Environmental Regulation and Industrial Performance: Evidence from China*

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Abstract

Sizable evidence in developed countries substantiates considerable costs of environmental regulation on industry profits and productivity levels. We present new evidence that stringent environmental protection policies are likely to provide *positive* forces leading to improved productivity in developing countries, because regulations i) stimulate within-industry selection dynamics through the entry of more efficient and exit of less efficient firms, and ii) create incentives for innovations and/or adoptions of cleaner technologies and enhance productivities. Our findings shed light on productivity growth in regulated industries by the Two Control Zone policy in China. Our evidence supports both selection mechanism and induced technology at work. The findings are robust to inclusions of city- and industry-specific trends and key *ex ante* determinants of firm growth. Supportive of our argument, especially in comparison with spuriously confounding preexisting trends, are performance similarities during the policy's enactment between regulated and non-regulated cities accompanied by their slow growth in productivity over the next several years.

JEL classifications: L1, Q5, D2
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I. Introduction

The neoclassical economics model argues that environmental regulations impose substantial costs and impede industrial performance. This model is supported by large and robust empirical evidence, e.g., the U.S. Clean Air Act has resulted in substantial economic losses. This has made such policies controversial in academic and policy discourse worldwide and led many scholars and policymakers to perceive a trade-off between environmental protection and economic development. As a result, while responsibility for climate change is increasing assigned to developing countries, their environmental policymaking is often stymied by concerns over hindering economic development. A longstanding question is whether key data from developed countries should even be extrapolated to the developing world.

In this paper, we address this issue by examining the extent to which a stricter environmental protection regime in China has impacted industrial performance. Specifically, we focus on the Two Control Zone (TCZ) policy. The policy was implemented in 1998 and is considered one of the largest scale environmental policies among developing countries. The legislation imposed stringent requirements to reduce pollution emissions in more than 200 prefectures exceeding nationally mandated pollution standards, including the use of lower-sulfur coal and the development and adoption of clean technologies.

Two potential channels make it plausible that the magnitude and even the sign of effects differ in China compared to U.S. First, environmental regulation may drive within-industry resource allocation and firm turnover, leading to productivity growth. This argument is particularly relevant for developing countries, where recent studies associate the existence and persistence of substantial productivity dispersion with resource misallocation.[1] Under such circumstances, regulation is more likely to promote a Darwinian selection of market dynamics, in which more productive firms displace less productive ones. Second, environmental policy may enhance productivity if regulations induce innovation among polluting firms. This concept, known as the Porter hypothesis, has met with relatively little empirical support in developed countries. On the other hand, such innovation effects are expected to be greater in developing countries relying on low technologies, which promote both high emissions and low production performance. Both

[1] See, for example, Banerjee and Duflo (2005); Alfaro, Charlton, and Kanczuk (2008); Hsieh and Klenow (2009); Banerjee and Moll (2010); and Restuccia and Rogerson (2013).

channels partially offset or even lead to net *positive* effect of environmental regulation on industrial performance.

Our empirical strategy is designed to estimate the effect of TCZ regulations on industrial activities for different levels of pollution and energy intensities. Essentially, it is based on a difference-in-differences framework exploiting two sources of variation in regulatory intensity across cities and industries: firms located in TCZ cities are subject to relatively more stringent environmental regulations than those in non-TCZ cities, whereas pollution-intensive firms are affected more than non-polluting firms within a city. Importantly, this approach allows the estimated regulation effect to be purged of industry- and city-specific trends. This rectifies shortcomings associated with (a) a simple comparison between TCZ and non-TCZ cities capturing heterogeneities other than TCZ regulatory status (i.e., differential patterns of economic growth across cities), and (b) a simple comparison between polluting and non-polluting industries that confounds factors causing differential mean growth (i.e., demand or supply shocks).

To implement the analysis, we use plant-level data from the Annual Surveys of Industrial Production (ASIP) from 1998 through 2005, collected by the National Bureau of Statistics of China. The ASIP provides detailed annual financial and operational data for the census of state-owned firms and all non-state-owned firms with annual revenues above five million yuan.[2] We use the plant's location at the county level to identify its TCZ status, reported by the State Council. We also collected information on industry-level pollution intensity, measured by the share of coal consumption or sulfur dioxide (SO_2) emissions, and energy-intensity, measured by the share of energy consumption, from the National Bureau of Statistics of China. This complete dataset includes more than one million plant-by-year observations across 33 power and manufacturing industries.

Such a unique and comprehensive dataset adds credibility to our analysis in two ways. First, the longitudinal nature of the dataset allows us to trace individual firms throughout the period and to observe market dynamics via their entries and exits. Second, detailed information on various facets of firms' activities allows us to carry out a comprehensive analysis of regulation effects (i.e., sales, profits, return of assets, return on equity, return on capital employed, net income, and total factor productivity). Many previous studies, on the other hand, have looked at

[2] The yuan appreciated substantially after our study period, and currently $1 USD is worth about 6 yuan. The five million yuan threshold is based upon the nominal value of revenues, and using the then exchange rate, five million yuan was worth about $600,000 in the 1998-2005 period.

only a single variable, e.g., an abatement cost or employment, to measure the cost of regulations. However, if compliance with environmental regulations can spur better industrial performance, such benefits may partially or fully offset compliance costs.

Our findings highlight substantial improvements in performance in pollution-intensive industries, suggesting that the regulations had *positive* effects on productivity and competitiveness. In particular, firms in pollution-intensive industries are associated with higher revenues in TCZ cities, holding their energy consumption constant. Importantly, this effect is evident across many specifications, a variety of alternative measures of industrial performance, and an alternative measure of pollution intensity.

Further analyses provide evidence in support of both selection mechanisms and induced innovation at work. For instance, the environmental regulation have encouraged greater selection dynamics by inducing entries of more productive firms and exits of less productive ones. Also, in an effort to illustrate productivity dynamics via induced innovation free from selection mechanism, we use the balanced panel observations and find some lags in the inception of productivity growth for firms in TCZ cities with initial characteristics similar to their counterparts.

In addition, we simultaneously test whether the TCZ regulatory policy had an externality effect on clean yet energy-intensive industries. The heavy reliance on coal for electricity generation in developing countries makes the power sector particularly sensitive to environmental regulations. Studies often measure relative effects of regulations on polluting versus non-polluting firms, which would be biased in this case, because non-polluting firms are likely to receive externality effects via energy-supply shortages. We find suggestive evidence that the TCZ regulation had negative externalities on energy-intensive firms, holding pollution-intensity constant.

