Navigating and Evaluating the Labyrinth of Environmental Regulation in China

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Introduction

China's rapid economic development over the past 40 years has lifted hundreds of millions out of poverty, but it has also had negative impacts on the country's natural environment. As early as 1996, the annual cost of environmental pollution and degradation was estimated to be 10 percent of GDP and perhaps as high as 15 percent of GDP (Smil 1996). Recent estimates put the figure for air pollution alone at 0.7 percent of GDP (Gu et al. 2018), which is large in absolute terms given China's current economic size. While air pollution in China's cities is improving, it still regularly exceeds the standards recommended by the World Health Organization. China's water and soil pollution threatens food safety and arable land, as well as ecosystems and biodiversity (Lu et al. 2015). In 2005, more than half of China's seven main rivers contained water that was unsafe for human consumption (World Bank 2006), and the associated digestive cancer is the second leading cause of the country's cancer-related deaths (Lin, Sun, and Zhao 2020).

In response to these environmental challenges, China has developed a multifaceted environmental regulatory system that includes environmental laws, standards, and regulations. The system is complicated and difficult to navigate, even for experienced researchers. Part of the problem is that although many of the system's components, such as the extensive set of laws and standards, are similar to those in the United States and Europe, China's environmental protection activities are not driven only—or even mainly—by these laws and standards. Instead, in an administrative system that is perhaps unique to China, environmental actions and outcomes on the ground are driven to a large extent by the central government's planning process. Through Five-Year Plans (FYPs), the central government sets environmental priorities and goals, as well as enforcement and assessment mechanisms. Given that FYPs are fundamentally about setting socioeconomic development goals, environmental

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protection goals are considered in tandem with (and have historically been viewed as secondary to) economic growth objectives. Shifting government priorities over time have contributed to a complex set of plans, directives, laws, standards, and other interventions that vary and overlap across time and space. The complicated, overlapping, and fragmented nature of environmental regulations poses formidable challenges to understanding China's environmental policies, assessing their impacts, and identifying the mechanisms through which they operate.

In this article, which is part of a symposium on China and the Environment,[1] we present an overview of China's environmental policy over time and discuss the relationships between its components, with the goal of helping researchers navigate this regulatory labyrinth. More specifically, we review the literature that has examined these policy components and highlight key findings about the effectiveness and limitations of policies. By mapping studies to specific policy developments, we aim to help readers identify gaps in the literature and design future research to evaluate China's environmental policies. Because of space limitations, we focus only on environmental pollution and policies.[2]

The remainder of the article is organized as follows. First, we provide an overview of the environmental regulatory system in China, highlighting the links between the system's three key components: legislation, planning, and implementation. We then review the literature on air pollution regulation and water pollution regulation, with an emphasis on studies that quantify the relationship between policy changes and environmental outcomes. Finally, we summarize lessons learned from China's experience with environmental regulation and identify directions for future research.

Background on China's Environmental Regulation: History, Institutions, and Key Policy Mechanisms

China began to address environmental pollution in 1973, with the First National Conference on Environmental Protection. In 1983, environmental protection was elevated to become one of the country's basic national policies. In the early 2000s, increases in pollution led to more rigorous efforts to control air and water pollution. Today, environmental protection occupies a prominent position among China's national priorities, reflected in the introduction of new, tougher limits on plant-level and ambient pollution, centrally led inspections, and detailed action plans.

Several government institutions support environmental protection. The main regulatory agency is the Ministry of Ecology and Environment (MEE), which replaced the Ministry of Environmental Protection (MEP) in 2018.[3] However, many other entities play a role in environmental

[1]The other articles in the symposium are by Auffhammer et al. (2021), who discuss China's renewable electricity development and policy, and by Greenstone et al. (2021), who examine recent trends in China's air and water quality.

[2]Mitigation of greenhouse gas emissions and auxiliary policies are discussed in secs. A and B of the online appendix.

[3]The country's environmental regulatory agencies have a complex history. In 1973, China established the Office of Environmental Protection Leadership Group in the State Council. In 1982, the office was merged into the Department of Environmental Protection under the Ministry of Urban and Rural Construction

policy-making and implementation. For example, an environmental pollution tax is administered by the Ministry of Finance, energy supply and resource recycling and reuse are regulated by the National Development and Reform Commission, energy conservation falls under the purview of the Ministry of Industry and Information Technology, and national parks and natural reserves are managed by the Ministry of Natural Resources.

China's environmental regulation system is composed of three main components: legislation and standards, the planning process, and implementation mechanisms. In the remainder of this section, we describe the evolution and key details of each of these components and the interconnections between them.[4]

Legislation

Environmental legislation provides authority for the government to enact and enforce environmental regulations. The National People's Congress authorizes new laws, while the main regulatory agency (i.e., MEE) codifies and implements them. China has also enacted an extensive and complex set of environmental standards.

Environmental laws

The Environmental Protection Law (EPL) established and formalized the system of environmental regulation in China. The Constitution was revised in 1978 to include environmental protection for the first time, and a trial version of the EPL was published in 1979 and became law in 1989. Revised in 2014 and effective starting in 2015, the revised EPL was touted as "the strictest environmental law in history" (National People's Congress 2014). The revised EPL was designed to address poor enforcement as the root cause of China's environmental regulation failures by introducing new penalties for environmental violations, including suspension of production, administrative detention, and criminal charges. Importantly, the revised EPL removed the cap on fines imposed on environmental violators.

There are also laws that focus on specific pollutants. These include the Law on the Prevention and Control of Water Pollution, the 2017 amendment of which created the national "river chief system"[5] and the Atmospheric Pollution Prevention and Control Law.[6]

Environmental standards

China's environmental laws usually establish general principles, leaving implementation details to government agencies, particularly the MEE. Environmental standards, which are

and Environmental Protection. In 1988, the department-level environmental protection agency was elevated to the vice ministry–level National Environmental Protection Administration (NEPA). In 1998, NEPA was elevated to the ministry level and renamed the State Environmental Protection Administration (SEPA). In 2008, SEPA was elevated to the MEP and became a member of the State Council.

