Incentivizing firm compliance with China's national emissions trading system

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ABSTRACT

When it launches in 2017, China's CO_2 emissions trading system (ETS) will cover the largest CO_2 emissions volume of any system to date and be among the very first to launch in a developing country. We evaluate the potential of an ETS to alter the emitting behavior of covered firms and to support the achievement of national CO_2 intensity reduction targets at least cost. Specifically, we focus on two questions: (1) What factors have limited firms' past compliance with environmental policy in China, and (2) what can be done to strengthen compliance with China's national ETS? We argue that altering firm behavior will require a simultaneous effort to strengthen firms' compliance incentives through changes to national institutions—in particular, a strong legal foundation for the system, a nationally unified set of measurement, reporting, and verification requirements subject to independent scrutiny, and ongoing broader economic reforms to support system operation. It will also require signaling a sustained commitment to experimentation, evaluation, and modification of the system based on performance, given that system effectiveness will depend on expectations about its longevity and credibility, but will inevitably require adjustments. We illustrate the importance of these recommendations for firm compliance behavior by drawing on the experience of the Beijing pilot ETS (2013-2015). Given vast heterogeneity across provinces, special attention should be given to strengthening institutional foundations where they are least developed alongside the construction of a national ETS.

Keywords: Climate change, emissions trading system, firm compliance, China

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1. INTRODUCTION

Strong regulation "on the books" but weak implementation in practice can undermine the performance of even the most theoretically-rigorous policy designs. As central policymakers prepare to launch China's national emissions trading system (ETS), an important question concerns the potential of this well-known form of market-based policy instrument to succeed in changing firm behavior where past instruments have fallen short. Widespread evidence that implementation of past environmental policies in China has been uneven or incomplete across industries and regions makes this question especially salient. Given that China's ETS will be the largest by covered emissions volume and will be among the very first in a developing country, the stakes are high. China's political and economic institutions also differ from prior im-

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plementation contexts. Against this backdrop, we organize our analysis around two questions: Will China's ETS succeed where past policies failed to elicit firm compliance? What can the system's architects do to incentivize firms to comply?

Many studies rightly focus on policy design. Policy design choices such as coverage, stringency, abatement flexibility, and the form of rewards or punishments directly affect the behavior of covered firms. Designs that exclude some emitters could induce a shift in production to unregulated firms (leakage) (Babiker 2005). Stringency determines the aggregate burden on the economy, while abatement flexibility affects marginal cost of emissions reductions taken. If the consequences of non-compliance are too benign, firms may fall short of obligations, or ignore the policy altogether. These design elements are generally embodied in the policy itself.

While policy design is important, cost effectiveness of policy also depends on the complementarity and dynamic interactions between policy design and underlying institutions (Jenner, Groba, and Indvik 2013; Viétor, Hoppe, and Clancy 2015; Lo et al. 2016). Institutions are rules and norms that govern behavior (North 1991), and can be formal or informal (Stiglitz 2000). The institutional dimension is important for at least two reasons. First, the division of authority and implementation responsibility in governing bodies can influence policy credibility as well as enforcement capacity and incentives. This division exists, for example, horizontally across agencies responsible for various government functions, or vertically across layers of a multi-tiered governing hierarchy. Shared understandings of who can require whom to do what can affect the extent to which covered parties comply with regulations and the ability of measurement, reporting, and verification (MRV) systems to function successfully. Second, the alignment of policy design with the incentives embedded in the institutional context is very important. Price formation in markets, rules of interregional exchange, and project permitting requirements all have the potential to interact with a policy aimed at encouraging cleaner production. A single environmental policy may bind on a wide range of institutional settings that vary by region or sector, which are in turn shaped by factors such as socioeconomic status, industry composition, market orientation, awareness, and resource endowments. An ETS will vary in how it interacts with diversity in local institutions across China, raising the importance of assessing and addressing interregional gaps as part of the process of establishing the system.

Both policy design and underlying institutions will affect how firms respond to a national ETS in China. The aim of this paper is to identify the origins of past compliance challenges, and outline options for addressing them in the design of China's national ETS. Section 2 describes the historical context and evolution of environmental policy in China. Section 3 contains case studies of two policies, a binding policy targeting SO_2 control and a quasi-voluntary policy promoting industrial energy efficiency, which were chosen because they are the two most recent examples of large-scale environmental policies in China. In Section 4, we synthesize implementation challenges from the two cases and consider additional challenges of moving to a market-based instrument. We offer several recommendations, and use the Beijing pilot ETS—one of the earliest attempts to control CO_2 using a market-based instrument in China—to illustrate their importance. Section 5 concludes.