The major challenge to the identification strategy is confounding preexisting differences in growth patterns. We explore and reject competing alternative hypotheses to explain the results. In particular, the finding is estimated with inclusions of industry-by-year and city-by-year fixed effects that flexibly control for industry- and city-specific trends. It is also robust to controlling for a variety of additional factors known to contribute to firms' growth (e.g., capital, labor, asset, age, ownership type, leverage, capital intensiveness and city-by-industry characteristics). Further, we show no evidence of preexisting differences in performance in the early years, of within-industry price variation to drive the main result, and of unobserved government policies to compensate negative regulation effect. Rather, the fact that changes in productive efficiency were slow and occurred over several years is supportive of our argument, especially in comparison with spuriously confounding preexisting trends.

The rest of the paper is structured as follows. Section II provides background on related studies on effects of environmental regulation and highlights our contributions to the literature. We also introduce the TCZ policy, existing evidence on its effectiveness, and variation in regulatory stringency that we exploit for the analysis. Section III describes the data and presents descriptive statistics. Section IV explains the identification strategy, and Section V presents empirical results and probes their robustness. Section VI tests alternative competing hypotheses, and finally Section VII concludes.

II. Background

A. Related Studies on Effects of Environmental Regulation and Our Contributions

Environmental regulations have been contentiously debated around the world. A central component in advocating a regulatory framework is strong associations between air pollution and human health, such as respiratory infections, cardiovascular diseases, lung caner, and infant mortality (Schwartz, Dockery, and Neas 1996; Chay and Greenstone 2003a; Neidell 2004; Kumar and Foster 2007; Currie, Neidell, Schmieder 2009; Jayachandran 2009; Greenstone and Hanna 2011; Tanaka 2014).[3] The U.S. Clean Air Act has led to substantial reductions both in air pollution and in infant mortality (Chay and Greenstone 2003b). Further, air quality has been found to affect various other economic outcomes, such as housing prices across the United States (Chay and Greenstone 2005); school absences among elementary and middle school children in Texas (Currie et al. 2009); and labor supply in Mexico City (Hanna and Oliva 2011).

However, despite all of the benefits, conventional neoclassical theory has provoked disagreements regarding regulatory policies. Regulations often impose substantial costs on productivity growth, lower total welfare and hamper the competitiveness of domestic firms in interna-

[3] Types and sources of pollution also matter. It is generally known that smaller particulates are more detrimental to human health. For example, PM_{10} or $PM_{2.5}$, whose particles are less than 10 or 2.5 μg/m^3 in diameter, respectively, or toxic gas, such as SO_2, are considered to be the most hazardous because, when inhaled, these particulate matters or gas can penetrate deep into the lungs and interfere with internal gas exchange. Currie and Neidell (2005) find that reductions in carbon monoxide (CO) had greater impacts on reductions in infant mortality in California over the 1990s, compared to PM_{10} and ozone (O_3).

tional markets. There is indeed substantial evidence in the U.S. Clean Air Act is associated with distortions in productivity (Gollop and Roberts 1983; Barbera and McConnell 1990; Greenstone, List, and Syverson 2012), firm's location decisions (Henderson 1996; Becker and Henderson 2000; List et al. 2003); employment (Greenstone 2002; Deschenes 2010; Walker 2011; Walker 2012); and foreign direct investment inflows and outflows (Keller and Levinson 2002; Eskeland and Harrison 2003; Hanna 2010).[4]

This paper both extends and departs from the previous literature in a fundamental way. We present new evidence supporting a more recent perspective on environmental policy interventions as *positive* forces leading to increased productivities and enhanced competitiveness in regulated industries. Since first proposed by Porter (1991), today known as the Porter hypothesis, there have been a growing number of debates on its empirical validity, yet the evidence is mixed.[5] For example, Jaffe and Palmer (1997) find that pollution abatement expenditure is significantly correlated with R&D expenditure but not with tangible outcomes, such as successful patent applications, in the U.S. manufacturing industries. In contrast, Brunnermeier and Cohen (2003) find an association between pollution abatement expenditures and increased successful patent applications in a different context. Berman and Bui (2001), on one hand, show increases in productivity among oil refineries in Los Angeles despite heavy compliance costs in response to local air pollution regulation. Gray and Shadbegian (1998), on the other hand, show that productive investments were crowded out by pollution abatement investment in the pulp and paper industry, whereas Greenstone (2002) finds that the overall regulation impact on costs and productivity was small in magnitudes.

Our study offers one of the first attempts to analyze the effect of environmental regulations on industrial productivity in developing countries. Two potential channels, particularly relevant to developing countries, may give rise to unique outcomes. One is that regulations may create constraints and incentives, which possibly induce technological change or innovation among affected industries. Firms in developing countries tend to rely on low technologies for

[4] A vast other studies present similar findings. See for example the summary in Fleishman et al. (2009).

[5] See Jaffe et al. (1995), Porter and van der Linde (1995), Jaffe, Newell, and Stavins (2003), and Popp, Newell, and Jaffe (2010) for a detailed overview of the related literature. Induced technological changes in response to environmental regulation are found in Goulder and Schneider (1999); Goulder and Mathai (2000); Nordhaus (2000); Snyder, Miller, and Stavins (2003); Greaker (2006); Lee, Veloso, and Hounshell (2007). Induced innovation is also examined in another context in response to changing energy prices (Newell, Jaffe, and Stavins 1999; Popp 2001, 2002; Linn 2008).

production, a main cause of both high pollution emissions and low productivity. Hence, the rate of technological change is expected to be larger, relative to modernized firms in developed countries that have already been producing at the efficient production frontier.

