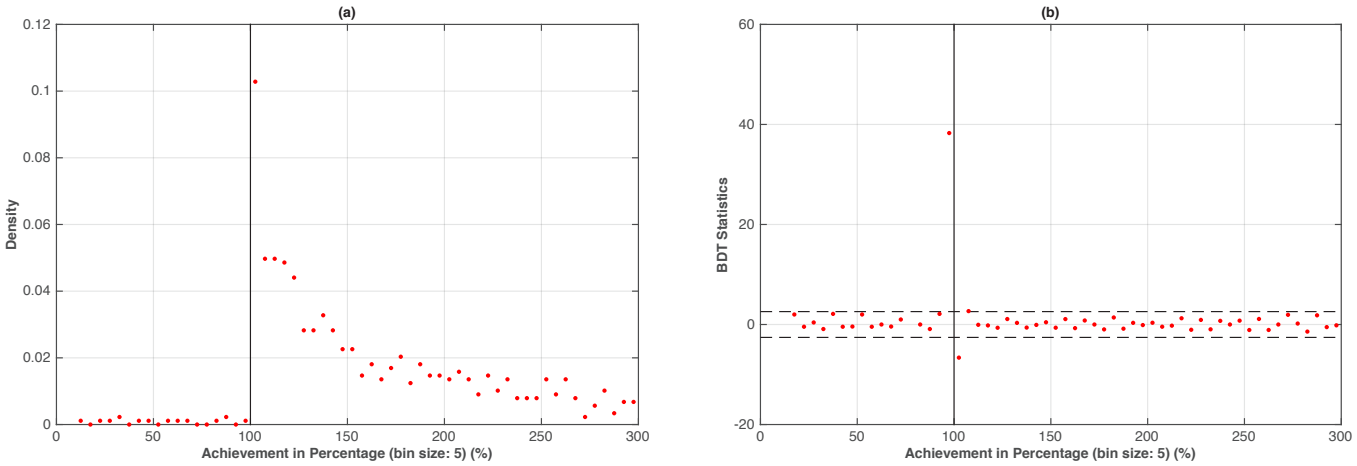

Figure 1. Probability distribution and the BDT test for energy saving achievement in percentage of firms under the Top 1,000 Enterprises Program (bin size: 2.5%).

ing achievement in percentage terms (AP) by dividing reported cumulative energy saving during the program by the energy saving target. If there is data manipulation that results in upward revision of the actual energy saving number to achieve the target, there must be a discontinuity of AP around 100%. This discontinuity does not necessarily prove data manipulation occurred, because firms may strategically achieve the energy saving target by a small margin. However, in practice this accurate hit is challenging as energy saving is affected both by total output in value terms and energy used, which are difficult to co-optimize with a high degree of precision, given that output value reflects current prices in the output market over which a firm usually has limited to no control.

The left panel of **Figure 1** shows the probability distribution of AP with the bin width of 2.5%. 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 density (p_j) with the average of the neighboring probability density (p_{j-1} and $p_{\wedge j+1}$):

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

where n is the total number of observations, and

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

According to Burgstahler and Dichev (1997) and Takeuchi (1997), BDT_j complies with a standard normal distribution if the true data is continuous. With a bigger sample size and narrower bin width, the test is more powerful. As discussed in Takeuchi (1997), the test is powerful if the sample size is more than 500, and our sample size of around 1,000 observations is substantially larger.

The right panel of **Figure 1** shows the result of the BDT test. Dashed lines indicate critical values with a confidence level of 99%. The data shows a significant discontinuity in the neighborhood of 100%. The results are still robust if we increase the bin size to 5% as shown in **Figure 2**.

For the Top 10,000 Enterprises Program, cumulative energy saving data during the Twelfth FYP are only available for the non-compliant firms in 2012, 2013 and 2014. Therefore, 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 A1, A2 and A3**, we do not observe any discontinuity around these potential thresholds. Though we cannot rule out the possibility of energy saving exaggeration by the Top 10,000 Enterprises (Zhao *et al.*, 2016), falsification of target achievement seems to have been eliminated. A campaign during the Twelfth FYP to crack down on statistical misreporting nationwide may also help to explain overall improvements in the quality of statistical reporting relative to the Eleventh FYP.

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

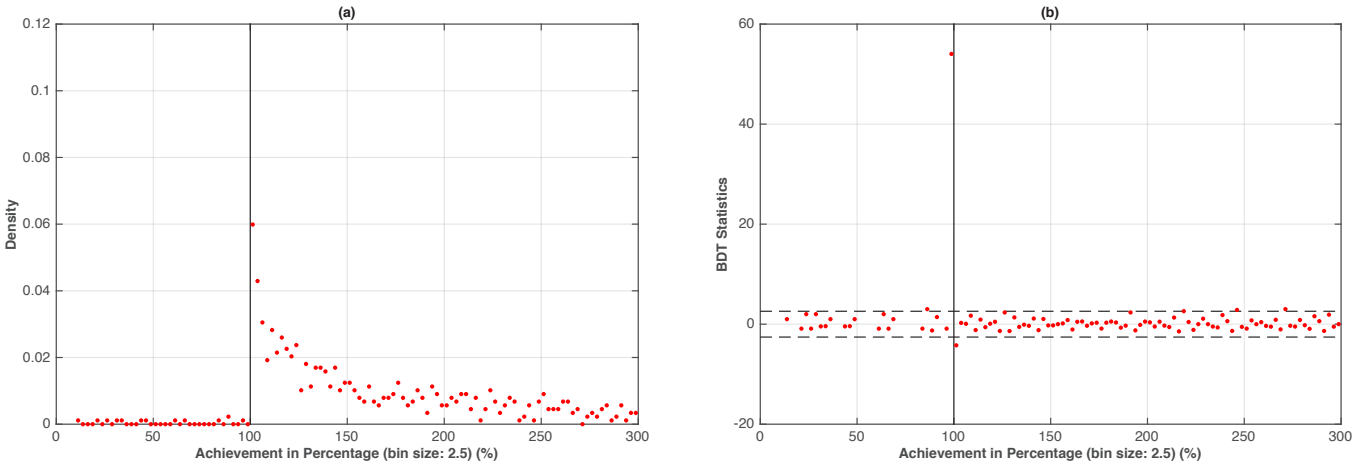

Figure 2. Probability distributsion and the BDT test for energy saving achievement in percentage of firms under the Top 1,000 Enterprises Program (bin size: 5%).

3. Why Do Firms Fail to Comply in the Top 10,000 Enterprises Programs?

In this section, we discuss the self-reported reasons why firms fail to achieve their assigned targets. Starting from the evaluation in 2012, some provinces submitted detailed explanations of the reason(s) for a firm's non-compliance. In 2013 and 2014, more provinces provided this information. Here we collect all the information and provide a detailed summary.

3.1 Reasons for non-compliance

We collect 803 records for non-compliant firms and categorize them in **Table 5**. Firms report a broad range of rationales for non-compliance. Reasons (1) and (2) were most frequently reported. Reports that some firms were unwilling to comply with the evaluation reflect the limits of the program's administrative reach. Firms that are local giants may have had strong bargaining power (Lorentzen *et al.*, 2014) and did not bother to support the program. 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, suggesting that NDRC is pushing the program very seriously, and the government does not want to hide non-compliance behavior.

Firms that closed, stopped production, merged, or changed production were excluded from the evaluation. Therefore, Reasons (3) to (5) should not be listed as reasons for non-compliance. Though those firms were supposed to be exempted, a potential explanation is that provincial or subordinate governments had discretion in policy implementation within their own borders. Reason (6) suggests that new program entrants faced more compliance difficulty. We also observe that in practice provinces behaved very differently when bringing new firms into the program. For example, among the firms which did not achieve the target, some were not found in the original list of the Top 10,000 Enterprises Program, suggesting that they were new firms introduced. We find new firms from Hunan in 2012, from Shanxi, Jiangxi, Henan, Hubei, Hunan, Guangxi and Ningxia in 2013, and from Shanxi, Guangdong and Qinghai in 2014.