[4]See table A1 for a summary.

[5]Under the river chief system, provincial and local government officials are held responsible for the water quality of the major rivers under their jurisdiction (Li et al. 2020). These hierarchical responsibilities are designed to address the fragmented management of rivers that run across jurisdictions.

[6]See sec. C of the online appendix for a more detailed discussion of these and other laws that address specific pollutants.

used to measure and evaluate polluter behavior, are set by both central and provincial governments. The first standard, promulgated in 1973, set emission limits for 13 air pollutants in five industrial sectors. The standards have increased in stringency and scope over time and have more recently shifted to target ambient environmental quality. By the end of 2019, China had published ambient environmental quality standards for water, air, noise, and soil, as well as 63 emission standards for water pollution, 34 emission standards for air pollution, 11 emission standards for noise pollution, and 42 emission standards for solid waste management.[7]

The Planning Process

Despite China's progress toward building a market economy, government planning continues to play a prominent role in both economic development and environmental protection. Planning determines the emphasis placed on environmental protection activities in day-to-day governance. As we will discuss, to a certain extent, planning plays a more important role than legislation in shaping China's environmental outcomes. Below, we discuss the FYPs, which dominate China's planning process, as well as environmental action plans, which have been a major development over the past decade.

FYPs

China's FYPs define overarching principles that guide national policies and priorities over 5-year intervals. Since the early 1970s, environmental protection has become an increasingly important component of the FYPs. For example, the Fifth FYP (1976–1980) included the control of three industrial wastes (waste gas, wastewater, and solid waste) in medium- and large-scale industrial firms. The Sixth FYP (1981–1985) dedicated a chapter to environmental protection, calling for the "Three Simultaneities" and stating that pollution control installations must be designed, constructed, and used simultaneously with industrial production facilities. In the Seventh FYP period (1986–1990), China published the first stand-alone Five-Year Environmental Protection Plan, which became an integral part of all future FYPs. In response to increasing environmental management challenges after 1990, the Eighth FYP (1991–1995) included environmental protection indicators in the national socioeconomic development plan, and the Ninth FYP (1996–2000) emphasized the total emission control policy, which placed a cap on provincial emissions of key pollutants.

After China joined the World Trade Organization in 2001, GDP growth accelerated, and the tension between economic growth and environmental protection grew sharper (Chen, Li, and Lu 2018). To limit environmental damages, the Tenth FYP (2001–2005) capped national emissions of six pollutants and set specific caps for each province. Because of lax enforcement, these caps were not achieved (Kahn, Li, and Zhao 2015). In response, the Eleventh FYP (2006–2010) incorporated the emission targets for some pollutants (such as sulfur dioxide [SO_2]) into the criteria used to evaluate provincial officials. By the end of the Eleventh

[7]Ambient standards impose limits on the concentration of pollutants at receiving locations, while emission standards impose limits on emissions from individual polluters. Sec. D of the online appendix documents the evolution of China's ambient and plant-level emission standards.

FYP, the country had largely achieved its targets for SO_2 and energy intensity (i.e., the ratio of energy use to GDP).

In the 2010s, environmental protection emerged as a key political ideology for the ruling Chinese Communist Party, which referred to environmental protection as the "ecological civilization." The Twelfth FYP (2011–2015) continued to strengthen binding targets for environmental protection, including plant-level standards for water pollutant emissions (chemical oxygen demand [COD] and ammonia [NH_3-N]) and air pollutant emissions (SO_2 and nitrogen oxide [NO_x]) and ambient water and urban air quality targets. Starting with the Thirteenth FYP (2016–2020), China further shifted its emphasis from emission targets to ambient targets.

Environmental action plans

Environmental legislation and the 5-year planning process have often lagged behind China's emerging environmental challenges. Thus, since the early 2010s, the Chinese government has relied heavily on environmental action plans to expedite pollution control. The action plans are directives issued by the central government that require changes to environmental targets, standards, and technologies at polluting facilities, often focusing on hot spot regions that have been prioritized for pollution control. Action plans are pollutant, region, or industry specific and are closely related to the 5-year planning process, although (depending on the urgency and extent of the environmental changes required) they may not be synchronized with FYPs. Action plans typically require the development of detailed implementation plans for target pollutants, regions, or industries.[8]

Many requirements and measures in the action plans go well beyond existing laws or policies. For example, the Action Plan on Air Pollution Prevention and Control, which was announced in September 2013 and focused on 10 key measures known as the "Air Ten," required early retirement of the most-polluting plants, accelerated substitution of natural gas for coal, and strengthened automobile tailpipe emissions and fuel quality standards. In 2018, the Air Ten was replaced by the Three-Year Action Plan for Winning the Blue Sky War, which set more aggressive targets for SO_2, NO_x, and fine particulate matter ($PM_{2.5}$) by 2020. The Action Plan on Water Pollution Prevention and Control, issued in 2015 and called the "Water Ten," is the most comprehensive water policy in China to date. The Water Ten names 7 key rivers, 9 key coastal bays, 3 key regions, and 36 key cities as priorities for increased pollution control. The Action Plan on Soil Pollution Prevention and Control, called the "Soil Ten," was released in 2016 and focuses on reducing soil pollution by 2020 and controlling soil pollution risks by 2030.

Implementation Mechanisms

Perhaps the most daunting challenge to understanding China's environmental regulation system is navigating the complicated set of implementation mechanisms. Some mechanisms are valid only during a specific time period or only in specific regions, and the same mechanism

[8]See table C2 (tables C1, C2, D1–D6 are available online) for more details on action plans.

can change substantially over time. In the discussion that follows, we describe the major implementation mechanisms.[9]

Emission permit system

Established in 1989, the emission permit system (EPS) limits the types and amount of pollution a firm is authorized to emit. However, before 2014, the EPS was not enforceable because it was not included in the EPL and there were no detailed rules describing how the EPS should be implemented (MEE 2020). In fact, the EPS was not regarded as an essential component of environmental management and was not connected with other regulatory instruments. However, starting in 2014, the EPS began to play a key role in the regulation of stationary sources (e.g., refineries, power plants, industrial facilities), with every polluter required to hold a permit. In 2016, the State Council, which is the chief administrative authority of the Chinese government, issued the Implementation Plan for Controlling the Pollutant Emissions Permit System and a road map for its implementation. The EPS is evolving into a firm-based bottom-up system and a clearinghouse for all information related to stationary source pollution. Allowable emission levels are determined by pollutant concentration limits, water and air discharge benchmarks, and scale of production. Polluting firms are required to self-monitor and publicly disclose their emissions, with local governments authorizing third-party organizations to audit a firm's emission records and conduct random inspections to verify and enforce the implementation of the EPS.