Also, environmental regulation stimulates within-industry selection dynamics, as more productive firms displace less productive ones, in the regulated industry. The notion that such selection mechanisms, through within-industry resource reallocation and firm turnover, leads to aggregate productivity growth has been explored theoretically (Jovanovic 1982; Hopenhayn 1992; Ericson and Pakes 1995; Melitz 2003; Eslava et al. 2004; and Asplund and Nocke 2006) and empirically (Dunne, Roberts, and Samuelson 1988; Aw, Chen, and Roberts 2001; Foster, Haltiwanger, and Krizan 2006; Foster, Haltiwanger, and Syverson 2008; Corcos et al. 2012; Ryan 2012; Bartelsman, Haltiwanger, and Scarpetta 2013; Eslava et al. 2013). We advance the research on environmental regulations as motivating factors triggering selection dynamics. Recent evidence substantiates a long left tail of firms with extremely low productivity in China, India, and other low-income countries relative to the United States and other developed countries (Hsieh and Klenow 2009). It still remains, however, an open question as to what types of policies and practices stimulate productivity dynamics and efficiencies in developing countries.

Further, we simultaneously examine the externality effects of an air pollution control on non-polluting energy-intensive firms. Coal, the world's most abundant fossil fuel, is a primary energy source for developing countries, many of whom enjoy its abundant reserves. Hence, an important empirical question is whether air pollution regulation, which heavily affects the power sector, has any impacts on clean, yet energy-intensive, firms. The net effect is theoretically ambiguous, as it depends on the magnitudes of negative forces of energy shortage in lowering economic activities among energy-intensive firms vs. positive impacts through deploying energy-saving productivity-enhancing technologies or greater market dynamics among the energy-intensive industries.

Despite the fact that developing countries are producing a large percentage of the pollution promoting global climate change, this review of existing studies clarifies that the literature is predominantly concentrated on developed countries and that evidence on the effect of environmental regulation in the developing world is scarce. What is more, some of the unique features of developing countries suggest that extrapolating the results from developed countries is not plausible. Further, the anticipated adverse effect on economic activities is central to regulation aversion in developing countries, where economic growth is often prioritized over the environment. Thus, it is clear that we need quantitative knowledge focusing on developing countries to offer insights over costs and benefits of environmental regulation.[6]

B. Two Control Zone Policy

China is infamous for its air pollution, due to emissions from a power sector that relies heavily on coal to generate electric power. As the world's largest coal producer, China possesses abundant and relatively cheap coal, which constitutes the country's primary energy resource endowment, accounting for 75.5 percent of total energy production in 1995 (National Bureau of Statistics of China 2006). However, coal generally emits more pollutants than other fossil fuels. As China underwent rapid economic growth, total SO_2 emissions increased from 18.4 million tons in 1990 to 23.7 million tons in 1995, and the ambient air pollution rose to levels detrimental to human health (State Environmental Protection Agency [SEPA] 1996).

During that decade, elevated air pollution gave rise to increasing public concern about adverse impacts on human health. In response, the Chinese government formulated a series of environmental regulatory policies, among which the most notable was the Two Control Zone (TCZ) policy implemented in 1998.[7] This legislation designated prefectures exceeding nationally mandated thresholds as either acid rain control zone or SO_2 pollution control zone. Based on the records in preceding years, prefectures were designated as SO_2 pollution control zone if;

- Average annual ambient SO_2 concentrations exceeded the Class II standard[8],
- Daily average concentrations exceeded the Class III standard, or
- High SO_2 emissions were recorded.

Alternatively, prefectures were designated as acid rain control zone if;

[6] In terms of health benefits with reduced air pollution, the magnitude of benefits associated with improved air quality is likely to be amplified in developing countries, due to less capacity to avoid pollution. Tanaka (2014) examines the effect of TCZ policy on infant mortality in China in the period of 1991-2000 and finds greater elasticities of infant mortality reductions with respect to air pollution reductions than those in developed countries, suggesting greater benefits of environmental policy when air pollution is initially higher. In general, developing countries suffer from much higher levels of air pollution, among which China is among the most polluted. For example, the TSP concentration level in China was close to 400 $\mu g/m^3$ (WHO standard is 100 $\mu g/m^3$) and SO_2 concentration level was close to 100 $\mu g/m^3$ (WHO standard is 50 $\mu g/m^3$) in 1995.

[7] See Tanaka (2014) for detailed history of environmental regulations in China.

[8] According to the Chinese National Ambient Air Quality Standards (CNAAQS) for SO_2, Class I standard designates an annual average concentration level not exceeding $20 \mu g/m^3$, Class II ranges $20 \mu g/m^3 < SO_2 < 60 \mu g/m^3$, and Class III ranges $60 \mu g/m^3 < SO_2 < 100 \mu g/m^3$. Cities should meet Class II, which is considered to be less harmful.

- Average annual pH values for precipitation were less than or equal to 4.5,
- Sulfate deposition was greater than the critical load, or
- High SO_2 emissions were recorded.

In total, 175 prefectures across 27 provinces were designated as TCZs (Figure A1).[9] They accounted for 11.4 percent of the nation's territory, 40.6 percent of its population, 62.4 percent of GDP, and 58.9 percent of the total SO_2 emissions in 1995 (Hao et al. 2001).

The TCZ status enforced more stringent regulations mandating the use of less high-sulfur coal and the development of clean coal technology. For example;

- No new coal mines producing coal with a sulfur content higher than 3-percent can be established, and existing mines that produce such coal must gradually be shut down or reduce output.
- Construction of any new coal-burning thermal power plants in large and medium-sized prefectures is prohibited.
- All new and renovated power plants are required to use coal with less than 1 percent sulfur content.
- Existing power plants using coal with sulfur content above 1 percent are required to install flue gas desulfurization (FGD) equipment.

C. Effectiveness of the TCZ Policy

Various pieces of evidence provide support to the efficacy of TCZ regulatory actions in reducing pollutant emissions and improving air quality. First, pollution emissions were cleared out at the sources. For example, by the end of 1999, mines producing more than 50 million tons of high-sulfur coal had been closed in TCZs (Hao et al. 2001). Further, small thermal power plants, with output capacity below 50MW, were actively shut down because they were relatively less efficient, had high coal consumption rates, and emitted massive amounts of pollutants.

Second, the amount of pollution emissions fell substantially more in TCZ cities. In total, SO_2 emissions fell by about 3 million tons, and about 71 percent of all factories producing over

[9] The SO_2 pollution control zone was concentrated in the north due to high SO_2 emissions for heating,[9] whereas the acid rain control zones were primarily in the south, where heat, humidity, and solar radiation combine to create high atmospheric acidity. Hence, acid rain in the south cannot necessarily be attributed to SO_2 emissions traveling down from the north, but is rather due to local emissions. This is even more evident because acid deposition is the greatest in the summer, when wind direction is generally south to north.