Reasons (7) to (15) reflect challenges in the target setting and evaluation system design, which have caused uneven stringency across firms of different sizes and production levels. The energy saving of year t for a firm, ES_t, is calculated using production data from the current year Y_t times the energy intensity difference between the current year t (EI_t) and the last year t–1 (EI_{t-1}).

$$ES_t = Y_t * (EI_{t-1} - EI_t) \quad (3)$$

Reason (7) suggests that firms with low levels of production found it very difficult to achieve the target, even though their production was very efficient, because a decrease in Y_t could translate into an additional requirement in the decrease in energy use per unit of output in order to achieve the same amount of energy saving. At the same time, a low level of production usually increases the energy intensity relative to production at full capacity, because of fixed energy requirements (e.g. for lighting or air conditioning) and more frequent starts and stops. On the contrary, researchers have pointed out that many firms just achieved the target by simply expanding the production with minor technical improvements (Zhao *et al.*, 2016). Reason (8) reflects that some sectors or firms experienced fluctuating energy intensity, requiring multiple years to build a stable baseline. Reason (9) shows that at least one firm claimed that the market price, which firms may not have the power to influence, could introduce additional uncertainty into target achievement.

Table 5. Self-reported reasons why firms failed to comply with the Top 10,000 Enterprises Program.

	Reasons	#	Description	Cases
1	Did not cooperate	115	Refused to submit self-checking report, energy data, or other required materials.	Firm IDs 241528447, 701515971 and others refused to submit required materials; energy saving was accounted as zero; firms were judged as non-compliant.
2	Incomplete materials	130	Did not provide the complete materials and/or data required by the evaluation.	Firms with ID 675122727 and 726283353 provided incorrect energy statistics; some other firms failed to provide complete materials for evaluation.
3	Ceased production	132	Temporarily or permanently stopped entire (or significant part of) production.	Firm ID 726960908 did not produce in the second half of 2013; firm ID 661156432 closed & moved, firm ID 677976195 suspended production for technology upgrades.
4	Merge	13	Merge significantly effected operations.	Firms with ID 755233953, 750204408 and others merged with other firms.
5	Product portfolios change	26	Firms that added energy-intensive products to their portfolios, or experienced certain changes in operations, also increased energy intensity.	Firm ID 727779270 changed product portfolios, resulting in higher energy intensity; firms with ID 748535654 and 669788071 changed from cement sintering to cement grinding; firm with ID 749347233 had to operate new bus lines; firm IDs 124030607 and 724873587 built a new pressure station to reach more remote areas of the city.
6	Lack of capacity; new to program	28	Firms newly included in the evaluation may not have accurate historical data or an energy management system, or lack capacity to meet targets or complete the evaluation.	Firm with ID 680242352 did not complete energy measurement; firm ID 554125606 achieved the energy saving target but had a very low energy management score.
7	Low or unstable production	161	Production was lower than expected, therefore the energy saving linked to production was limited. This may increase the unit energy consumption of the product as more frequent starts and stops reduce efficiency of operation.	Firm with ID 718902097 stopped one fertilizer production line to allow redirection of natural gas supply for household use; firm ID 751122279 reported that real estate depression & severe competition lowered the cement production; firm ID 744566859 reported low production due to low gold price; firm ID 775877086 reported low polysilicon production due to weak international market.
8	Uncertain energy use per unit of production	26	Some firms had production process with fluctuating energy use, especially for some transportation firms.	Firm IDs 607279837, 769410578 and others reported that unit energy use could vary a lot due to vehicle speed change; firm ID 66425867X reported that it only had two customers for steam production, and unavoidable adjustments to meet demand limited energy savings; firm ID 751122279 reported that the unstable quality of limestone used for cement production required more energy to smash; firm ID 684892141 reported more energy was consumed to provide heat in 2013 due to lower incoming water temperature.
9	Product price decrease	5	Decreasing product price decreases output value of a firm with same input use (therefore energy consumption per unit of output value increases).	Firm with ID 744566859 reported that low gold price increased energy consumption per unit of output; firm with ID 741835152 reported product price decreased due to the expansion of production capacity.
10	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.	Firms with ID 241525481 and 241654021 reported ongoing technology upgrading programs; firms with ID 752995776 and 589213438 claimed that they would start energy efficiency programs in later years.
11	Ongoing construction	5	Energy use increased due to new projects under construction.	Firms with ID 463158672 and 606551659 were starting new construction projects.
12	Lower heating value fuels	5	Switching to a lower heating value fuel may increase reported energy use if energy use is not correctly converted to coal-equivalent units by measuring the heating value change.	Firms with ID 214650738 and 791593438 used coal gangue to generate electricity; firm with ID 298980370 reported lower quality of coal.
13	Little room to improve efficiency	34	Firms were very efficient already, with little room to improve.	Firms with ID 66427977X and 767861738 reported that energy use per unit of product was already very low, and the energy saving target was too high.
14	Schools with more buildings	8	School energy targets were linked to the number of students, therefore constructing new buildings made targets harder to achieve if the number of students went unchanged.	Schools with ID 460030008, 460029402 and others constructed new buildings.
15	Poor energy management	12	Firms had very low energy management scores.	Firms with ID 781030850, 754054152, and others achieved energy saving targets, but did not meet energy management requirements.
16	Other "reasons"	98	For example, firms changed their names, or firms saved some energy but not enough.	Firm IDs 775071672 and 19804979X changed names; firm ID 604814160, 751554784, and others reported progress but not compliance; firm ID 791558405 had higher energy use; firm ID 67732965X and 66425867X had outdated equipment; firm ID 578663441 and 128512937 claimed insufficient funds to invest in energy efficiency; firm ID 753710840, 718804075 and others claimed to have too many light-duty vehicles; firm ID 681506399 and 767027313 claimed to have no independent accounting or decision power; firm ID 753063719 achieved energy saving, but had low evaluation scores.

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

A decreasing output price makes it harder for firms to comply, while an increasing price may allow firms to hit the target with no substantive effort. However, Zhao *et al.* (2016) points out that the national standard for energy saving auditing requires using a constant price when calculating energy saving. Therefore, in this case either the firm mistakenly used the current price, or the local government applied the wrong price for evaluation.

Reason (10) relates to the time flexibility of target achievement. To prevent the "Eleventh-Hour" efforts like 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 a disaggregated annual target. However, this requirement meant that firms had limited temporal flexibility to undertake the required upgrades. As energy saving from a single technology upgrade may exceed the target required for the whole five years, and there is no reward from government for early achievement, firms may simply implement the upgrades after considering opportunity cost, e.g. the potential for a decrease in upgrade cost and loss of sales due to the suspension of production while the upgrade is made. Reasons (11) and (12) suggest that more rigorous energy accounting standards are required. It may be defensible to exclude temporary energy use increases due to new construction when calculating energy saving, but in principle changing fuel quality should not make compliance more difficult if the correct heating value is applied in the conversion. Some firms may be switching to lower cost, lower heating value fuels but do not know how to accurately convert to standard ton-equivalent coal use, so they reported this as a reason for non-compliance. However, it should not be a problem if they comply with the requirement of energy accounting and build the capacity to measure the heat value change correctly.