Emissions trading system

In the early 1990s, China began to experiment with emissions trading system (ETS) approaches, primarily at the local or regional level. Of the 16 cities that established an air pollutant EPS in 1991, six piloted an ETS for SO_2 in 1994. Then, in 2001, Taiyuan, the capital city of Shanxi Province, piloted an SO_2 ETS and was followed by seven provinces and cities in 2002. Despite China's nearly 30 years of experience with it, emissions trading plays a limited role in China's environmental regulation.[10]

Emission fee or tax

Pollution charges have long played an important role in the government's environmental policy. The concept of emission fees or levies was first introduced nationwide through the EPL in 1982. However, it was not until 1992 that a fee for SO_2 emissions associated with industrial coal burning came into force. Emission fees for other pollutants were not adopted nationwide until after 2003. Several factors have limited the effectiveness of emission fees in general. First, the fees applied mostly to emissions that exceeded standards and were typically set to be lower than the marginal costs of abatement, thus providing insufficient incentives for firms to abate their emissions. Second, a firm paid fees only on the one pollutant (before 2003) or three pollutants (after 2003) that exceeded the standards by the greatest amount, and a firm's total payment was often capped. Third, local governments tended to

[9]Table A1 shows how these mechanisms are related to China's legislation and planning process.
[10]One possible exception is the country's emerging carbon market (see sec. A of the online appendix).

interfere with enforcement to protect local industries. Finally, the fees were often intended as a revenue source for local environmental protection bureaus rather than as a means to internalize the marginal damages of emissions, which means that they were often implemented through a bargaining process rather than being targeted at reducing the environmental externalities. To address these problems, the Environmental Protection Tax Law of 2018 replaced the emission fees with an environmental tax. Importantly, firms now pay tax on inframarginal emissions (i.e., emissions that are below the standards) as well as emissions that exceed the standards, and caps on total payments have been eliminated.

Total emission control

Most firm-level limits (e.g., standards) target emission intensities. To reduce total emissions, China also set caps on total emissions by province. These targets are frequently disaggregated to the city, county, and even firm level. This approach, known as the total emission control system, was first introduced in the State Council's Decision on Several Issues in Environmental Protection, published in 1996. As discussed above, provincial caps were introduced in the Ninth FYP and have been more strictly enforced since the Eleventh FYP. In addition, over the past decade, the provincial emission caps have gradually been replaced by ambient environmental quality standards.

Regional approaches

Because of the uneven distribution of economic activities in China, there is tremendous regional heterogeneity in ambient environmental quality. The central government began to adopt regional approaches to regulate environmental pollution in 1996. In particular, in response to increasing SO_2 emissions and acid rain, the central government created an acid rain control zone and an SO_2 control zone; this was called the Two Control Zones (TCZs) policy, which was approved by the State Council in 1998 and remained in effect until 2010 (when it became part of Air Ten).[11] The TCZs included 175 cities (or some of their urban districts) across 27 provinces, covering about 60 percent of SO_2 emissions nationwide when the policy started (Tanaka 2015). The policy mandated technology standards such as clean coal technologies, and regions in the TCZs faced stricter targets for reducing total SO_2 emissions that were more rigorously enforced during the Eleventh FYP (Hering and Poncet 2014).

Regional approaches are also applied to manage water pollution, as is the case for the "Three River and Three Lake Basin" policy. More specifically, three river basins (of the Huai, Liao, and Hai Rivers) and three lake basins (of the Tai, Dian, and Chao Lakes) have been identified by the central government as key areas for pollution control, and heavy polluters have been subject to stricter emission restrictions there since 1996 (Wang, Wu, and Zhang 2018). More recent regional approaches include the "2+26" program (started in 2017), which imposes strict air pollution emission standards in two municipalities and 26 cities in northern China, and the

[11] It is common in China for policies to end without an official communication, which can lead to local governments and firms continuing to implement policies that are no longer strictly binding. Several years after the TCZs policy ended, e.g., local governments were writing to MEE to seek clarity on its implementation. See http://www.mee.gov.cn/hdjl/hfhz/201901/t20190107_688656.shtml (in Chinese).

"Black and Smelly Waters" program (started in 2015), which aims to improve water quality in urban areas.

Subsidies for clean technologies

Subsidies for the purchase, installation, and operation of low-emission technologies are another measure that has been used to reduce industrial pollution. For example, power generators that meet the standards for SO_2, NO_x, and PM are allowed to sell electricity at prices above the benchmark rate.[12] To implement Air Ten (2013–2017), China has also provided subsidies for fuel switching from coal to natural gas or electricity, mainly around the Beijing-Tianjin-Hebei region. Vehicle owners who turn in "yellow-label" vehicles—vehicles that fail to meet emission standards—are entitled to subsidies for the purchase of cleaner vehicles (http://jtgl.beijing.gov.cn/jgj/jgxx/94246/mtlj/127689/index.html). Finally, tariff adjustments have been used to pressure firms that are out of compliance with environmental regulations to close down by making it relatively more expensive for plants with older outdated equipment to purchase electricity and other inputs.

Environmental inspections

Environmental inspections began in 2002 to verify that localities were implementing central government policies. Six Regional Environmental Inspection Centers, which initially reported directly to SEPA, the predecessor of MEP and MEE, were established. The regional centers conducted inspections of polluting firms, but they did not enforce environmental regulations because they were not authorized to investigate and punish local officials. At the end of 2015, the central government launched a revised system, the central environmental inspection (CEI), which targeted government officials in a manner similar to the national anti-corruption campaign (Xu 2017).[13] Importantly, the CEI held party and executive branch officials equally accountable for adhering to environmental regulations. Inspection teams have visited every province in China, conducting spot checks at polluting firms and creating hotlines and mailboxes to collect citizen complaints. As of mid-2020, a second round of inspections was underway.