100 tons of emissions per year reduced their SO_2 emissions to the standard between 1998 and 2000 among TCZs (He, Huo, and Zhang 2002). This translated into improved overall air quality; Tanaka (2014) shows that air pollution, as measured by TSP concentration and SO_2 concentration, fell relatively more in TCZ cities between 1991 and 2000. Between 1998 and 2005, the number of prefectures in the SO_2 pollution control zone (the acid rain control zone) meeting the Class II standard rose by 12.3 (3.3) percent, those meeting the Class III standard increased by 4.2 (7.9) percent, and those not meeting the Class III standard fell by 16.5 (11.2) percent (United Nations Environment Programme 2009).

Lastly, increasing number of firms was equipped with green technologies. By the end of 2000, the total power capacity with FGD equipment exceeded 10,000MW.

D. Variation in Regulatory Stringency

This subsection describes the sources of variation in TCZ regulations, which provide insight into identifying the effects of stricter environmental regulations on industrial activities. The first variation is that TCZ status is highly correlated with regulation stringency across cities as the regulations were implemented and enforced mainly within the TCZ cities, and the regulations were less stringent in non-TCZ cities. This has resulted in substantial improvements in air pollution in TCZ cities relative to non-TCZ cities (Tanaka 2014). It is worth noting that, since the TCZ status implies a uniform standard across a nation, it is less likely to reflect differences in local production decisions.

The second variation is that the regulation had a greater impact on firms producing high initial levels of pollution; non-polluting industries, even within TCZ cities, were not subject to the regulation. Hence, firms heavily reliant on coal thus experienced greater regulatory impact because they were initially heavy polluters and the regulations emphasized the use of clean coal and adoption of technologies to clean coal.[10] On the other hand, because the power sector was a primary contributor of pollution and consumer of coal, the regulations were likely to impact firms initially using more energy or electricity due to energy supply shortage.

[10] Hering and Poncet (2011) exploit similar differences with an additional difference before and after the policy implementation, using the city-level observations in the 1997-2003 period, and show the effectiveness of the TCZ policy in reducing exports relatively more within pollution-intensive industries in the TCZ cities in the post-reform period.

Before we illustrate our econometric framework below, it is worth emphasizing here that the interactions of these two sources of variation allow the subsequent analysis to address two critical concerns. First, TCZ status is likely to covary with various other heterogeneities. In particular, because the pollution level is highly correlated with local economic activities, TCZ cities are likely to be more responsive to rapid economic growth during the study period of 1998-2005. The within-city variation across industries controls for variables associated with time-varying shocks common to all firms within a city.

Second, a simple comparison of more and less polluting industries within a city is confounded by heterogeneous industry-specific shocks. For example, the power industries may have faced increased demand for electricity to support rapid economic growth. Since the same industries, whether they are polluting or energy-intensive, both exist in TCZ and non-TCZ cities, the across-cities variation separated by TCZ status helps isolate effects through time-varying shocks unrelated to the regulation and common to all firms within an industry.

III. Data and Descriptive Statistics

A. Data

Plant-level Information – Our data on industrial activities come from Annual Surveys of Industrial Production (ASIP) from 1998 through 2005, collected by the National Bureau of Statistics of China. The ASIP covers the census of state-owned firms and all non-state-owned firms whose annual revenues exceeded five million yuan (about $600,000). For each firm, the survey reports detailed information on their financial and operational characteristics, covering more than 165,000 firms in 1998 to 270,000 firms in 2005. Importantly, ASIP uses a unique identifier for each firm across years, allowing us to construct a panel dataset and to trace individual firms over time. In addition, we use the two-digit industry code to identify their polluting and energy intensive levels, whereas the six-digit geographical code pins down to the county level, making it possible to identify their TCZ status.[11]

[11] Chinese administrative divisions consist of six levels. Six-digit geographical codes can be decomposed into three two-digit parts; one for the provincial level, the second one for the prefecture level, and the third one for county level. The county level includes districts (*shixiaqu*), cities (*xianjishi*), and counties (*xian*). In general, districts and cities are urban areas in the prefecture, while counties are outer, rural areas. In the remaining paper, we use the term "city" to refer to administrative divisions at the county level.

We restrict the sample in our main analysis in two ways. First, it is restricted to the manufacturing sector (which consists of 30 industries and accounts for 91.4% of the original data) and the power sector (which consists of 3 industries and accounts for 4% of the original data). Second, we restrict the sample to firms whose total number of units of industrial activity is one, allowing the main analysis to focus on observations at the plant level. The original dataset contains information regarding geographical location for the firm, in some cases where headquarter is located, but does not identify exact locations of each plant. This causes measurement error in determining the extent to which a firm is effectively regulated under the TCZ policy, when multiple plants operate in both TCZ and non-TCZ cities. The majority of the original sample (86.7%) is indeed plant-level observations.

TCZ Information – The TCZ regulatory status is reported in the document "Official Reply to the State Council Concerning Acid Rain Control Areas and Sulfur Dioxide Pollution Control Areas," published by the State Council in 1998. The document lists the names of all places that were designated either acid rain control zone or SO_2 control zone (Figure A1). We follow Tanaka (2014) in determining the TCZ status at the county level. The assignment was made primarily at the county level, which can be directly linked to ASIP. If the assignment was made at the prefecture level, all districts and cities that belong to the prefecture are given the same TCZ status assigned to the prefecture. The document states that impoverished counties are exempt from the regulations, even when they belong to a TCZ prefecture. Most prefectures specify exact counties that are or are not exempted, but when the names of exempted counties are not listed, we eliminate observations in these counties to reduce measure error in the TCZ status. The TCZ status may have changed over time when a county was upgraded to a district or a city. Though this is rare, we drop observations in these places to further avoid contamination in the TCZ status.

Pollution- and Energy-Intensity Information – The TCZ policy disproportionately targeted polluting firms relative to non-polluting firms, and because the power sector was heavily affected, energy-intensive firms were likely to receive externality effects. However, as we lack information on emission or energy consumption levels at the firm level, we use the two-digit industry-level observations in the baseline year, reported by the National Bureau of Statistics of

China.[12] An industry-level pollution-intensity is measured based on the national share of SO_2 emissions, or the national share of coal consumption. Coal consumption is highly correlated with emissions, as coal is a primary contributor of SO_2. Accordingly, the TCZ policy imposed strict requirements for the use of less polluting coals and the adoption of technologies to clean coal. Industry-level energy-intensity is measured by the national share of energy consumption.