2. BACKGROUND

Since the late 1970s, reform and opening to world markets has transformed China's economy, reducing the role of central planning. This transformation has involved the complete or partial privatization of state assets and the introduction of market-based pricing for most goods and services (electricity and natural gas are notable exceptions). An influx of foreign-direct investment and growth of production for export fueled double-digit economic expansion over

three decades, although economic growth and development have proceeded unevenly across China's diverse regions and sectors.

Rapid industrial growth imposed a rising environmental toll. By the mid-2000s, China had become the world's largest energy user and CO_2 emitter. Many areas of the country were suffering from severe air, water, and soil pollution. Emphasis of national policy on environmental alongside economic goals gradually increased during the reform period.

Broadly speaking, China's past environmental protection efforts have been comprised of command-and-control policies that impose requirements directly on firms, for instance, in the form of emissions limits or technology standards. These policies are designed to be consistent with overarching environmental policy goals outlined in the country's five-year plans. For example, the State Environmental Protection Administration (now the Ministry of Environmental Protection or MEP) set standards limiting water pollution concentrations and later placed absolute limits on waste; both approaches met with uneven success at the local level (Ma and Ortolano 2000).

Market-based instruments, while less common, are not new to China. Emissions quotas for projects were first discussed in the 1980s (Yang and Schreifels 2003). Many of the public and private supporters of an ETS in China had previously benefited from experience generating and selling offsets as certified emissions reductions into the European Union's Emissions Trading System (EU-ETS). China also introduced environmental levies (pollution charges), although problems with collection were widespread. Pilot trading systems for SO_2 emissions also increased familiarity with market-based environmental policy. Today, an ETS for CO_2 in China builds on experience gathered over decades in a range of different settings.

Command-and-control and market-based environmental policies alike have suffered from weak implementation in China. Evidence suggests that firms have perceived new environmental protection directives as interfering with status quo operations and have sought to avoid, delay, or minimize regulatory burdens. For instance, firms that installed SO_2 scrubbers were found not to run them in order to save operating cost (Steinfeld et al. 2009). Prior to 2007, fines for violating the SO_2 emissions rules were so low that many firms chose to pay fines rather than abate pollution (Xu 2011; Schreifels, Fu, and Wilson 2012). More than 80% of levy revenues were recycled to emitters to fund abatement, while the remainder was used to fund the operations of local environmental protection bureaus (Schreifels, Fu, and Wilson 2012). However, some firms reportedly never remitted funds to the government, nor were funds always used for abatement (Ellerman 2002). When the central government introduced environmental criteria into official evaluations, local governments were found to have exaggerated or fabricated environmental performance data to improve their own evaluation prospects (Ghanem and Zhang 2014). While the balance of evidence suggests that enforcement has improved over time (van Rooij and Lo 2009; Karplus, Shen, and Zhang 2016; Lo et al. 2016), lapses still occur.

Weaknesses in policy implementation can be at least partially attributed to the status of supporting institutions. With a growing number of environmental policy initiatives and cleanup campaigns initiated throughout the 1990s and 2000s, the salience of environmental protection and the capabilities to mitigate pollution in industries and regions evolved as well. This evolution took place at different rates in different parts of the country, reflecting differences in the stage and drivers of development as well as other factors, such as the interaction between local governments and China's central leadership. As a result, enforcement of environmental policy varies widely across China. Prior studies observe more frequent and higher punishments for polluters in the relatively developed East compared to other parts of the country (van Rooij and Lo 2009).

These institutional differences also translate into variation in expectations over who should pay for emissions reductions targeted by environmental policies. Firms often look to the government to subsidize environmental cleanup. Consultation and bargaining between regulators and firms over required actions and sharing of compliance costs is common. Many firms expect to be reimbursed, or at least subsidized, for efforts to upgrade facilities or abate pollution in line with environmental protection goals. This shared understanding has its origins in the primacy of economic growth as a policy goal, and shifting the compliance cost burden to firms has proven challenging.

3. CASE STUDIES OF PAST ENVIRONMENTAL POLICY ENFORCEMENT

We focus on two policies—one targeting SO_2 control, the other targeting energy efficiency—to illustrate and analyze past policy implementation challenges. We consider how each implementation challenge reflects interaction between policy design and underlying institutions, and discuss whether or not these challenges could be remedied in the design of the national ETS. In both policy cases, we find that supporting institutions were as important as policy design choice to the outcomes, and outcomes improved over time when underlying institutions evolved in supportive directions. These experiences have implications for China's national ETS.