Information provision

In response to public concerns about increasing pollution, the government allows, to a certain extent, informal regulatory approaches such as information provision (Chen, Zhao, and Zhou 2021). In particular, the 2014 revision of the EPL added a new chapter on information disclosure and public participation requiring central, provincial, and local governments to regularly disclose to the public information about ambient air and water quality, emissions from key sources, pollution accidents, and environmental compliance and enforcement. The EPL also requires key firms to disclose detailed information about pollutant emissions and

[12] According to the Rules on Cleaner Electricity Price and Operation of Environmental Protection Facilities for Coal-Fired Power Plants, issued in 2014, the subsidy can be up to 3.7 cents per kWh.

[13] The Chinese character spellings of "environmental inspections" are 环保督查 (huan bao du cha), while those of CEI are 中央环保督察 (zhong yang huan bao du cha). The characters 查 and 察 are spelled identically in their English transliteration, "cha." The first is uniformly translated as "inspection," while the second is translated in official documents as both "supervision" and "inspection."

the operational status of pollution control facilities. The news media has also become more active in covering major pollution incidents (Tu et al. 2020).

Review of the Literature on Air Pollution Regulation

With this background on the development of China's environmental regulation system, we next review studies that quantify the relationship between policy changes and environmental and economic outcomes.[14] First, we consider studies on air pollution regulations; we examine studies on water pollution in the next section. Our review roughly follows the chronological order of the key policies discussed in the section above.

Before 2005

The assessment of China's earliest efforts to reduce air pollution is limited by the availability of data. Cities reported SO_2, NO_x, total suspended particles, and PM_{10} levels before 2005, but they did not report $PM_{2.5}$, O_3, and CO levels until 2013. In addition, self-reporting by firms and, increasingly, political incentives to manipulate data raise questions about data reliability (Chen et al. 2012).

A handful of studies have examined the effectiveness of air pollution fees and local inspections of polluting firms. One drawback of these studies is that regulatory enforcement likely focuses on plants whose emissions are expected to cause the most damage, which means that the policy treatment and enforcement status could be endogenous. For example, in a study of the city of Zhenjiang from 1993 to 1997, Dasgupta et al. (2001) treat lagged emission charges and lagged cumulative inspections as exogenous and estimate their effects on firm-level changes in air and water pollution. They find that variation in inspections has a greater effect on the environmental performance of industrial polluters than variation in emission fees. They also note that the deterrence effect of inspections appears to be much lower in China than in Canada or in the United States. In contrast, using data from 3,000 factories in China, Wang and Wheeler (2005) find that the combination of progressive pollution fees and limited avenues for appealing penalties can generate a strong deterrent effect. However, Wang and Wheeler (2005) do not account for the effect of inspections. In addition, Dasgupta et al. (2001) focus on a single city with very limited variation in the pollution fee. Although, to some extent, Dasgupta et al. (2001) control for the unobserved heterogeneity that could drive the relationship between inspections/fees and pollution levels, neither study includes truly exogenous variables that may have affected inspections and fees.

Another strand of the literature focuses on the TCZs policy. There is some evidence that the TCZs policy was effective in terms of health outcomes. More specifically, Tanaka (2015) finds a 20 percent decline in infant mortality in targeted cities between 1998 and 2000, which corresponds to 3.29 fewer infant deaths per 1,000 live births. Other studies focus on the effect of TCZs on economic outcomes. For example, Hering and Poncet (2014) find that for firms located in the TCZs across a panel of Chinese cities, there was a sharper reduction in exports between 1999 and 2003 for industries that are more pollution intensive. Exports from

[14]See the bottom row of table A1, which lists the studies and the environmental policies they analyze.

state-owned enterprises (SOEs) were unaffected by the stricter enforcement of TCZs, suggesting that these firms are to some extent insulated from the effects of environmental policy. Cai et al. (2016) find that the TCZs regulation led to reductions in foreign direct investment, with foreign multinational firms from countries with worse environmental protection records showing the sharpest declines. In contrast, Jefferson, Tanaka, and Yin (2013) find that the TCZs policy raised performance (net revenues) among dirty firms, which they hypothesize occurred as a result of the exit of poor performers. Overall, these studies suggest that the TCZs regulation did have the impact of reducing or displacing pollution-intensive industrial activities in cities located within the TCZs.

The papers discussed in the above paragraph use difference-in-differences (DID) or difference-in-difference-in-differences (DDD) approaches to estimate the impacts of the TCZs policy.[15] One issue that they do not address is whether industrial activities in non-TCZ regions were also affected by the TCZs policy. If TCZs (or other contemporaneous policies) induced relocation of dirty firms from TCZ regions covered by the policy to regions not covered by the policy, then the pollution in the non-TCZ regions would have likely increased, which means that the environmental impact of the policy might be overestimated. Another drawback of these studies is that the lack of available data before implementation of the TCZs policy makes it difficult to fully establish parallel trends (i.e., to ensure that pollution trends in TCZ regions and non-TCZ regions were similar before the start of the program). In addition, the firm-level analysis is usually based on firms above a certain scale. Larger firms may have benefited from the regulation because of an increase in market share that resulted from the exit of small, less efficient firms as regulations were tightened. These issues suggest that when using DID or DDD methods, it is important to rigorously establish their validity and applicability to specific policy settings.

2006–2012

China failed to meet the SO_2 reduction target of 10 percent during the Tenth FYP (2001–2005); in fact, SO_2 rose by 28 percent (Schreifels, Fu, and Wilson 2012). In response, during the Eleventh FYP, the government strengthened both policies and bureaucratic incentives for implementation. In particular, emitting facilities that together accounted for 85 percent of air and water pollutant–based emissions were required to install continuous emissions monitoring systems (CEMSs), and the SO_2 targets were subsequently achieved during the Eleventh FYP.