B. Descriptive Statistics

In total, we have a sample of close to 140,000 firms in 1998 up to more than 250,000 firms in 2005, with 33 two-digit industries over the period of 1998 through 2005, resulting in a total of more than one million firms-by-year observations. The economic variables used in the main analysis and their descriptive statistics are reported in Table 1. All monetary values are in constant 2000 RMB. See Data Appendix in Online Appendix II for detailed variable definitions and constructions. It shows that average revenues from sales are 56 million RMB, out of which 2.4 million RMB are profits. Approximately 22% of total observations are from state-owned firms. We find that about 70% of all firms operated in TCZ cities.

The last three rows provide average consumption share by an industry, weighted by the number of firms in the industries. It indicates that the share of SO_2 emissions and coal consumption from each industry was small – the mean share is only about 2% for both variables. This is also true for energy consumption – the mean share is only about 3%. In Table A1, we provide more detailed variation in pollution- and energy-intensity across industries. We use two alternative measures of pollution intensity: coal consumption and SO_2 emission. It is revealed that the electric power production industry was the largest coal consumer, using 31.8% of total national coals, followed by the nonmetal minerals industry (9.75%) and ferrous metals industry (9.38%). Clearly, there is a high correlation between coal consumption and SO_2 emissions (correlation coefficient = 0.95).

In total, the power and manufacturing sectors emitted more than 95% of SO_2 and consumed 78% of coal. With regard to the energy consumption, the smelting and pressing of ferrous metals industry accounts for the largest share of 14.1%. The power and manufacturing sectors

[12] We use 1995 as the baseline year for coal and energy consumption. We use 1996 as the baseline year for SO_2 emissions, simply because no such information was reported for SO_2 in 1995. Using 1995 instead of 1997 provides pre-treatment information less affected by the amendment of APPCL in 1995. No information for any of the four measures was reported prior to 1995.

jointly consumed 65.8% of total energy across the nation. A comparison between the second and third columns reveals that coal consumption is associated with energy consumption (correlation coefficient = 0.58), indicating that it is important to control for energy consumption when estimating the effect on pollution-intensity.

IV. Identification Strategy

We begin with the conventional model of firm productivity in the form of a basic production function:

$$y_{fict} = \alpha_1 l_{fict} + \alpha_2 k_{fict} + \varepsilon_{fict}, \tag{1}$$

where Y = deflated sales, L = labor, K = capital, of firm *f* in industry *i* in city *c* at time *t*, and all lower cases represent natural logarithms (i.e., y = ln(Y)).

We add two sources of variation in TCZ regulations to equation (1) in an effort to identify the effects of stricter environmental regulations on performance. The first variation comes from the comparison across geographical locations between TCZ cities and non-TCZ cities. This comparison captures not only the impact of the more stringent regulations imposed by TCZ policy but also inherent heterogeneities across cities. For example, firms in TCZ cities were initially polluting more, suggesting greater industrial activities in the first place. The second variation compares more pollution-intensive (or energy-intensive) industries and less pollution-intensive (or energy-intensive) industries within a city, effectively removing the effect common within the city but different across pollution (or energy) intensity levels.

Essentially, this approach shares the same spirit with a difference-in-differences framework. In particular, the data are fit to the following regressions:

$$y_{fict} = \beta_0 + \beta_1 Pollution_i \times TCZ_c + \beta_2 Energy_i \times TCZ_c + \eta_{ct} + \lambda_{it} + \alpha_1 l_{fict} + \alpha_2 k_{fict} + \alpha_3' X_{ic} + \varepsilon_{fict}, \tag{2}$$

where *Pollution* measures the share of pollution emissions and *Energy* measures the share of energy consumption at the industry level, interacting with a dummy variable, TCZ, which takes the value of one if the firm operates in a city designated as a TCZ. ε_{fidt} is the idiosyncratic error term, and all standard errors are clustered at the city-industry level.

The coefficient of interest, β_1, captures the direct effect of TCZ policy on a firm within an industry producing an increasing share of pollution and operating within a TCZ city. The estimate is expected to be positive if the regulation led to improved productivity or negative if the regulation had adverse impacts on industrial performance. The coefficient, β_2, measures the indirect effect of TCZ policy on a firm in an industry consuming a greater share of energy within a TCZ city. Because the power industry was the most heavily targeted by the TCZ policy, it is expected to have positive externalities if energy supply shortage led to improved performance among energy intensive industries or negative externalities if it retarded industrial activities among industries consuming more energy.

The specification illustrated in equation (2) has a number of advantages that allow subsequent analysis to address a number of concerns. First, TCZ status is likely to covary with various other heterogeneities. In particular, because pollution levels are highly correlated with local economic activities, TCZ cities are likely to be driving rapid economic growth during the study period of 1998-2005. The inclusion of city-by-year fixed effects (η_{ct}) non-parametrically controls for time-varying shocks common to all firms in a particular city. In this model, the treatment effect, β_1, can be interpreted as a within-city variation in the outcome variable between polluting and non-polluting industries, while subtracting the inherent differences across the industries without the policy using evidence in non-TCZ cities produces a difference-in-difference estimate of;

$$\beta_1 = E\big[\big(y_{P,TCZ} - y_{NP,TCZ}\big) - \big(y_{P,nonTCZ} - y_{NP,nonTCZ}\big)\big|\bullet\big], \qquad (3)$$

where the subscripts, *P*, represents polluting industries, and, *NP*, represents non-polluting industries, *TCZ* represents a TCZ city, and *nonTCZ* represents a non-TCZ city.