3.1 Case #1: SO_2 control policy

Regulations focused on controlling SO_2 emissions in China have been on the books since the late 1990s. Enforcement was weak at the outset, and has grown stronger over time. The *Two Control Zones* policy, launched in 1998 and aimed at reducing SO_2 emissions, focused on controlling emissions in areas either heavily responsible for or affected by acid rain. Emissions increases driven by industrial growth in the early- to mid-2000s overwhelmed efforts to install controls in existing plants. Although there is evidence that the targets had some effect on air quality and infant mortality (Tanaka 2015), the policy failed to reverse rising SO_2 emissions. During the Tenth Five-Year Plan (FYP, 2001-2005), SO_2 emissions increased 28%, while the national reduction target was 10% (Schreifels, Fu, and Wilson 2012).

In a redoubled effort to introduce a 10% reduction target for SO_2 during the Eleventh Five-Year Plan (2006-2010), policy makers paid greater attention to creating enabling conditions. An important difference was stronger central government leadership, and the introduction of environmental performance criteria in the evaluations of local officials. A dedicated program targeting large emitters was set up with the label "national control" or *guo kong*. Under the program, firms were ranked according to emissions totals, and a cutoff was applied to include the largest point sources (approximately 3,600 firms) that accounted for 65% of aggregate industry-wide emissions. Firms that fell within the cutoff were subject to tough limits on annual emissions and were required to install continuous emissions monitoring systems (CEMS). The upward trajectory in national SO_2 emissions was reversed around 2006 and began to come down, ultimately exceeding the national reduction goal by realizing a 14% reduction in SO_2 emissions (Schreifels, Fu, and Wilson 2012).

Several supporting measures laid the foundation for target achievement. First, the central government's leadership was critical to the success of the program. It resulted in a streamlined and uniform set of rules on program administration, backed by the resources and implementation authority that many local governments lacked. Second, with the support of the Ministry

of Environmental Protection, the National Development and Reform Commission introduced an electricity surcharge of 0.015 yuan per kWh to offset the cost of scrubber operation for compliant plants (Schreifels, Fu, and Wilson 2012). This financial incentive proved effective, while stronger penalties for non-compliance were introduced in parallel (Xu 2011). Third, the government required and invested in improvements to MRV for SO_2 emissions. Continuous emissions monitoring systems (CEMS) were installed for SO_2 and later for NO_X and PM, providing a more objective and real-time measure of firm emissions. The program targeted scrubber installation on the 503 largest SO_2-emitting facilities (Xu 2011), which meant that the time and resources of government inspection teams could be spread effectively across a relatively small number of plants. Fourth, the policy was directly targeted toward large state-owned power generation firms with oversight at the central or provincial government level, and these linkages facilitated information exchange, training, and transmission of pressure to comply. The fact that these firms outrank city governments has historically limited the ability of local city environmental protection bureaus to curb polluting behavior (Kostka, 2014). Fifth, environmental criteria were formally incorporated into performance evaluations for government officials in the Eleventh FYP. Failure to achieve environmental targets could even trigger a "one-vote veto," which meant non-compliance would negate an official's achievements in other areas, although there is scant evidence of how often this actually occurred. While some have questioned whether environmental criteria were given sufficient weight to affect promotion outcomes, they did increase attention to the point that officials in some cities were found to manipulate air quality data to improve their environmental records (Ghanem and Zhang 2014), suggesting that the policy did not go unnoticed.

In summary, the main developments that made SO_2 policy under the Eleventh Five-Year Plan more effective were largely institutional. Among them, strong central government leadership and political accountability that cascaded to subordinate levels of government and industry are often singled out as being particularly important to the success of SO2 control efforts in the Chinese context. Policy changes were also important—the main changes to the policy itself involved streamlining and unifying program rules and introducing stronger economic incentives (electricity surcharge) to support compliance.

Even as the SO_2 control effort succeeded, it also highlighted some significant limitations. Government financial support for the installation and operation of scrubbers was critical to the success of the program; it is not clear that without these carrots, rising penalties alone would have induced a change in firm behavior. Expanding the program to include smaller power generators and other industrial emitters would bring new challenges. Many of the firms in these industries were not state controlled and therefore often less responsive to political incentives. The costs of pollution abatement also varied widely across industries and technology vintages. Differences in economic composition and development level across localities translated into uneven incentives to comply with new central directives. As a result, the national control program succeeded in cleaning up the sectors and regions where administrative frictions and control costs were least problematic.

Early efforts to control SO_2 in the 1990s and 2000s involved emissions trading on a limited scale to strengthen implementation of national SO_2 targets. The effectiveness of pilot SO_2 programs was limited for several reasons. Enterprises facing strict SO_2 reduction limits and expectations of tougher future targets were reluctant to engage in emissions trading, preferring instead to hold on to excess allowances. Pilots also interacted with subsidies to support installation and operation of SO_2 control equipment, interfering with the trading system's ability to incentivize least-cost abatement. The pilots also covered only limited areas (in some cases, only

a few firms), resulting in limited opportunity for trading to improve efficiency. At the time, there was no legal framework for extending the program nationwide.