Economic studies on air pollution during this period are limited. This is due in part to the challenge of data availability as well as the difficulty of identifying the impact of the policy at the firm level; that is, substantial overlap in policies and their effects has made it difficult to attribute responses to specific initiatives. In one of the few studies of this period, Shi and Xu (2018) evaluate the Eleventh FYP's SO_2 reduction targets and (similar to Hering and Poncet 2014) find that in more pollution-intensive industries, greater regulatory stringency decreases

[15] DID and DDD are quasi-experimental methods that estimate a policy's "treatment effects" by comparing the changes in outcomes over time (i.e., between periods before and after the introduction of the policy) between regions covered by the policy (the "treated" regions) and those not covered by the policy (the "control" regions).

the likelihood of a firm exporting, except among SOEs. The literature also suggests that the Eleventh FYP began to successfully address problems of enforcement by incorporating environmental performance into evaluations of government officials. For example, Chen, Li, and Lu (2018) show that adding SO_2 emissions control to the performance review criteria of local bureaucrats in the TCZs resulted in statistically significant decreases in emissions as well as GDP growth, and Zheng et al. (2014) find that PM_{10} pollution reductions increased the chances of a mayor's promotion.

Stronger enforcement during this period also created incentives to manipulate data. Indeed, multiple studies have found evidence that air pollution data were manipulated. Chen et al. (2012) find evidence that cities manipulated air quality index data to remain below the thresholds for "blue sky days." Ghanem and Zhang (2014) and Ghanem, Shen, and Zhang (2020) report similar findings, with suspicious PM_{10} reporting occurring on days when it was most difficult to detect.

2013 to the Present

The announcement of the Air Ten (under the Action Plan on Air Pollution Prevention and Control) marks the start of the most recent era in the regulation of air pollution. Independent estimates indicate that air pollution fell substantially between 2013 and 2020. For example, on the basis of $PM_{2.5}$ remote sensing data, Ma et al. (2019) show that following implementation of the Air Ten, $PM_{2.5}$ levels declined by 4.27 $\mu g/m^3$ every year through 2017. Tang et al. (2019) find that this decline was due largely to the increased installation and operation of SO_2 removal technology, which was far from complete at the end of the Eleventh FYP (2010). Karplus, Zhang, and Almond (2018) find that the July 2014 implementation deadline for China's tougher 2011 standard for SO_2 pollution led to a sharp decline in air pollution recorded at plant-level CEMSs.

This period also witnessed general improvements in data quality. Karplus, Zhang, and Almond (2018) find that pollution reductions in most areas corresponded closely with satellite measurements over the same period but that this correspondence was weaker for plants in regions facing the toughest targets (i.e., those located in key regions targeted by the Action Plan on Air Pollution Prevention and Control), suggesting possible data manipulation. By contrast, plants in nonkey regions showed large reductions in both plant and satellite data around the time of the policy deadline, suggesting that data manipulation is not universal. Greenstone et al. (2020) show that a shift to automated monitoring can help address the problem of data manipulation by sending data directly to central authorities rather than going through local environmental protection bureaus. In this study, reported PM_{10} concentrations increased by 35 percent after automated monitoring was introduced, suggesting that underreporting was prevalent. Greenstone et al. (2020) also find that automation led to an increase in online searches for face masks and air filters and argue that access to information improved welfare outcomes by prompting appropriate protective behavior. Finally, in a recent study of reporting integrity in China's carbon markets, Zhang et al. (2019) find no evidence of systematic data manipulation when there are third-party verifications and audits. However, they find large discrepancies between self-reported and verified data, suggesting that inattention or inadequate training may also undermine data integrity.

Review of the Literature on Water Pollution Regulation

In this section, we review the literature that evaluates China's water pollution control efforts.

Before 2005

Because of a lack of data, relatively few studies have evaluated the effects of water regulations implemented before 2000. As discussed in the above section, Dasgupta et al. (2001) find that inspections play a role in reducing both air and water pollution. Lin (2013) finds that firms paid fees on self-reported rather than true emissions and that inspections served mainly to prevent firms from underreporting emissions rather than incentivizing them to actually reduce emissions. On the basis of 2002 firm-level data, Lin (2013) finds that increased inspections did indeed lead to more reported emissions.

The 1996 amendment to the Law on the Prevention and Control of Water Pollution replaced administrative region–based implementation plans with river basin–based implementation plans and introduced explicit environmental goals, including provincial water quality goals to be achieved during the Tenth FYP (2001–2005). Using data on 24 major rivers in China (with each crossing at least one provincial border), Cai, Chen, and Gong (2016) examine the effects of the Tenth FYP and find that provinces implemented different policies for upstream versus downstream counties, indicating a pattern of "polluting thy neighbors." Specifically, downstream counties along provincial borders have up to 20 percent more value added in water-polluting industries than upstream counties that are in the provincial interiors.[16]

Wang, Wu, and Zhang (2018) evaluate the effects of the Three River and Three Lake Basin policy, which was implemented between 1998 and 2007. Using firm-level emissions and output data, they show that the policy reduced neither COD emissions nor the polluters' total factor productivity (TFP). This is because the policy was never strictly enforced for large polluters; for the most part, local governments simply shut down small heavy polluters such as paper mills.

Overall, these studies suggest that before 2005, local governments failed to enforce water pollution laws and regulations. As with air pollution, even when the government set water quality and pollution targets, they were not strictly enforced and thus were not met during the Tenth FYP period.

2005–2010

As discussed above, the Eleventh FYP (2006–2010) launched the policy of including the achievement of environmental goals in the performance evaluations of local government officials, and for water pollution, this change was formally incorporated into the 2008 revision of the Law on the Prevention and Control of Water Pollution. More specifically, provincial governors were required to sign responsibility pledges with the State Council to meet environmental protection targets, including water quality targets, and local environmental protection

[16] They also find that private firms contributed the most to the downstream effect, indicating that private firms are the most sensitive to enforcement and levies.

bureaus were given more enforcement power, including the authority to impose higher fines on violators. The targets were set partly to address the polluting thy neighbor problem discussed above, with the responsibility pledges emphasizing water quality at provincial borders. As is common in China, the implementation of the new policies first occurred as a pilot program (in this case, in the Huai River Basin between 2005 and 2007). When officially implemented in 2008, the policy included nine river and lake basins and was further expanded during the Twelfth FYP period to include a total of 10 river and lake basins (Lin, Sun, and Zhao 2020).