Second, a simple comparison of more and less polluting industries within a city is confounded by heterogeneous industry-specific shocks. The inclusion of industry-by-year fixed effects (λ_{it}) helps remove trends among all firms in industries unrelated to environmental regulation. This controls for unobservable demand and/or supply shocks to a particular industry during this period (i.e., the differential pattern of demand structure for polluting products in a rapidly growing economy or of supply structure based on price/quantity of coal or electricity). In this case, the coefficient can also be interpreted as;

$$\beta_1 = E\big[\big(y_{P,TCZ} - y_{P,nonTCZ}\big) - \big(y_{NP,TCZ} - y_{NP,nonTCZ}\big)\big|\bullet\big], \qquad (4)$$

which attributes differences in industrial performance among polluting industries between TCZ and non-TCZ cities to the effect of the policy, while subtracting intrinsic differences between TCZ and non-TCZ cities using observations in non-polluting industries.

Overall, the panel structure of our dataset allows us to circumvent many endogeneity issues. In particular, estimated regulation effects are robust to unobserved transitory determinants of growth common in both more and less polluting industries and unobserved factors contributing to a firm's growth within a city whose effects are allowed to vary over time.

It is worth mentioning that the above efforts may help purge many potential sources of bias, if not all. There may be several other sources of bias. Namely, one of the key remaining issues would be differences in the permanent characteristics associated with polluting firms in TCZ cities. The inclusion of firm fixed effects is unfortunately not feasible because of multicolinearity with the time-invariant interaction term. Instead, we directly control for initial differences in a vector of variables at the industry-city level, X_{ic}, that have been identified as important determinants of firm growth (i.e., firm size, age, and ownership type, asset, age, leverage, capital intensiveness) (Dunne, Roberts, and Samuelson 1989; Greenstone 2002; Huang, Jin, and Qian 2013). Below, we provide evidence that firms' performances are similar after controlling for all of these characteristics.

V. Empirical Results

This section provides regression results based on the econometric framework discussed above. In the first subsection, we present the main effect of TCZ policy over the entire period for different levels of pollution and energy intensity. We use total revenues as a measure of industrial performance. In the second subsection, we probe the robustness of the main results using alternative measures of industrial performance. We then consider two mechanisms driving the main result. In subsection C, we examine the patterns of firm turnover and selection dynamics as well as the nature of entrants and dropouts. In subsection D, we focus on the balanced panel of firms over the period and highlight patterns of productivity shifts to shed light on induced innovation among incumbent firms.

A. Effect on Industrial Performance

Table 2 reports the estimated coefficients based on equation 2, using a firm-by-year level of observations in the period of 1998-2005. Across all specifications, city-by-year fixed effects and industry-by-year fixed effects are included, and thus the estimated effects are purged of spurious correlations arising from differential city- or industry-specific trends across years. Positive values of the coefficients imply that the TCZ regulation led to an increase in the outcome variable, whereas negative values indicate the opposite.

We first investigate the effect of TCZ policy on total revenues as a key measurement of industrial performance. Column (1) presents the estimated policy effect on pollution-intensive firms. The estimated effect is positive and significant at the 1 percent level, suggesting that total revenues increased among polluting firms in response to the TCZ regulations. The estimate indicates that a 1-percentage point increase in the share of coal consumption led to a 1.4 percent increase in a firm's revenues in a TCZ city. However, in this specification, the estimate may be biased if the regulations had externality effects on non-polluting energy-intensive firms since many polluting firms are also energy intensive. The bias can go in either directions; the estimated effect is understated if the regulation exhibited negative externalities on energy-intensive firms due to energy shortage, or is overstated if the regulation also led to enhanced performance among energy-intensive firms.

Column (2) thus includes an additional control of energy intensity in an effort to disentangle these two effects. The estimated effect on polluting firms is pronounced more in magnitude and remains highly significant, suggesting that a 1-percentage point increase in coal consumption is associated with a 3.6 percent increase in revenue. On the other hand, the coefficient for energy-intensive firms is negative and significant at the 1 percent level, indicating that a 1-percentage point increase in energy share leads to a 4.13 percent decrease in revenues in a TCZ city. The comparison of these two opposing effects indicates contrasted stories; while pollution intensity led to greater revenues, energy intensity had negative impacts on revenues in TCZ cities.

A potential concern with this analysis is that because the interaction term between the pollution (or energy) intensity and the TCZ status is invariant over time, we cannot obtain any inference on the effect of a city-by-industry effect on performance from the within-groups estimator. This may bias the results if, say, key characteristics of industries differ across cities in a way that they are correlated with the TCZ status. The best we can do is controlling for initial differences in important determinants of firm growth at the city-by-industry level. In particular, we compute the average firms' ages, firm sizes, and ownership types in 1998.[13] These control varia-

[13] Firm sizes are in dummy variables for four levels of sizes that are denoted originally in the dataset. The ownership types are in dummy variables for three different types: state-owned firms, domestic private firms,

bles follow the literature on firm productivity and growth (Dunne, Roberts, and Samuelson 1989; Greenstone 2002; Huang, Jin, and Qian 2013). The results are presented in column (3). The magnitude of the coefficient drops by about 23.8 percent, indicating that these variables help capture a large share of the differences in latent firm's productivity advantages but not completely—it continues to suggest that polluting firms received positive effects from the environmental regulation.

The results presented so far shed light on a strong positive association between TCZ policy and total revenues, but how will the revenues eventually be affected? We provide suggestive evidence by adding capital and labor based on the basic production function laid out in equation (1). Note that these two variables are both endogenous to the policy effect; any changes in the coefficients of interests should thus be interpreted as indicating that changes in capital and labor play a key role through which the environmental regulation affected overall revenues. The results are shown in column (4). Both capital and labor variables have reasonable signs and statistically significant effects on revenues at the 1 percent level. The coefficient of the interaction term between pollution intensity and TCZ status almost halves, suggesting that adjustments in these two important inputs have been made in response to the regulation. On the other hand, the coefficient remains highly significant, suggesting that there are other important mechanisms at work that improved the overall performance among polluting industries other than labor and capital adjustments. The result in column (5), which controls for initial differences at the key city-by-industry level adds support that these controls do not confound the effect.