Reasons (13) and (14) shed light on one important aspect of the program: how to allocate targets to firms in a manner that balances economic efficiency and equity considerations. Though the documents for the Top 10,000 Enterprises Program do not explicitly explain how the national 250 million tons of coal-equivalent energy saving target was disaggregated to the firms, previous research (Zhao *et al.*, 2014) has suggested that firms' historical energy use played a dominant role in the allocation process, probably with some (limited) provincial or firm-specific adjustments based on estimated energy-saving potential.

Therefore, firms that are already at the energy efficiency frontier may still face very stringent targets, if they are large energy users. 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. Another challenge concerns under what conditions the target should be adjusted. It seems that schools that exceeded their original target because they needed to build a new library, stadium, or dormitory to provide better educational service were still deemed non-compliant.

Reason (15) reflects an additional requirement implemented by the NDRC during the Top 10,000 Enterprises Program. Firms that did not meet the energy management requirement were treated as non-compliers, even if they have achieved the energy saving target. This is crucial because the energy data adopted in the evaluation is largely based on firms' self-reported data, and observers rightly worry about the data quality if no standard energy management system is established. Moreover, the energy management system itself is designed to mitigate inattention to energy saving by raising awareness among a firm's leadership.

3.2 Firm characteristics associated with non-compliance

Previous research has shown that compliance behavior can vary with firm capacity, e.g. economic resources and management level (Weaver, 2014), and external environment, e.g. deterrent fears of being punished for violation (Gunningham *et al.*, 2002), and social pressures from the media and citizens (Kagan *et al.*, 2003). Here we ask which characteristics are associated with non-compliance in the Top 10,000 Enterprises Program. We speculate that firm size, profitability, ownership status, and inclusion in the Top 1,000 Enterprises Program may affect compliance. These factors are common control variables used in previous literature (e.g. Doshi *et al.*, 2013 and Bajo *et al.*, 2009), and are also potentially connected to reasons of non-compliance listed above. 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 apply the logit model to analyze the effects of these factors on the firm compliance. 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.

In **Figure 3**, we rank provinces according to the non-compliance rate in 2012 from high to low. Dashed lines show the non-compliance rate of firms that are matched with CIC, 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 CIC is able to approximate the full data set. The range of non-compliance rates

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

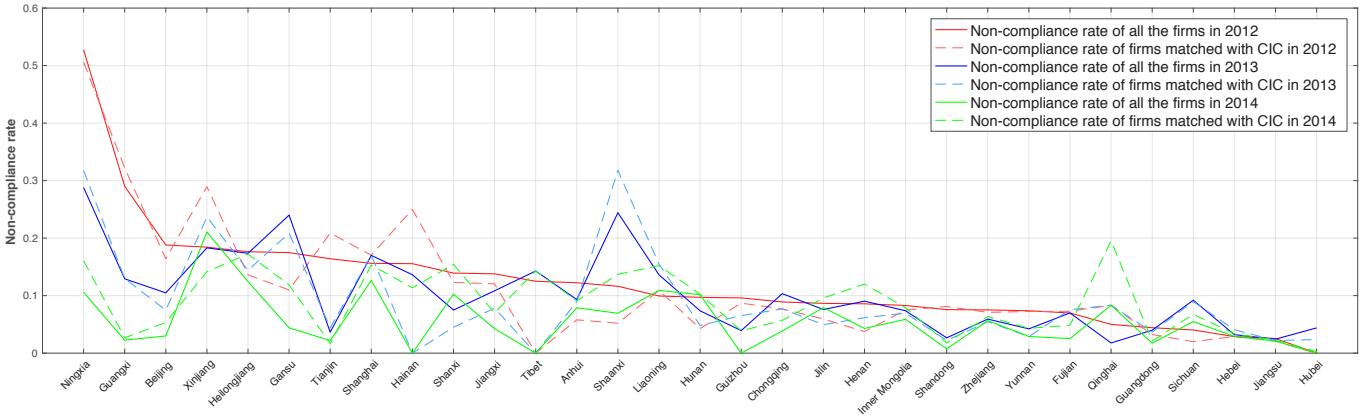

Figure 3. Non-compliance rate by province for all the firms and firms matched with CIC data in 2012, 2013 and 2014.

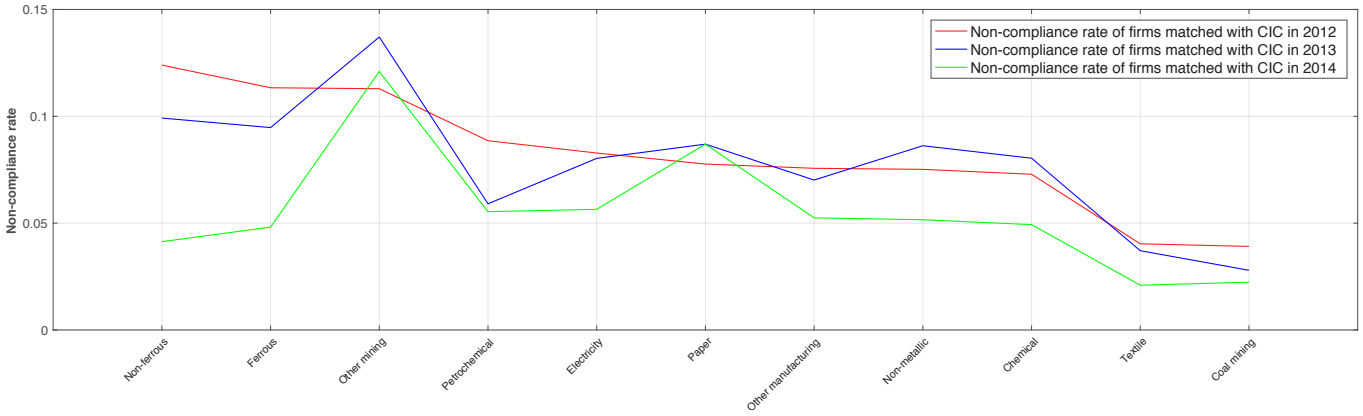

Figure 4. Non-compliance rate by sector for firms matched with CIC data in 2012, 2013 and 2014.

across provinces varies widely, especially in 2012, with the highest rate above 0.5 and lowest rate of 0[10]. 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 local government is very strict in the evaluation. Compliance rates across different sectors[11] also vary, but exhibit a much narrower range and higher consistency over the three years, as shown in **Figure 4**.

We run a logit regression to analyze factors associated with non-compliance, shown in **Table 6**. The dependent variable is a binary variable for non-compliance. The value of the dependent variable is 1 if a firm is non-compliant and 0 if a firm is compliant. We use the log of main business revenue as a proxy for firm size, and profit rate (total profit divided by main business revenue) as a proxy for profitability. A 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 is included in the Top 1,000 Enterprises Program or not.

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. This may be especially true for those non-SOEs, which are not obligated by the government to report energy saving as part of annual cadre evaluations[12]. Though not significant, firms with lower profitability tend to fail to achieve the target as we discussed previously. Compared to the non-state owned firms, SOEs under central supervision have slightly lower non-compliance

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 Top 1,000 Enterprises Program, and the other two sectors are other mining industries and other manufacturing industries besides those nine sectors.

12 In a robustness check we interact the size proxy, i.e. log revenue, with SOE dummies, and find the coefficient of size variable still significant and positive, but the coefficients of interaction terms are significant and negative, which means large SOEs have relatively low non-compliance rates.

Table 6. Factors predicting non-compliance with the Top 10,000 Enterprises Program.