During this period, the Chinese government also greatly enhanced its efforts to monitor surface water quality and, more importantly, made the data publicly available. China has been gradually building a national surface water quality monitoring network since 1988. By 2003, the network had expanded to include 759 monitoring stations on 318 major rivers and 26 lakes, and the total number of stations increased to 972 by 2013 (Lin, Sun, and Zhao 2020). During the 2003–2010 period, data from the monitoring stations were made publicly available in various yearbooks.

The performance evaluations of government officials that started in 2005 and the availability of station-level water quality monitoring data during the 2003–2010 period have resulted in the emergence of a relatively large literature on the effects of regulatory enforcement, which has provided insights into China's environmental regulation in general and water regulation in particular.[17] Below, we discuss the key findings of these studies, focusing on the impacts of water pollution regulations on water quality, firm behavior, and overall social welfare.

Impacts of policies on water quality

Perhaps the most important findings from the studies are that, overall, environmental policies did improve water quality for covered regions between 2005 and 2010 and that there was greater improvement at provincial borders or when the provincial leadership (party secretaries or governors) had more potential for promotion within the Chinese government's bureaucratic system (Kahn, Li, and Zhao 2015; Lin, Sun, and Zhao 2020). Using data from almost 500 water quality monitoring stations on major rivers, Kahn, Li, and Zhao (2015) find that between 2005 and 2010, water quality improved along provincial borders relative to provincial interiors.[18] This differs from the pattern identified by Cai, Chen, and Gong (2016), who find that pollution levels during the Tenth FYP were higher along provincial borders than in provincial interiors. Kahn, Li, and Zhao (2015) also find that the treatment effect of water pollution regulation increased over time during the Eleventh FYP and that the relative improvement along provincial borders was higher when a province's party secretary was younger and thus had more potential to be promoted within China's bureaucratic system, which has strict age limits.

Lin, Sun, and Zhao (2020) also analyze water quality measures at the monitoring station level. But rather than comparing results between border and interior stations, they focus on the gradual expansion of the policy over space and time (i.e., the expansion from the Huai

[17]Some of the studies take advantage of different targets across different regions to obtain identification, but most of the studies employ regression discontinuity design or DID in response to the spatial and temporal differences in enforcement levels.

[18]They use a DID approach, with the treated group being monitoring stations at provincial borders and the control group being stations within provincial interiors.

River Basin in 2005 to nine river basins in 2008). They find that the stricter policy enforcement reduced COD and NH_3-N concentrations and that this effect was larger along provincial borders or when a provincial governor had higher potential for promotion.

In contrast, Liang and Langbein (2015) find that the policies of the Eleventh FYP (2006–2010) failed to reduce water pollution (but did reduce air pollution). One drawback of their analysis is that they consider the average effect of the Eleventh FYP on water pollution for the entire country, while the policy targeted only nine watersheds and 72 of the 492 river water monitoring stations (Lin, Sun, and Zhao 2020). Thus, even if the policy improved water quality at the treated stations, the effects might be difficult to detect based on the average changes in water quality measures at all stations.

In another example of the complexities of the policy's effects, Chen et al. (2018) find evidence that between 2005 and 2010, water quality along the upstream part of the Yangtze River deteriorated but water quality in the downstream part of the river experienced modest improvement. They attribute this result to the differences in the stringency of environmental regulation and enforcement. In particular, the 2006–2010 mandates to reduce COD at the city level varied significantly along Yangtze River, with downstream cities facing more stringent mandates. The spatial variations in water quality found in this study again suggest that local officials responded to the central government's water pollution policies during this period.

Firms' responses to environmental policies

Overall, the literature on firm behavior suggests that industrial firms have responded to the environmental policies and their enforcement by reducing outputs, installing abatement devices, and moving to locations with more lax regulation. Unlike energy-intensive firms that are major emitters of air pollution, firms with heavy water pollution discharges are able to relocate more easily because they have lower relocation costs. Because the stringency of water regulation varied significantly across space during the Eleventh FYP, the most significant response by industrial firms was to relocate to areas with less stringent mandates. Kahn, Li, and Zhao (2015) show that polluting firms moved from the border regions to provincial interiors upstream.[19] In a larger-scale study, Wu et al. (2017) analyze a data set of more than 31,000 new manufacturing firms established during the 2006–2010 period and find that the policy led new firms to locate in western China, where the policy mandate was less stringent, rather than in coastal provinces. They also find that foreign-owned firms responded to the policy immediately, while domestic firms did not respond to the policy until after 2007.

There is also evidence that firms responded to the policy by changing their pollution and production practices. For example, Fan et al. (2019) find that polluting firms located in cities with more stringent COD emission targets reduced COD emissions more than other firms, with 30 percent of the reduction stemming from reducing output and 70 percent from reducing pollution intensity. These firms abated their emissions mainly through installing pollution control devices and experienced reductions in their profit, employment, capital, and market share, suggesting that abatement was costly. Chen et al. (2018) examine why water quality deteriorated upstream of the Yangtze River but slightly improved downstream. More

[19]This finding contrasts with the pattern during the Tenth FYP, when polluting firms were concentrated downstream close to provincial borders (Cai, Chen, and Gong 2016).

specifically, they analyze how differences in the stringency of water quality mandates across cities along the Yangtze affected the output values of water-polluting industries at the city level and find that post-2006 enforcement measures reduced industry output values for water-polluting industries but not for non-water-polluting industries. This suggests that abatement was costly for polluters targeted by the policies. Firm responses were again found to be heterogeneous, with smaller, private, and domestic firms being more responsive to the regulation than larger, state-owned, and foreign firms.