Our identification strategy hinges on the relative similarity of performance between polluting firms in TCZ cities and polluting firms in non-TCZ cities, after controlling for mean differences between TCZ and non-TCZ cities (this interpretation is illustrated in equation 4). A major limitation in this analysis is that we do not have observations prior to the policy implementation. The notion that the better performance by polluting firms in TCZ cities reflects a causal impact of environmental regulation would be supported if the improvement does not reflect preexisting differences or heterogeneous pre-trends in performance. We look for such evidence by illustrating the dynamic effect on performance over this time period. In Figure 1, we plot on the y-axis the coefficients of the interaction term of TCZ status with pollution intensity in Panel A and

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and others, such as foreign-owned firms. We compute their averages (and thus the share of firms under respective type) within the city-by-industry group. To avoid endogenous shifts in these compositions, we focus on these observations in 1998 to account for initial differences in characteristics.

with energy intensity in Panel B over the years on the x-axis, estimated from separate regressions by each year. All regressions control for industry and city fixed effects, initial industry-city characteristics and firm's characteristics to account for mean differences across cities and industries and adjustments through these variables.

If the improved performance estimated above was a mere reflection of a preexisting trend, we would expect to see a difference during the initial years. Or, if the environmental regulation indeed resulted in lower performance among polluting firms in TCZ cities, while their revenues remained higher than their counterparts in non-TCZ cities due to their initial differences, we would expect to see a gradual downward movement over the years, starting from substantially higher performance to somewhat lower. Both cases would produce (spurious) positive estimates in the main analysis.

Figure 1 demonstrates two important facts contrasting with these alternative hypotheses. First, it shows that polluting firms in TCZ cities performed quite similarly with their counterparts in the beginning. If anything, their revenues were lower in the first three years. Similarly, we find no baseline difference in performance among energy-intensive firms in TCZ cities compared to their counterparts up to 2000. These findings add credibility to our estimation strategy that the main analysis does not confound initial differences in performance after controlling for mean city and industry differences.

Second, we find a fairly sharp improvement in performance among pollution-intensive firms and a gradual decline in performance among energy-intensive firms around 2001. The fact that disparities in productive efficiency were lagged and occurred over several years makes it less likely to spuriously confound preexisting trends. Rather, it is plausible to take two to three years before the regulations were fully carried out and before firms made adjustments.[14] This is also relevant in our context because the regulation required power plants to alter energy sources and install costly technologies (such as FGD). Time-lags are also likely in China because it is common for the government to set policy targets or guidelines, often very ambitious ones, with-

[14] Chay and Greenstone (2005) are based on a similar argument when they use 1975 nonattainment status as an instrumental variable in estimating the effect of the 1970 Clean Air Act on housing prices between 1970 and 1980. In their context, the nonattainment status changes every year. By using the mid-decade regulation, they also take into account a two- to three-year lag before the policy was fully executed.

out specifying critical details until later, thereby largely leaving implementation up to the local governments or individual firms.[15]

An increasing trend among pollution-intensive industries and a decreasing trend among energy intensive industries suggests that even taking account of variation in performance over time does not essentially alter the results. In particular, suppose we use the observation in 1998 as "pre-"reform evidence. In this case, the analysis is on a par with difference-in-differences-in-differences (DDD), where we regress the performance measure on the triple-interaction term between pollution (or energy) intensity, TCZ status, and pre-post observations based on;

$$y_{fict} = \beta_0 + \beta_1 Pollution_i \times TCZ_c \times Post_t + \beta_2 Energy_i \times TCZ_c \times Post_t + \eta_{ct} + \lambda_{it} + \mu_{ic} + \alpha_1 l_{fict} + \alpha_2 k_{fict} + \alpha_3' X_{ic} + \varepsilon_{fict}. \quad (5)$$

The additional inclusion of double-interaction term between industry and city (μ_{ic}) flexibly controls for any permanent differences at industry-by-city level. Evidence in Figure 1 not only suggests that we would get similar coefficients of interests in signs and even in magnitudes, but also that the role of industry-city fixed effects can be accounted for by the other two fixed effects and inclusion of industry-city characteristics in X_{ic}.

Overall, we find strong evidence that the environmental regulation had net positive effects on industrial performance within targeted polluting industries, despite their requirement to incur some adjustment costs. On the other hand, the environmental regulation imposed some negative spillover effects among non-targeted, energy-intensive industries, potentially due to an energy shortage.[16] We bolster this finding by looking at various alternative measures of industrial performance in the following subsection and examining mechanisms leading to improved performance in the subsequent two subsections.

B. Robustness Using Alternative Measures of Performance

The results in the subsection above present strong evidence that the environmental regulation improved performance among polluting firms. We conduct robustness checks of this finding by investigating alternative measures of a firm's performance, following the financial literature.

[15] Informal conversations with officials at local power plants provide anecdotal evidence to support this assertion.

[16] Ideally, we can also examine whether there was an energy shortage by looking at fluctuations in energy prices. However, this is not feasible for two reasons. First, we could not find information on energy prices at the county level for the same period. Second, even if the data are available, the energy prices were severely regulated by the government, and thus price changes do not truly reflect the market conditions.

They are; total profits, overall financial benefits realized after accounting for all expenses; return on assets (ROA), which is an indicator of a company's profitability generated from invested capital, measured by the ratio of net income to beginning-of-year assets (Desai, Foley & Hines 2004a; Joh 2003; Huang, Jin, and Qian 2013); returns on equity (ROE), which is an indicator of a company's profitability relative to the money shareholders have invested, measured by net income divided by equity ownership rights (Desai, Foley & Hines 2004b; Nissim and Ziv 2001); returns on capital employed (ROCE), indicating the company's efficient use of its capital for the acquisition of profits (Bertrand and Schoar 2003; Bloom and Van Reenen 2007), measured by earnings before interest and taxes divided by capital employed; and net income, an important measure of the profitability of a company over a period of time, reflecting revenues taking into account business expenses. A greater detail of these variable constructions is described in the Data Appendix in Online Appendix II.

We make further adjustments to our regression model to account for the potential confounding effects on performance. First, following the literature, we control for crucial characteristics impacting these alternative measures. They are a company's age, assets, and leverage, in addition to capital and labor as in the production function. We also control for capital intensiveness to account for the fact that many Chinese firms are constrained by capital (Huang, Jin, and Qian 2013). We additionally include a dummy for state ownership, as state-owned and private firms may differ in important management strategies. Note that some of these control variables are endogenous to the policy effect and thus their coefficients do not present causal inferences. However, the inclusion of these variables helps isolate effect on firm's productivity unexplained by observable channels.