	(1)	(2)	(3)	(4)
Log (main business revenue)	0.04*	0.05**	0.06**	0.08***
	(0.02)	(0.02)	(0.02)	(0.02)
Profit rate		-0.25	-0.26	-0.28
		(0.33)	(0.34)	(0.34)
Central SOE			-0.21	-0.19
			(0.13)	(0.13)
Local SOE			0.06	0.08
			(0.07)	(0.07)
Top 1,000 enterprise				-0.33*
				(0.13)
Constant	-2.32***	-2.34***	-2.42***	-2.54***
	(0.32)	(0.32)	(0.32)	(0.32)
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	20793	20793	20793	20793

rate, but local SOEs have slightly higher non-compliance rates. This is consistent with the finding of Lo (2015)'s case study on the compliance behavior of the Top 10,000 enterprises in Changchun City, Jilin Province.

Central SOEs face more pressure from the central government to achieve the targets. They 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 Top 1,000 Enterprises Program have relatively low non-compliance rates, as they may have a well-established energy management system and take the energy saving targets more seriously. The expected non-compliance rate is 4.2% for those firms compared to 5.7% for others if all the other variables are held at the mean value.

We further explore if macroeconomic and institutional factors matter as previous research has found the local political economy can affect environmental policy implementation in China (Eaton and Kostka, 2014). 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 mitigation cost is higher. Similarly, the expected effect of GDP growth rate is also unclear. 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 it easier to achieve the target. **Table 7** shows the regression results.

Consistent with the latter explanation, we find a highly significant and positive coefficient on GDP growth rate. We further find evidence that the development level of the city where the firm is located does not affect compliance behavior.

4. Command-and-Control Meets Market-Based Approaches

4.1 Incompatibility

China has recently announced that a national emission trading system (ETS) will be started by the end of 2017, and the fate of command-and-control energy saving programs such as the Top 1,000 and 10,000 Enterprises Programs remains unclear. These two approaches, which impact energy (an emissions trading system would tar-

Table 7. Factors including local economic indicators predicting non-compliance with the Top 10,000 Enterprises Program.

	(1)	(2)	(3)
Log (main business revenue)	0.07**	0.07**	0.07**
	(0.02)	(0.02)	(0.02)
Profit rate	-0.44	-0.42	-0.43
	(0.33)	(0.33)	(0.33)
Central SOE	-0.17	-0.16	-0.16
	(0.14)	(0.14)	(0.14)
Local SOE	0.09	0.09	0.09
	(0.08)	(0.08)	(0.08)
Top 1,000 enterprises	-0.34*	-0.34*	-0.34*
	(0.15)	(0.15)	(0.15)
Per-capita GDP	0.006		0.004
		(0.01)	(0.01)
GDP growth rate		-0.03***	-0.03***
		(0.01)	(0.01)
Constant	-2.67***	-2.29***	-2.33***
	(0.35)	(0.35)	(0.37)
Province fixed effects	YES	YES	YES
Sector fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Number of years	3	3	3
Number of observations	17999	17999	17999

get only fossil energy), may be incompatible. An ETS encourages flexible target compliance by allowances trading, while command-and-control programs require a hard target for each firm to save energy or reduce emissions within a firm's own fence. We find evidence that this inflexibility has caused some firms that are already very energy efficient to fail to achieve the target, consistent with the finding in Zhao *et al.* (2014). Among the reasons that explain why firms fail to comply, one given for Datang Jixi Thermal Power Company in 2013 is noteworthy:

"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[13], 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 bilateral energy saving trading implies that the stringency across different companies could be very different, and the potential opportunity for trading to reduce aggregate compliance costs is large. Though the implementation plan for the Top 10,000 Enterprises Program endorsed the necessity of the energy saving trading scheme, Jiangsu Province is the only province which has officially launched energy saving trading in 2015[14]. However, firms may be reluctant to participate in large-scale trading programs, given that they feel pres-

13 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 Top 10,000 Enterprises Program.

14 Energy saving trading is not limited to the Top 10,000 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".

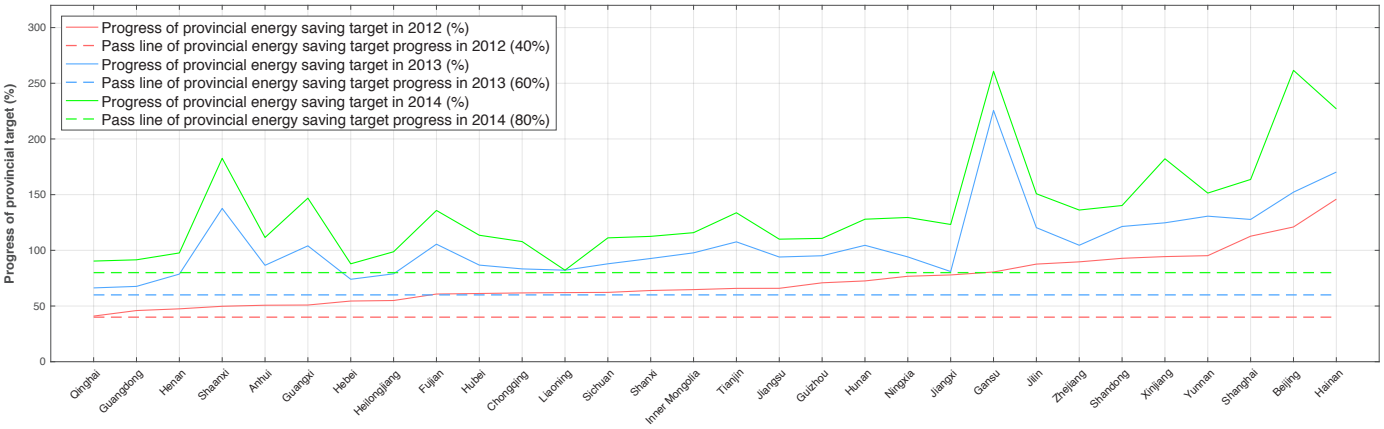

Figure 5. Overall energy saving achievement rate at the provincial level in 2012, 2013 and 2014.

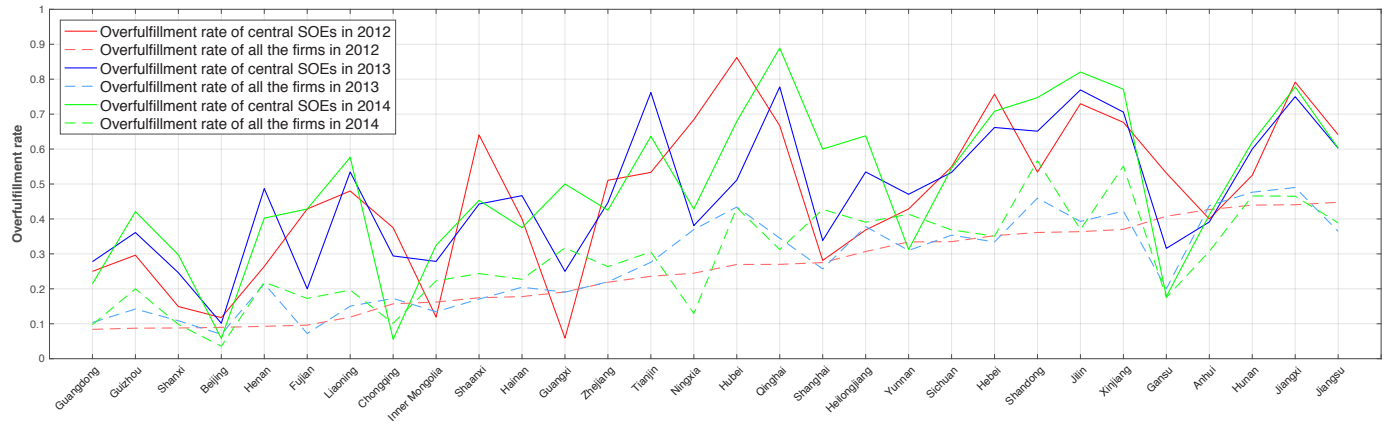

Figure 6. Overfulfillment rate by province for central SOEs and all the firms in 2012, 2013 and 2014.

sure to undertake the reductions within their organization to comply with the Top 10,000 Enterprises Program.