There are both technical and institutional reasons why an ETS now makes more sense for CO_2 control: (1) unlike SO_2 control, which relies largely on an end-of-pipe pollutant removal technology that allows removal efficiency to be largely determined by its operators, most CO_2-emitting processes require changes to core technology or infrastructure that, once made, are not easy to reverse at low cost. Changes in compliance status on a time scale of hours to weeks is therefore unlikely to be feasible or profitable; (2) abatement opportunities are spread across sectors nationwide, offering potentially large cost reductions from trading; and (3) increased central government support for environmental protection since the early 2000s has improved the prospects for establishing a strong legal basis for a national ETS in China.

3.2 Case #2: Energy saving programs

The Top 1000 Firms Program (T1000P, Eleventh Five-Year Plan, 2006-2010) and the Top 10,000 Firms Program (T10000P, Twelfth Five-Year Plan, 2011-2015) were nationwide efforts that enlisted firms exceeding an energy consumption threshold (of 18,000 and 10,000 tons of coal equivalent or tce, respectively) to adopt targets for reducing energy intensity. While targets were designed to be voluntary, target compliance was included in the evaluations of state-controlled firm leaders. As a result, compliance was essentially mandatory for state-controlled firms. The national government established subsidies to support firms in achieving their energy saving targets. It is thus perhaps not surprising that during the T1000P—in which the majority of participating firms were controlled by the state—compliance rates were very high. When the program was expanded in the Twelfth FYP to include a broader set of sectors and ownership types, non-compliance rates increased substantially, from 2% in the T1000P to around 10% in 2012. Non-compliance rates then declined to 8% in 2013 and to 7% in 2014 (Karplus, Shen, and Zhang 2016).

The main drawbacks of the T1000P and T10000P included the lack of penalties for non-compliance, reliance on self-reported data with no independent verification, and use of primarily political channels to incentivize compliance. Many firms had no incentive to undertake any costly measure unless they were reimbursed, for instance, through national energy saving subsidy programs, and even then firms incurred opportunity costs. Provincial governments, while largely responsible for program implementation, varied widely in terms of local resources, capabilities, and incentives to develop inventories for energy use and to quantify energy savings.

Under the T10000P, firms provided a variety of reasons to explain non-compliance behavior. Many firms did not provide complete data to support compliance (Karplus, Shen, and Zhang 2016). Changes in production status as well as low or unstable production were also self-reported reasons why firms did not comply. Several firms reported difficulty in improving on savings delivered by prior large retrofits, while others claimed an unforeseen expansion in production or usage. One major reason why the T1000P and T10000P were not extended is that the Ministry of Finance stopped the energy saving allowance bonus program in 2013 as it was concerned that a long-lasting subsidy program would distort firms' resource allocation decisions and inadvertently undermine the phase out of excess production capacity in the wake of economic slowdown in China.

Large, non-state firms, were disproportionately non-compliant during the T10000P, which may be attributable to the fact that they faced no official penalties, financial or otherwise, for