In a similar type of study, Liu, Shadbegian, and Zhang (2017) examine the effects of a new wastewater discharge standard imposed on textile printing and dyeing firms in the Taihu Lake region during the Eleventh FYP. The new standard required reduced discharge of COD, biological oxygen demand, and NH_3-N. Using a data set of more than 600 enterprises, they find that the standard reduced firms' labor demand between 2004 and 2007. Most of the effects were concentrated in private enterprises, with no or little effect on SOEs or foreign-owned enterprises, suggesting that firms with different ownership structures were treated differently. This is consistent with the firm effects literature, which finds that private firms tend to be the most sensitive to environmental regulation changes (Cai, Chen, and Gong 2016).

Costs and benefits of regulations

There is a lack of systematic research on the costs and benefits of China's environmental regulation in general and water regulation in particular. However, there have been some recent efforts in this area. Lin, Sun, and Zhao (2020) estimate that water regulation during the Eleventh FYP improved water quality, reduced the mortality rates of digestive cancer, and reduced the county-level GDP growth rate, with the reductions in mortality and GDP growth increasing over time following the start of the policy. Consistent with the pattern of water quality changes discussed above, the effects on digestive cancer mortality and GDP were more pronounced at provincial borders and when the governor had more promotion potential. They also find that the mortality benefits generally exceeded the GDP costs, with the net gain more pronounced in rural regions than in urban regions.

He, Wang, and Zhang (2020) analyze the effects of water regulation during the Eleventh FYP on firm productivity and find that the TFP of upstream firms is 24 percent lower than that of downstream firms. They attribute this difference to stricter enforcement upstream relative to downstream; these results provide further evidence of the potentially high costs of environmental regulation in China.

After 2010

As discussed above, water quality regulation has been further strengthened since 2010. The water quality monitoring system has also been expanded and upgraded, with more than 2,000 surface water monitoring stations on lakes and rivers automatically reporting data on key pollutants at 2- or 4-hour intervals.[20] However, for most of the 2010s, data from only

[20]See the China National Environmental Monitoring Center website (http://www.cnemc.cn/) for details. In the case of groundwater, after almost 5 years and ¥2.2 billion of investment, China has just completed the establishment of a system of 20,469 groundwater monitoring stations. However, data from these stations are not currently publicly available.

a small set of 148 automatic monitoring stations are available. These stations were initially designed to be controlled by the central government, with water quality automatically sampled multiple times a day and data automatically released to the public (Lin, Sun, and Zhao 2020). For the rest of the stations, China has only recently started to livestream the station-level data. Possibly because of this lack of data, few studies of post-2010 water policies have been conducted. In one exception, Li et al. (2020) examine the impacts of the river chief system policy from 2004 to 2016, taking advantage of its gradual introduction. They find that while the policy reduced ambient concentrations of some pollutants (e.g., NH_3-N), it actually raised the concentrations of COD and dissolved oxygen and reduced the overall water quality. One caveat of this study is that although the river chief system was introduced over large geographical areas, the study's sample size is small because of the small number of automatic stations, which limits the representativeness of the results.

Key Findings and Conclusions

This article has presented a comprehensive—though far from exhaustive—review of the evolution and performance of China's environmental policies. We have argued that the planning process, especially the FYPs, has played an important role in shaping China's regulatory approaches and targets and that the country's environmental priorities have shifted over time. Enforcement of early regulations was limited because it conflicted with the top priority of economic growth. As environmental damage and pressure to address it have mounted, China has shifted its approach from enacting regulations that lacked oversight and enforcement to accelerating targets via action plans and strengthening implementation (van Rooij 2006; Eaton and Kostka 2017; van Rooij et al. 2017).

There has also been a gradual shift in priorities concerning pollutants. The initial focus was on water pollution regulation because industrial activities were causing heavy water pollution; after 2000, air pollution became a major focus because of widespread SO_2 and PM pollution. Soil pollution became a high priority only during the most recent FYP period (2016–2020), despite its severity and its impact on food safety. Thus, the empirical literature on China's environmental regulation is heavy on air and water pollution but extremely light on soil pollution.

As is evident in the overview of China's regulatory labyrinth, local governments were not always properly incentivized to enforce environmental regulations, and their approaches have tended to be more command and control than market based. Recent efforts, including action plans and environmental inspections, have called for using more central government–level authority and using criminal laws to enforce emission and ambient standards. There is also an encouraging shift toward market-based approaches, with emission fees being transitioned to emission taxes and the establishment of a national carbon market.

Data and Other Challenges

The empirical literature on China's environmental regulation has focused on only a small subset of the country's policies.[21] As we have emphasized, this is due largely to a lack of available

[21]See table A1.

data. Weak enforcement of regulations before 2000 means that the effects of the policies were difficult to detect in ambient pollution data. Future research will be able to take advantage of the increase in enforcement and air pollution data availability.[22]

Nevertheless, formidable data challenges remain at both the firm and ambient levels. Firm-level data exist but are difficult to obtain and are not easy to merge with the industrial firms database of the National Bureau of Statistics of China. There is also a lack of high-frequency firm-level data, which makes it difficult to identify the impacts of regulations and to analyze firms' responses to regulation. Ambient data other than on air pollution are limited. For example, post-2010 water pollution data from a large number of monitoring stations are no longer available, and detailed soil pollution data are not publicly available at all. Thus, despite widespread concerns about data quality in China, the biggest challenge is actually a lack of available data. Another challenge is the difficulty of separating the effects of policy shocks from contemporaneous developments in other environmental or economic policies.