However, moving to a market system such as an ETS could 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 5** 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. For all three years, all the provinces have passed the progress target (40%, 60%, and 80% respectively). Surprisingly, in 2013 about half (15) of the provinces had already achieved their Five-Year energy saving targets. The number of provinces increased to 25 by the end of 2014. This suggests that many firms significantly overfulfill their energy saving target, because of either cheap energy saving opportunities or great support/pressure from the government. In other words, in order to achieve the provincial target, the provincial government does not necessarily push every firm to achieve the 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. For example, Beijing and Shanghai are among the provinces with 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 could 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 overfulfillment rates of central SOEs[15] are higher than the rates of all the firms in most provinces shown in **Figure 6**. It is worth considering whether government enforcement pressure will be as effective if these firms have opportunities to purchase reduction credits from outside their own boundaries.

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

On the other hand, the (over-)reliance on these limited 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. It is understandable that local governments may "wave through" self-reported firm-level energy saving, as they do not want the total energy saving in their provinces to fall. At the central level, there is no detail available on the scrutiny of the energy saving data (i.e. no results of inspection or auditing are published) from more than 10,000 enterprises, which is no doubt a very challenging task that requires significant investment in monitoring infrastructure and personnel training. This prompts a need for independent third-party auditing, which will be essential for the enforcement of energy and environmental policies. This third-party auditing could be coordinated with the development of a national ETS and financed by the government at the beginning to limit the risk of industry capture (Duflo *et al.*, 2013).

4.2 Lessons for future policy design

The Top 1,000 and 10,000 Enterprises Program provides an important common basis for future policies, regardless of whether it is command-and-control or market-based. First, the large scale of the program has successfully drawn enough attention of those company executives, who might just simply ignore energy saving opportunities, even if their firms are large energy users and face highly profitable energy saving opportunities. The publication of compliance information further adds pressure. Second, the program to some extent addressed the financing problem of energy efficiency retrofits. Beyond the aid of the central government, many provincial governments also initiated similar energy saving programs that set firm-specific targets and provided financial aid involving more 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 Top 1,000 Enterprises Program during the 11th FYP (Government of Shanxi Province, 2008). Third, data collection mechanisms required for program effectiveness are now established and being improved. Only with this system fully functional is it possible to have targets allocated in line with policy objectives, such as equity or cost-effectiveness, and policies ultimately enforced. Finally, NDRC's release of the program's compliance documents is a positive step that increases the transparency of the policy and offers a chance to engage public participation in the energy saving campaign. Previous studies have found that higher public participation, transparency of results, and easier access to information could help environmental policies achieve improved outcomes (Scruggs, 2003; Lipscy, 2011). Transparency also makes it possible for researchers to conduct quantitative analysis, and provides information to policymakers that can use it to improve the effectiveness of the program. Besides the findings presented above, we also note some minor inconsistencies and errors in these documents (limited to firms in some provinces, see the Appendix for details), and transparency can help to improve the quality of data reporting.

Shifting the regulated unit from firm to installation could further help to improve the effectiveness of the program. Currently, both the Top 10,000 Enterprises Program and ETS pilots give firms energy saving targets or emissions allowances, different from the EU-ETS, which includes the installation as the unit for compliance. We propose moving towards the installation-level compliance for several reasons. First, there are many cases that the same firm has different names or even different IDs, or one firm has various branches (see examples in **Table A2**), which can cause confusion or potential double counting issues. For example, 华新水泥股份有限公司 (Huaxin Cement Co., Ltd.) appears twice in the 2010 evaluation of the Top 1,000 Enterprises Program, as it has two branches in Hubei; additionally, there are three firms with different firm names and IDs[16] that are exactly the same firm covered in the Top 10,000 Enterprises Program. Second, target setting at the installation level could avoid the need for adjustments when firms merge, split or significantly change product portfolios. For example, in the 2010 evaluation of the Top 1,000 Enterprises Program, the energy saving target for 包头钢铁（集团）有限责任公司（含包钢联）(Baotou Steel (Group) Co., Ltd. (including Baoganglian)) was adjusted from 755,100 tons to 832,600 tons after it acquired another firm 包钢联 (Baoganglian); conversely, the target for 白银有色集团股份有限公司 (Baiyin Non-ferrous Metal Group Co., Ltd.) in 2009 was shared by two firms 白银公司 (Baiyin Company) and 甘肃华鹭铝业公司 (Gansu Hualu Aluminum Company), which are newly included in the Top 1,000 Enterprises Program in 2010. There are also many examples of firms that change their sectors or production portfolios so their targets have to be adjusted. Similarly, issues that cause non-compliance like ongoing construction or having new buildings can be avoided. Setting the target on installations can also be helpful for benchmarking and online energy/emissions monitoring.

16 These three firms are 国网能源开发有限公司天津大港发电厂 (Tianjin Dagang Huashi Power Generation Co., Ltd.; ID: 803060357), 天津大港华实发电有限责任公司 (Tianjin Dagang Huashi Power Generation Co., Ltd.; ID: 735474880), and 天津大港广安津能发电有限责任公司 (Tianjin Dagang Guang'an Jinneng Power Generation Co., Ltd.; ID: 718258879).

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 shirking of central directives is usually not easy. The detailed records released for the Top 1,000 and 10,000 Enterprises Program provide us with a unique opportunity to study non-compliance behavior in firms. We find evidence of the potential and limits of industrial energy conservation programs in China, which offers lessons for future adjustments as well as for programs design in other emerging markets.

The fact that non-compliance significantly increased from the Top 1,000 to the Top 10,000 Enterprises Program suggests that further expansion of the program could exacerbate compliance challenges. The increase in the non-compliance rate seems to reflect, at least in part, the increasing diversity of firms in the expanded program. Indeed, the Top 1,000 Enterprises Program was predominantly state-owned firms that faced significant pressure to report, if not actually achieve, compliance. In the Top 10,000 Enterprises Program, firms that were larger, new program entrants, and firms in cities with low growth tended to fail to comply, consistent with a story in which the state's span of control over covered firms during the Top 1,000 Enterprises Program was diluted by a weaker span of control and local resource constraints once the program was expanded.

Our analysis also identifies gaps in program administration that future iterations could usefully address. The first is to shift the regulated unit targeted from firm to installation. Currently, both the Top 10,000 Enterprises Program and ETS pilots give firms energy saving targets or emissions allowances, which is a fundamental difference compared to the EU-ETS, which focuses on the installation as the unit for compliance. Evaluating compliance at the installation level is attractive because: a) we found many cases in which the same firm has different names or even different IDs, or one firm has different branches, which can cause confusion or potential double counting issues; b) target setting at the installation level could avoid the need for adjustments when firms merge, split, significantly change product portfolios, or ongoing construction, which frequently occurred during the 2006–2015 period. We also note that although we do not find evidence of intentional data manipulation under the Top 10,000 Enterprises Program in the Twelfth FYP, we cannot prove that it is not occurring. Future programs could benefit from stronger auditing and third-party verification, which is currently required for firms included in China's future national emissions trading system.