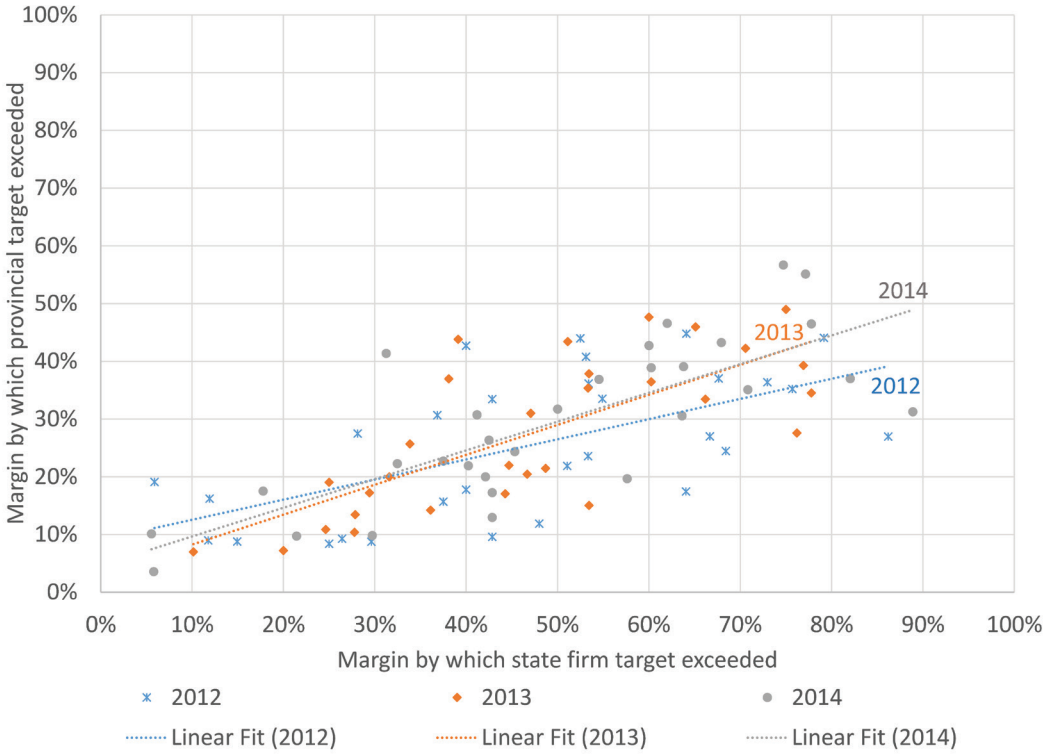

FIGURE 1

T10000P for Energy Saving: Central state-controlled firm over-compliance is strongly associated with provincial energy saving target over-compliance (Margin by which a target was exceeded is a measure of the extent to which state firms or provinces exceeded energy intensity reduction targets, equal to the quantity of firm energy intensity reduction achieved divided by the quantity of reduction targeted, minus one and expressed as a percentage).

Source: Data from NDRC (National Development and Reform Commission) (2015).

failing to comply (Karplus, Shen, and Zhang 2016). State-controlled firms, by contrast, faced the strongest incentives to report compliance. As shown in Figure 1, central state-controlled firm over-compliance (the extent to which firms exceeded their energy conservation target) was strongly positively correlated with provincial target over-fulfillment. Provincial target over-fulfillment refers to the extent to which each province exceeded its assigned CO_2 intensity target during the Twelfth Five-Year Plan. The fact that state firm over-compliance was strongly positively correlated with target over-fulfillment suggests that provinces relied heavily on state firms to outperform in order to support provincial target achievement.

The ETS was in part an answer to increasing evidence that voluntary energy saving programs were reaching the limits of effectiveness and imposing high and uneven costs on firms. Interest in improving energy and CO_2 emissions accounting was also growing as officials sought a basis for evaluating progress on domestic and international climate policy. Seven pilot systems were established and operated during 2013-2015 to study the viability of emissions trading in diverse provinces and cities across China. These pilots paved the way for establishing a national ETS, and its architects have attempted to address shortcomings observed in the energy-saving programs in ETS design.

4. INCENTIVIZING FIRM COMPLIANCE UNDER A NATIONAL ETS

4.1 Lessons from the two case studies

The case studies illuminate several challenges that have influenced the effectiveness of China's energy saving and environmental policy. These challenges are summarized in Table 1. Challenges included insufficient economic punishments for non-compliance, tensions between environmental protection and economic growth objectives, differences in regulatory accountability across firms, poor quality of firm emissions data, regional and sectoral variation in ability to detect violators, and overcoming the expectation among firms that government should pay for environmental retrofits and upgrades. Each of these challenges has its origins either in policy design or in institutional context, as described in Table 1. Ways in which the design of the national ETS addresses each challenge is indicated in the rightmost column of Table 1, and discussed below. "Partially addressed" indicates that measures to address a challenge are either not yet finalized, or otherwise require further resources, parallel reforms, or ETS design modifications to be resolved. These observed challenges lead us to several recommendations.

First, a strong legal basis for the national ETS will be crucial to establishing its authority and priority among local officials and covered firms in provinces and localities, and to mobilizing the legal system to penalize errant firm behavior, such as data falsification or non-compliance. Currently, the National ETS Directive has entered into the State Council's approval process. The Directive would specify the obligations of firms in terms of emissions control and MRV, and allow non-compliant firms to face much higher penalties than what the General Administrative Punishment Law allows (no more than 100,000 yuan).

Second, measurement, reporting, and verification procedures for CO_2 emissions data, energy use, and output should be standardized at the national level. Subordinate levels of government should be responsible for implementing the standardized design, although in some cases additional training will be needed to ensure that there is a shared understanding of implementation responsibilities across relevant government offices and covered firm participants. Independent verification of firm emissions and production data should be required for compliance, given that permits will be granted on the basis of the ratio between CO_2 emissions and physical output. The central government should provide resources to support the independent cross-checking of at least a subset of third-party audits, and monitor data closely and consistently for quality concerns. Provincial governments and participating firms should be provided with specific instructions that include procedural and data formatting requirements to ensure consistency across provinces.