Key Findings of the Literature

Despite these limitations and challenges, the empirical literature we have reviewed does offer a number of important insights. First, policies such as TCZs, binding water pollution targets, the war on air pollution, and the Action Plan on Air Pollution Prevention and Control's Air Ten have been shown to be effective in improving environmental quality. The costs can be substantial, but the few studies that compare the costs and benefits suggest that the benefits tend to exceed the costs, possibly because the starting pollution level is high. Second, enforcement is key for environmental performance, and an important enforcement mechanism is to hold local officials accountable for progress. Accountability in the form of annual reviews of local officials and inspections by the central government has been found to lead to environmental improvements. Third, firms do respond to environmental regulation—by adjusting their outputs and inputs, adopting new technologies and innovating, and relocating. There is significant heterogeneity in their responses based on ownership structure, firm size, and mobility of the firm's industry. Fourth, because China's economy has been growing rapidly and many environmental regulations have targeted firm-level emissions, firm emission intensity has decreased but ambient concentration has increased, especially in the case of water pollution. Over the past several years, the central government has started to emphasize ambient environmental targets, which means that total emission growth is likely to be limited. Fifth, institutional support can be as important as the regulations themselves. Weaknesses in monitoring, reporting, and verification have contributed to data manipulation by cities and firms. Even when ambient pollution is carefully monitored, as in the case of air pollution, entities have found ways to "game" the system. Extremely aggressive targets and enforcement measures can encourage such data gaming. Finally, although informal measures such as public information about pollution are still in the early stages, there is limited evidence that these measures can be effective in influencing consumer behavior.

[22]This is already happening to some extent with emerging studies that examine recent air pollution action plans.

Future Research Needs

Despite the recent increase in empirical studies of China's environmental regulation, a number of issues require further research. First, it remains unclear how heterogeneous firms respond to environmental regulation. For example, while there is some evidence on how firms responded to water pollution policies during the Eleventh FYP, firm responses have been harder to identify in the case of air pollution because of the lack of detailed firm-level data and the simultaneous introduction of a range of air, energy, and climate policies. The impact of firm ownership, especially state ownership, on environmental performance also remains poorly understood. Second, more empirical research on the cost-effectiveness and efficiency of China's environmental regulatory and enforcement efforts is needed. The majority of the research thus far has emphasized only the environmental and health outcomes. In addition, while there is anecdotal evidence that local officials have taken steps to ensure compliance or, more recently, deter data manipulation, formal evaluations of the costs of these actions are lacking. Third, we have shown here that China's environmental policies tend to be fragmented, with many moving parts. Thus, a priority for future research should be to investigate policy interactions, synergies, and conflicts. Finally, there is an urgent need for rigorous economic research on soil and heavy metal pollution.

Appendix

Table A1 Overview of China's environmental policy developments and related literature

	1981–1990	1991–2000	2001–2005	2006–2010	2011–2015	2016–2020
Legislation						
Environmental laws[a]	EPL (1989); Law on the Prevention and Control of Water Pollution (1984); Law on the Prevention and Control of Atmospheric Pollution (1987); Marine Environment Protection Law (1982)	Law on the Prevention and Control of Solid Waste (1995); Law on the Prevention and Control of Environmental Noise Pollution (1996)	Law on the Prevention and Control of Radioactive Pollution (2003); Environmental Impact Assessment Law (2002); Circular Economy Promotion Law (2008)			Environmental Protection Tax Law (2016); Law on the Prevention and Control of Soil Pollution (2018)
Plant-level standards[b]		Emission Standards of Air Pollutants for Coal-Fired Power Plants (1991)			Emissions Standards for Coal Power Plants (2014); ultralow emissions standards	
Ambient standards[c]	AAQS for SO_2, NO_x, and PM_{10} (1982)	AAQS (1996)	AAQS (2000)		AAQS revised to include $PM_{2.5}$, O_3, and CO (2012)[1]	
Planning						
FYPs	Sixth and Seventh FYPs	Eighth and Ninth FYPs	Tenth FYP	Eleventh FYP	Twelfth FYP	Thirteenth FYP
Major FYP innovations	"Three Simultaneities" Five-Year Environmental Protection Plan	Environmental protection indicators	National and provincial caps on six pollutants[1]	Environmental targets in bureaucratic review[1–11]	"Ecological civilization"	Focus on richer set of ambient environmental quality goals
Action plans[d]					Action Plan on Air Pollution Prevention and Control (2013–2017);[2–4] Action Plan on Water Pollution Prevention and Control (2015–2020)	Three-Year Action Plan for Winning the Blue Sky War (2018–2020); Action Plan on Soil Pollution Prevention and Control (2016–2020)

Implementation	EPS (1989)	ETS (1991);[8,9] emission fees (1992–2018);[1–3] total emission control system (1996); TCZs policy for SO_2;[4–7] Three River and Three Lake Basin policy for COD;[10] environmental protection indicators developed	Environmental inspection (2002); national and provincial targets for SO_2; CEMSs required for power plants (2008)	National and provincial targets for SO_2, energy intensity	EPS enhanced (2014); pilot ETSs for CO_2 (2013–2015); national and provincial targets for SO_2, NO_x, CO_2, energy intensity; Black and Smelly Waters (2015); National Air Pollution Monitoring Network (2015); Under the Dome (2015);[5] cadmium rice (2013)[6]	CEI (2015); river chief system (2016);[1] emission taxes (2018); national ETS for CO_2 (under development); "2+26" cities (2017)
Literature		[1]Dasgupta et al. 2001; [2]Wang and Wheeler 2005; [3]Lin 2013; [4]Hering and Poncet 2014; [5]Tanaka 2015; [6]Cai et al. 2016; [7]Jefferson, Tanaka, and Yin 2013; [9]Tao and Mah 2009; [10]Wang, Wu, and Zhang 2018	[1]Cai, Chen, and Gong 2016	[1]Shi and Xu 2018; [2]Xu 2017; [3]Chen et al. 2018; [4]Zheng et al. 2014; [5]Kahn, Li, and Zhao 2015; [6]Liang and Langbein 2015; [7]Wu et al. 2017; [8]Liu, Shadbegian, and Zhang 2017; [9]He, Wang, and Zhang 2020; [10]Lin, Sun, and Zhao 2020; [11]Fan et al. 2019	[1]Karplus, Zhang, and Almond 2018; [2]Ma et al. 2019; [3]Tang et al. 2019; [4]Li, Sun, and Zhao 2020; [5]Tu et al. 2020; [6]Chen, Zhao, and Zhou 2021	[1]Li et al. 2020

Note: Policies are organized according to start date. AAQS = ambient air quality standards.
[a]See table C1 for details.
[b]See section D in the online appendix for details.
[c]See section D in the online appendix for details.
[d]See table C2 for details.

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