We note the potential for incompatibilities to arise between the national emission trading system (ETS) proposed to start in 2017 and energy conservation programs such as the Top 1,000 and Top 10,000 Enterprises Programs, which follow the command-and-control approach. If they coexist, these programs will likely target many of the same firms. The large and growing non-compliance rate observed in China's energy conservation programs suggests that the rigidity of the program has resulted in some already very energy efficient firms failing to achieve the target, while at the other extreme, there are firms that surpass their energy saving targets by a large margin. A potential reason for this phenomenon is that provincial governments lean hard on firms over which they have direct control to deliver the balance of the provincial contribution to the national aggregate energy intensity reduction target, making up for the shortfall among those firms that for technical or other reasons do not fulfill their targets. Indeed, the fact that central SOEs report the higher rate of over-achievement lends support to the argument that it is politically much easier to reduce energy use by targeting a few key firms, especially SOEs. Overlaying a market system would require a heavy lift in setting up new institutions, e.g. well-functioning third-party auditing and exchange markets, and efficient operation would require refraining from using government channels of influence that have proven effective in soliciting compliance under command-and-control programs.

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Appendix

Table A1. Comparison between the "Top 1,000 Enterprises" and "Top 10,000 Enterprises" Programs.

	Top 1,000 Enterprises	Top 10,000 Enterprises	Note
Policy document	NDRC (Resources Conservation and Environment Protection) [2006] No. 571 (April 7th, 2006)	NDRC (Resources Conservation and Environment Protection) [2011] No. 2873 (December 7th, 2011)	The documents are issued by the same government agency, therefore two programs have the same legal power.
Ministries involved	Five: NDRC, National Energy Administration (NEA), National Bureau of Statistics (NBS), General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), and State-owned Assets Supervision and Administration Commission (SASAC)	Twelve: NDRC, Ministry of Education (MOE), Ministry of Industry and Information Technology (MIIT), Ministry of Finance (MOF), Ministry of Housing and Urban-Rural Development (MOHURD), Ministry of Transport (MOT), Ministry of Commerce (MOFCOM), State-owned Assets Supervision and Administration Commission (SASAC), General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), National Bureau of Statistics (NBS), China Banking Regulatory Commission (CBRC), and National Energy Administration (NEA)	More ministries are involved as competent authorities in the Top 10,000 Enterprises Program as more sectors are covered. MOF and CBRC are involved in introducing more financial policies to incentivize the firms.
Document summary	The full text (4,011 characters in total) is divided into five sections: Significance, Guiding ideology and objectives, Task requirement (6 articles), Tracking and evaluation (6 articles), and Supporting measures (7 articles).	The full text (5,212 characters in total) is divided into five sections: Scope of the program, Guiding ideology, basic principles and objectives, Task requirement (10 articles), Responsibility of relevant ministries (6 articles), and Supporting measures (6 articles).	Similar structure. The Top 10,000 Enterprises Program has more detailed task requirement, more clear responsibility of each ministry involved, and stronger supporting measures.
Role in the energy saving	The Top 1,000 Enterprises Program achieved about 25% of total national energy saving during the Eleventh FYP.	The Top 10,000 Enterprises Program is targeted at achieving about 37% of total national energy saving during the Twelfth FYP.	Both programs are core elements of the national energy saving policy. The role of the Top 10,000 Enterprises Program is more critical.
Sector coverage & threshold	Firms with energy consumption higher than 180,000 tons of coal equivalent in 2004 in the nine sectors: coal, textile, paper, chemical, petroleum and petrochemicals, building materials, steel, non-ferrous metal, and power and heat	Industrial firms with energy consumption higher than 10,000 tons of coal equivalent in 2010, transportation firms that consume more than 10,000 tons of coal equivalent energy in 2010, or have more than 600 vehicles, or higher than 50 million tons throughput, and hotels, restaurants, commercial and trade enterprises, and schools that consume more than 5,000 tons of coal equivalent energy in 2010, or hotels and restaurants that have a business area larger than 80,000 square meters, or commercial and trade enterprises that have a business area larger than 50,000 square meters, or schools that have more than 10,000 students.	The Top 1,000 Enterprises Program only includes energy-intensive industries, while the Top 10,000 Enterprises Program expands the coverage to almost all the sectors. The threshold to be included in the program has also been significantly lowered.
New practices in the Top 10,000 Enterprises Program			
Energy management	In the pilot regions for Certified Energy Manager, the person in charge of energy management in the firms should acquire Energy Manager Certificate from the government. Firms should follow the national standard "Requirements on the energy management system" (GB/T23331) to establish energy management systems.		
Energy measurement	Firms should strive to achieve the online collection and online reporting of energy use data, and keep a comprehensive record of energy consumption.		
Retrofit	Firms should cooperate with energy service company (ESCO) to implement energy saving retrofits via energy performance contracting (EPC).		
Benchmarking	Firms should satisfy the national standards of unit energy consumption for their products. Local standards should also be satisfied if they exist. Stricter local standards should be encouraged.		
Trading	Explore the possibility to establish the energy saving trading scheme.		
Financing	CBRC should urge banks to provide credit support to firms' energy saving projects, and limit lending to firms which are far behind the target. Banks should include "green credit" in the performance evaluation of their executives.		
Oversight	Energy saving supervision agencies at all levels should organize special inspection on firms' energy saving management, energy saving evaluation of fixed assets investment, benchmarking of energy standards, elimination of backward equipment, and implementation of their energy saving plans.		

A1. Inconsistencies and errors in the documents of the two programs

It is entirely understandable that inconsistencies and errors could happen in the program with this size and coverage. We include some minor ones that we find just to give a flavor that engaging the academia and public can help to improve the implementation of the program.

In the Top 1,000 Enterprises Program, there are multiple firms with identical firm ID in the original list shown in **Table A2**.

In the Top 1,000 Enterprises Program, 安徽省六安市建来化工有限公司 (Anhui Lu'an Jianlai Chemical Co., Ltd.) appeared in the 2008 evaluation list and did not appear in the 2009 list, but it was not included in the list of firms that closed, stopped production, merged, or changed production significantly in 2009. 中化平原化工有　限公司（原山东德齐龙化工集团有限公司）(Sinochem Pingyuan Chemical Co., Ltd., formerly Shandong Deqilong Chemical Co., Ltd.), 延边晨鸣纸业有限公司 (Yanbian Chenming Paper Co., Ltd.), 唐山市清泉钢铁有限 责任公司 (Tangshan Qingquan Steel Co., Ltd.), and 唐山市德龙钢铁有限公司（原唐山恒安实业有限公司）(Tangshan Delong Steel Co., Ltd., formerly Tangshan Heng'an Co., Ltd.) appeared in the 2009 and 2010 list, but did not appear either in 2008 list or the original list. The energy saving target for 浙江江山虎球水泥有限公司 (Zhejiang Jiangshan Huqiu Cement Co., Ltd.) was adjusted from 124,800 tons of coal equivalent to 21,100 tons of coal equivalent without explanation.

In the Top 10,000 Enterprises Program, some firms have inconsistent ID in the original firm list and non-compliant firm list in later years. Though some firms may change their ID, there is also clear evidence of typo for some other firms shown in **Table A3**.

In the Top 10,000 Enterprises Program, provinces seem to adopt very different rules when including non-industrial firms in the program. For example, Liaoning, Fujian, Jiangxi, Shandong, Henan, Guangxi and Guizhou did not include any hotels and restaurants, Zhejiang, Jiangxi, Shandong and Henan did not include any commercial and trade enterprises. Xinjiang only included industrial firms and schools, and Tibet and Qinghai only included industrial firms.

Table A2. Firms with the same ID in the original list of the Top 1,000 Enterprises Program.