4.2 Other challenges associated with an ETS

As the first nationwide application of a market-based instrument to manage energy-related CO_2 emissions in China, an ETS also raises a number of unique challenges that prior command-and-control policies did not. These challenges and their origins point to a third important enabler of a national ETS—continued commitment to broad-based market-oriented reforms. For the ETS, particularly salient reforms include harmonizing trading rules nationwide to facilitate inter-provincial allowance exchange, which is important for reducing variation in marginal abatement costs across provinces. Also important will be to clarify conditions under which provinces can restrict allowance trading (for instance, to avoid worsening of air pollution hotspots). Continued progress on energy price reform, emphasizing economic over political incentives for compliance, reducing preferential treatment of state-controlled

TABLE 1

Summary of the challenges encountered in environmental policy implementation in the two case studies, their origins, and the extent to which each has been addressed in national ETS design

Challenge	Policy design and/or institutional origin	Status of and steps to implementation in national ETS design (as of April 2017)
Unable to levy sufficiently high penalties for excess emissions	Statutory limits on maximum environmental or administrative fines	Partially addressed—National ETS directive would allow penalties for non-compliance to substantially exceed those allowed by China's existing Administrative Punishment Law. Directive is not yet finalized.
Salience of environmental directives vis-a-vis other policy priorities in firms and government	Decentralized policy enforcement and perceived tradeoffs between economic growth and environmental protection	Addressed—Centralization of policy design at the center under NDRC leadership offers potential to strengthen local government attention to implementation.
Central state-controlled firms respond to political incentives more than private firms	Large emitters are more likely to be state-owned firms, which are more responsive to government requirements	Addressed—A CO_2 price will send a clear encourage companies to abate emissions. System will benefit from greater emphasis on an economic rather than political rewards.
Poor quality or manipulation of firm emissions data	Managers do not always systematically track energy use and emissions, and data quality varies widely	Partially addressed—ETS Directive would establish a nationwide standard for accounting, audits, and independent-funded cross-checking of reported emissions, subject to continuous evaluation and improvement.
Localities vary in their capacity to detect and prosecute policy violators	City/county governments vary in local incentives to promote environmental protection alongside economic growth.	Partially addressed—Centralize collection and verification of firm emissions data at the provincial level, with cases of suspect reporting forwarded to the national level. Provide training across provinces to improve accounting capabilities. A strong legal basis for the national ETS will help.
Firms expect government to pay the cost of implementing environmental control technology	Norm that promoting growth necessitates limiting undue regulatory burdens on firms	Addressed—By pricing CO_2, firms will face an economic incentive to switch to cleaner forms of energy.

firms, and increasing market orientation in sectors such as electricity will not be showstoppers for ETS operation, but over time will be important to supporting its function as a low cost instrument for controlling CO_2 emissions.

A final recommendation that would address several past and anticipated challenges is to clearly signal the longevity of the policy, while establishing a timetable for experimentation, evaluation, and adjustment that recognizes the policy is unlikely to function perfectly from the outset. Evaluation will require defining "success" in the context of the national ETS. Is success a carbon price at or above a particular level? Is it all firms surrendering allowances sufficient to cover annual emissions? Is it achieving a targeted aggregate level of emissions intensity or emissions abatement? Is it achieving this level at a sufficiently low or "least" cost? Initially, success might focus heavily on some intermediate milestones, such as obtaining and verifying benchmark emissions data for all firms, while over time, adjustments could be aimed at strengthening MRV or increasing flexibility. Establishing the longevity of the system will be important because the prospect of repeat business combined with the threat of being discredited through cross-checking will provide third-party verifiers with the right incentives to expose non-compliant behavior. Signaling eventual program scale up or the complementary emissions control measures for non-ETS sectors could help to discourage leakage.

4.3 Institutions and policy design in the Beijing ETS pilot

The case studies above pointed to four important categories of institutional enablers for China's national ETS: a strong legal basis; a unified set of measurement, reporting, and verification rules subject to independent scrutiny; ongoing broader market-oriented economic reforms; and signals of the system's durability and flexibility to incorporate lessons learned along the way. To understand the role of these recommendations in a real-world Chinese CO_2 emissions trading scenario, we turn to the Beijing ETS pilot system. The case of Beijing helps us to analyze whether or not our early recommendations can be easily operationalized in the context of an ETS for CO_2. We find that the Beijing system offers evidence of how carefully-coordinated policy design and institution building efforts can result in a functional CO_2 emissions trading program. The case also highlights potential challenges when extending such a system to all of China.

The Beijing pilot emissions trading system (Beijing ETS) was launched in 2013 and initially scheduled to operate from 2013 to 2015. As of 2015, the Beijing ETS covered 551 liable entities, with the accounting boundary set at the firm (not installation) level. Allowances for existing firms were allocated based on historical emissions intensity in 2009-2012 for the power and heat sector and based on the absolute quantity of historical emissions for the industrial and building sectors, while allocations to new firms with capacity expansion were based on benchmarking. The system allowed banking of permits across (one-year) compliance periods, but not borrowing. The threshold for inclusion in the program was initially set at 10,000 tons of CO_2 per year. In 2015, it was lowered to 5,000 tons of CO_2 per year, increasing the number of covered entities by approximately 600.

National policy makers view the Beijing ETS as a success for several reasons. First of all, it resulted in absolute CO_2 emissions reductions of 4.5% in 2013, 6.0% in 2014, and 6.2% in 2015. During its operation, 12.5 million tons were traded in 2,668 transactions between 2013 and 2015 (the market covers 50 million tons of CO_2, while Beijing's total emissions are approximately 180 million tons). The CO_2 price was relatively stable over this period at around

50 yuan/ton. Compliance rates among covered entities were also very high, at 97% in 2013, 100% in 2014, and 99.3% in 2015.

Evidence that the Beijing ETS affected the incentives of emitting entities comes from indirect observation of applications for energy saving subsidies provided by the Beijing government. Subsidies were intended to fund energy saving projects, including retrofits, equipment upgrading, and operational efficiencies, among other efforts. The application process involved some cost on the part of the firm, as administrative and engineering effort was required to produce a complete submission of the proposed project and its estimated energy savings to the subsidy program. At the end of the process, there remained some uncertainty over whether or not a firm's application would ultimately be accepted. Nevertheless, it remained a puzzle as to why some firms appeared unwilling to submit funding applications. After the ETS was introduced many firms that had never previously sought subsidies began to apply.

A major reason why Beijing's pilot ETS performed well was its strong legal basis. The top leaders in the Beijing government give more weight to environmental protection than its department chiefs who are in charge of economic development issues. Given that the Beijing ETS was expected to deliver substantial air quality co-benefits in terms of smog control, the ETS received special political support from the top leaders in Beijing. As a result, the ETS has been given priority in the regulatory process. The Decision on Beijing ETS Development passed by the Beijing Congress in 2013 laid a strong legal foundation for the ETS operations in Beijing together with detailed implementing regulations. The legislation codifies punishments for non-compliance, sending a strong signal to participating firms. This aspect of the Beijing system helps to ensure that all firm types, regardless of the strength of state linkages, feel sufficient enforcement pressure. Also, a strong legal foundation ensures that local government officials feel sufficient pressure to invest in establishing a credible MRV process, in the midst of competing priorities and demands.

Penalties for non-compliance with the Beijing were non-financial as well as financial. One source of these incentives involved reputation. Once firms were included in the program, the Beijing government so strongly emphasized the importance of compliance that it would have been embarrassing for a firm to shirk. This reputation risk was backed up with high costs for non-compliance: a penalty three to five times the average carbon price level over the last six months for every ton a firm exceeded its allowance allocation, disqualification from applying for Beijing's own energy conservation subsidy program, and delayed approval of new projects proposed by the firm, in addition to the image/reputation risk associated with being publicly listed as a non-compliant firm.

Another reason why the Beijing ETS worked well was the choice of approach and continuous adjustments made to the MRV system. Substantial resources were devoted to supporting third-party verification of emissions data supplied by the covered firms. The audits provided by third-party verifiers were further cross-checked for 20% of the firms on a randomly-selected basis by another independent auditor. Through 2015, both third-party audits and further cross checking were funded entirely by the Beijing government, rather than the firms themselves. The MRV process benefited from a comprehensive online infrastructure (also supported by the Beijing government) to register and solicit reports from firms. This system was also linked with the trading platform, which rapidly updated allowance totals to reflect actual trades based on verified emissions volumes, strengthening the reliability, internal consistency, and responsiveness of the system.

What can Beijing's pilot emissions trading system tell us about the enabling conditions needed to support a national ETS in China? The positive outcomes noted above are in many ways dependent on Beijing's strong institutions and the importance political leaders assigned to its success. As the national capital, Beijing is a showcase for new initiatives in China. The project of building the seven initial ETS pilots and now the national ETS has benefited from the backing of arguably the most powerful organization within the Chinese government, the National Development and Reform Commission (NDRC). The NDRC develops the nation's economic policies and leads initiatives of strategic national importance. In Beijing, NDRC leadership translated into strong implementation through its vertical (central to local) reporting lines, and benefited from the strong interaction between the NDRC and the Beijing Development and Reform Commission. While it holds useful lessons, the experience of the Beijing pilot may not easily or quickly transfer to other parts of the country.