Firm ID	Firm name 1	Firm name 2
110391196	大同水泥股份有限公司 Datong Cement Co., Ltd.	大同水泥集团有限公司 Datong Cement Co., Ltd.
169951928	中国石化工股份有限公司河南油田分公司 Sinopec Henan Oilfield Company	中国石化集团河南石油勘探局 Sinopec Henan Oilfield Survey
220603110	西安热电有限责任公司 Xi'an Thermal Power Co., Ltd.	西安西化热点化工有限责任公司 Xi'an Xihua Thermal Power Chemical Co., Ltd.
614410741	河南豫港集团公司 Henan Yugang Group	豫港(济源)焦化有限公司 Yugang (Jiyuan) Coking Co., Ltd.
701755932	凌源钢铁股份有限公司 Lingyuan Steel Co., Ltd.	凌源钢铁集团有限责任公司 Lingyuan Steel Group Co., Ltd.
71009796X	长庆石油勘探局 Changqing Oil Survey	长庆油田公司 Changqing Oil Company
710926094	中国石油化工股份有限公司巴陵分公司 Sinopec Baling Company	中国石油化工股份有限公司济南分公司[17] Sinopec Jinan Company
723856718	中国石化胜利油田有限公司 Sinopec Shengli Oilfield Co., Ltd.	胜利油田有限公司 Shengli Oilfield Co., Ltd.

17 We believe the correct Firm ID for 710926094 should be OS0482771.

Table A3. Firms with ID changed in the original list and non-compliance list for later years of the Top 10,000 Enterprises Program.

Firm Name	Firm ID in Original List	Firm ID in Non-Compliance List
山西东方资源发展有限公司 Shanxi Dongfang Resource Development Co., Ltd.	736327516	736322516
青海宜化化工有限责任公司 Qinghai Yihua Chemical Co., Ltd.	619175011	679175017
杨凌职业技术学院 Yanglin Vocational Technical Institute	437096960	437096930
太原晋阳发电有限公司 Taiyuan Jinyang Power Co., Ltd.	71980929X	91980929X
察右前旗泰康铁合金有限公司 Chayouqian Banner Taikang Ferroalloy Co., Ltd.	116782525	116782825
朝阳东鑫有色金属有限公司 Chaoyang Dongxin Nonferrous Metal Co., Ltd.	76833506X	37683506X
珲春市天盛墙体材料有限责任公司 Huichun Tiansheng Wall Materials Co., Ltd.	788722805	778722805
西安邮电学院 Xi'an Institute of Post and Telecommunications	437205106	437205105
丰镇市南山铁合金有限责任公司 Fengzhen Nanshan Ferroalloy Co., Ltd.	752564239	757564239
文水县振兴化肥有限公司 Wenshui Zhenxing Fertilizer Co., Ltd.	70112484X	701724848
海南金红叶纸业有限公司 Hainan Jinhongye Paper Co., Ltd.	774286544	774286524
长治市晋鑫煤焦有限责任公司 Changzhi Jinxin Coking Co., Ltd.	602309427	608309427
杭州华胜纸业有限公司 Hangzhou Huasheng Paper Co., Ltd.	747185138	745081853
海南海峡航运股份有限公司 Hainan Haixia Shipping Co., Ltd.	742989256	742589256
宁波大学 Ningbo University	419529106	419529016
喀左康泰热力有限公司 Kazuo Kangtai Thermal Power Co., Ltd.	768301594	768305194
营口BL矿业有限公司 Yingkou BL Mining Co., Ltd.	726866225	726886225
北京理工大学珠海学院 Beijing Institute of Technology, Zhuhai College	762900857	762900859
平利县光大特种硅业有限公司（陕西） Pingli Guangda Special Silicon Co., Ltd. (Shaanxi)	766305369	776305369
内蒙古双赢化工有限公司 Inner Mongolia Shuangying Chemical Co., Ltd.	752559536	752959536
宝兴县大渔溪电冶有限公司 Baoxing Dayuxi Electrometallurgy Co., Ltd.	75662020X	75662052X
韩城韩禹建材矿业有限责任公司 Hancheng Hanyu Building Materials Co., Ltd.	709971920	909971920

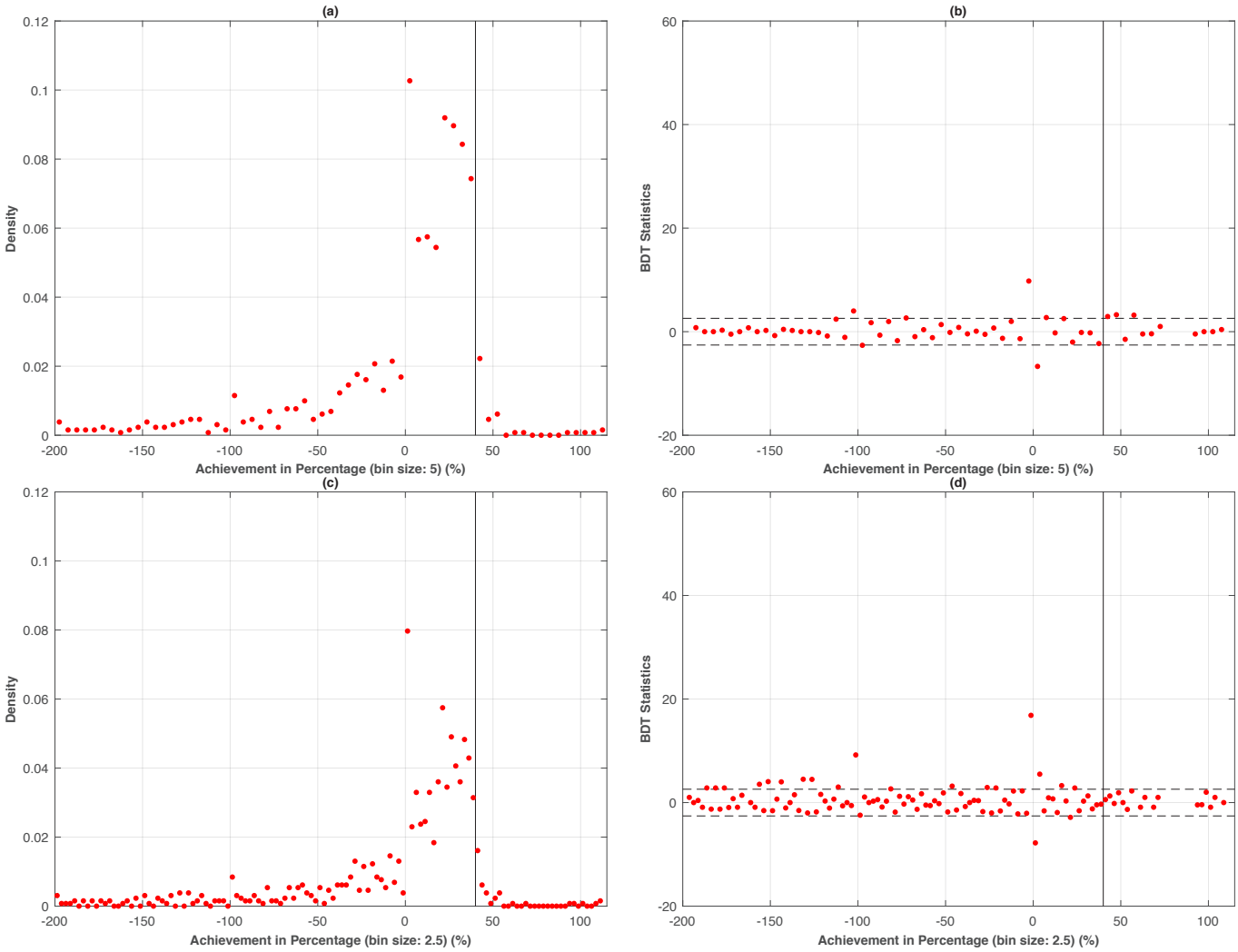

Figure A1. Probability distribution and the BDT test for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2012.