5. CONCLUSION

By putting a price on CO_2, policy makers are eager for a national ETS to alter firms' expectations and behaviors in ways that achieve emissions reductions at least cost. This is a feasible and worthy goal, but will not be achieved overnight. Developing an ETS first and foremost as a mechanism for ensuring compliance with a tradable performance standard that is consistent with national climate change policy is an important step forward. Our discussion above of the complementarities between institutions and policy design suggests that efforts to develop strong supporting institutions will be at least as important as getting the ETS design right. We offered four recommendations on how to accomplish this: a strong legal basis for the ETS; a a consistent approach to MRV subject to independent scrutiny; ongoing broader market-oriented economic reforms; and signaling the system's durability and flexibility to incorporate lessons learned along the way.

Beijing to some extent represents an exceptional case of relatively professionally-managed large firms operating in a strong service-sector oriented economy faced with a clear and strong mandate to comply with the ETS originating from both the central *and* local authorities. Policy makers worked closely with academic experts to design the system. It is likely to be challenging to elicit the same degree of cooperation from firms operating in China's diverse localities, especially in places where the economy depends heavily on energy-intensive industry, intellectual communities are less well developed and have limited engagement in policy design, and local government priorities are less closely aligned with national ones.

Among the four recommendations above, the first and second will be perhaps the most important at the outset of China's national ETS. Without a strong legal basis, establishing a nationwide CO_2 price and encouraging firms to trade to meet compliance obligations will be challenging, in part because there will be no basis for overriding conflicting policy mandates. Without a unified MRV system, ensuring the integrity of system operation will be very tough, as any fabricated emissions reductions will dilute CO_2 prices in the market without delivering additional abatement. Expanding and reinforcing the MRV system should be pursued in parallel with national ETS development. Developing a strong MRV system will be important for monitoring the economy-wide performance of the national ETS, for instance, by enabling the quantification of emissions leakage. It would further support development of a national CO_2 emissions inventory that could be used when reporting progress towards international climate change mitigation goals and inform plans for ETS expansion.

The third and fourth recommendations will be important for the long-term durability of the ETS. Market-based economic reforms will support the marginal abatement cost discovery function of the ETS. Inevitably, there will be some mismatches in the timing of ETS rollout and reforms as well as MRV system development, with consequences for system function. It is therefore very important that China's policy makers signal a long-term commitment to the ETS as a policy and institution-building project, which would allow for adjustment in the timing and design based on emerging information. Recognizing that conditions for ETS operation vary across sectors and regions, we recommend starting with a subset of sectors where MRV and other enforceability conditions are most conducive. For instance, the ETS could launch with a subset of the currently targeted sectors, power generation, cement, and aluminum production. Data for these subsectors are relatively well developed and abatement strategies and costs are relatively homogeneous. Performance for these subsectors could be monitored closely, and more attention and resources could be devoted to detecting any problems with MRV. At the same time, policy makers could signal from the outset intention to include 7,000 enterprises in 20 subsectors across 37 provinces and cities by 2020, undertake necessary data and other preparations in parallel, with incentives for early action to certify data and limit emissions in these sectors. As the system is scaled up, the NDRC could serve a watchdog function by conducting facility comparisons to uncover data manipulation. One strategy for revealing data problems could involve establishing a peer supervisory mechanism, whereby firms anonymously report suspected errant behavior for investigation by the National Enterprise Credit System of the NRDC.

Several questions will need to be answered as the national system is scaled up. For instance, will it be possible for the government to fund third-party verification and randomized checks of MRV quality for firms in the national system, as was the case in Beijing pilot ETS? The answer is likely to be no, given the size of resources and administrative effort required. Therefore, it will be critical to design an MRV system that balances these resource constraints with the need to establish the cross-regional credibility of a firm's compliance activities. Prior work demonstrates the value of removing conflicts of interests (regulated firms paying for audits) and conducting cross-checks to verify auditor performance (Duflo et al. 2013).

Defining success in the context of China's emissions trading system remains a tough but important challenge. This definition should be allowed to evolve as its architects gain experience and data in the early months and years of operation. Setting an expectation that the system is here to stay, and that future changes will be made in a regular and transparent manner, will go a long way towards establishing the confidence and credibility needed for the system to outlast inevitable hiccups and become a mainstay of energy and climate policy in the world's largest emitting nation.

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