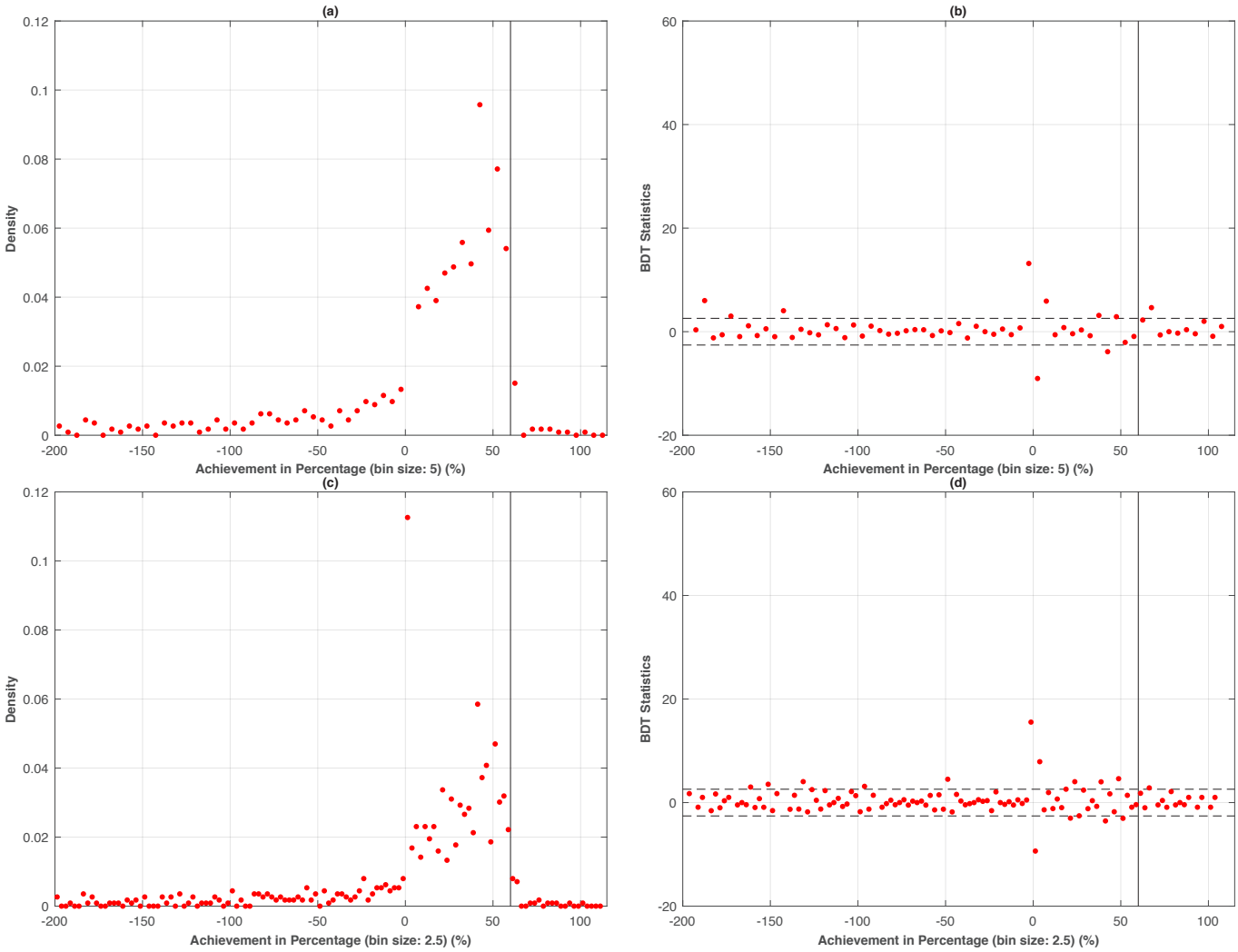

Figure A2. Probability distribution and the BDT test for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2013.

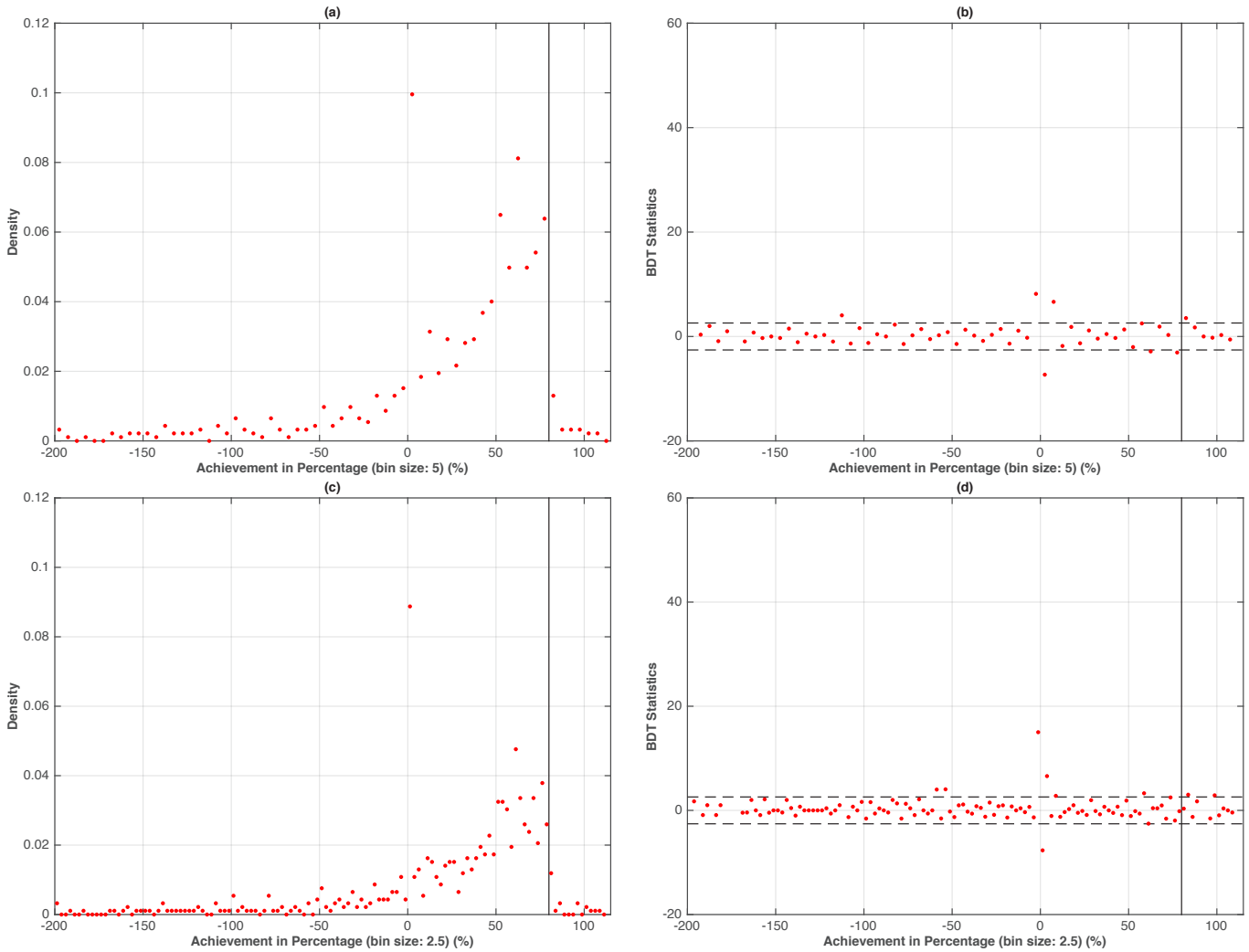

Figure A3. Probability distribution and the BDT test for energy saving achievement in percentage of non-compliant firms under the Top 10,000 Enterprises Program in 2014.

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