The results are presented in Table 3. All specifications control for industry-by-year fixed effects and city-by-year fixed effects. In addition, Panel B controls for firm characteristics (natural log of capital, natural log of labor, natural log of assets, age, a dummy for state ownership, leverage, and capital intensiveness), Panel C controls for city-by-industry characteristics in 1998, and Panel D controls for all of these controls. In all specifications, we find positive coefficients on polluting industries in the TCZ cities, while we find mixed signs on energy-intensive industries. The results on polluting industries are qualitatively and quantitatively robust to the inclusions of extended controls, confirming the overall productivity effect in the main analysis. Overall, these findings using extensive measures with a variety of controls substantiate the improved performance among polluting firms in response to the environmental regulation.

C. Effect on Firm Turnover and Selection Dynamics

The preceding subsections focus on the overall effect of the environmental regulation on industrial performance. These analyses, on the other hand, mask the dynamic effects of firms' entries and exits. In this subsection, we explore the behaviors of market dynamics. The longitudinal nature of our dataset using the unique firm identification allows us to exactly identify the year when each firm entered or exited the market. An "entry" is defined as: firms with unreported observations in the prior year (denoted as enter1 in Table 4 column 1) or as the first year that a firm is observed in the dataset (denoted as enter2 in Table 4 column 2). The exit is defined as the last year that a firm is observed in the dataset.[17]

We begin by estimating the linear probability model using the binary variables of entry and exit as dependent variables, regressed on pollution and energy intensity interacting with TCZ status along with a number of other controls used in the previous analyses. The results are presented in Table 4. The first column, using the first definition of entry, reports negative and statistically significant coefficients for polluting firms, indicating that there was lower likelihood of entry due to the TCZ policy. The second column, using an alternative definition of entry, confirms this finding. This may sound counterintuitive if one believes that there were more business opportunities in TCZ cities, which spuriously resulted in better performance in the previous analysis. Putting this result into the context of the main findings, these results suggest that in the better performing industries with higher levels of pollution, individual firms found it more difficult to enter the market, which is consistent with theoretical predictions on greater entry barriers and a greater selection of firms that can enter the market.

We now turn to the effect on the probability of exiting the market. In column (3), using the entire sample, we find a positive and significant effect on polluting firms. Because new firms may frequently exit and then reenter the market, we restrict the sample to incumbent firms: those that had already exited in 1998 in column (4). The finding is unchanged. These findings are

[17] This is a rather conventional definition of entry rather than using ages of firms, which are misleading when firms have undergone substantial structural changes such as those in ownership or management system. Because our dataset starts in 1998, we naturally exclude this year as the first year of observations, except for the firms that started operating in 1998. Similar to the definition of entry, exit can also be defined the year that its observation is missing in the following year. The results are robust to this alternative definition.

again not consistent with an alternative hypothesis that polluting industries that are more profitable are likely to stay in TCZ cities, which spuriously creates a positive association between productivity and the interaction term. Instead, it is consistent with evidence that compliance costs associated with the environmental regulations are higher for firms that are more polluting to begin with, and thereby are more likely to exit the market.

Interestingly, the coefficients on energy-intensive firms are negative and significant, which is consistent with the previous finding that such firms would often remained in the market even while suffering from lower performance. These findings suggest that stagnated productivities with respect to financial outcomes may not be a key determinant of exit decisions for energy-intensive firms over the short-term period; rather, the expected long-term costs, along with short-term complying costs generated from environmental regulation, were a main factor affecting firm's exit decisions.

Evidence that the regulation had impacts on firms' entry and exit behaviors warrants a further analysis on how those firms that entered (exited) had behaved after (before) the market entry (exit). In column (5), we repeat the main analysis using only entrants: firms that were not in the market in 1998 and entered afterward. The coefficient represents the comparison of performance between TCZ and non-TCZ cities within the same industries. Because the control group is also comprised of entrants, estimated impacts are purged of any characteristics common to potential entrants so long as they are not correlated with TCZ status. The positive coefficient on polluting industries indicates that TCZ-city entrants performed better than those in non-TCZ cities, which is consistent with the conjecture of greater barriers to entry due to stricter environmental protection. At the same time, we find a negative coefficient on energy intensity, indicating that newly embarking firms did worse in the TCZ cities, refuting an alternative hypothesis that entrants to TCZ cities inevitably or innately perform better.

Column (6) focuses on dropouts: firms that exited the market at some point during the study period. The inclusion of city-by-year fixed effects and industry-by-year fixed effects controls for a number of factors driving firms out of the market. Namely, time-variant shocks at the city levels or time-variant industry-level shocks are controlled for. Further, our analysis of the comparison of dropouts between TCZ and non-TCZ cities controls for common factors among dropouts leading to low performance, such as level of technology or management schemes. The negative coefficient we find in column (6) indicates that firms exiting the market suffered from even lower performance in TCZ cities, possibly due to the heavy compliance costs they already incurred.[18]

In sum, we find that greater market dynamics through entry and exit serve as an important selection mechanism leading to the superior performance of polluting firms in TCZ cities. These findings are consistent with models explaining that increased market dynamics spur within-industry resource allocation and firm turnover among firms with heterogeneous productivities. We highlight the first evidence that environmental regulation can also be an underlying factor triggering such a selection mechanism.

D. Effect on Induced Innovation

Another important theoretical conjecture leading to better performance among firms impacted by environmental regulation is through induced innovation among existing firms. In this subsection, we explore whether the requirements for existing firms to install better technologies may explain greater economic performance. To purge the effect of firms entering and exiting the market, we focus on a balanced panel of firms in this analysis. Hence, the sample includes only firms observed in the dataset throughout the period. Clearly, it is possible that we observe better performance among these firms in TCZ cities due to greater costs imposed by regulation, resulting in the selection of only better-performing firms remaining in the market, without any inference on induced innovation. Thus, we examine the performance over time. Specifically, we run separate regressions in each year and plot the coefficients in Figure 2.

Panel A focuses on pollution-intensive industries. Two important findings are depicted. First, the coefficient on polluting firms is very small and quantitatively close to zero in 1998; the estimated effects are not statistically significant until 2001. This evidence suggests that firms in TCZ cities did not initially perform any better than their counterparts in non-TCZ cities even within the balanced panel, rejecting intrinsic differences in productivity between the two regions in the first place. Second, the coefficients increase in magnitude over time and become statistically significant in 2003 and 2004, illuminating better performance in later years. Because we

[18] Theoretically speaking, if the regulation only changed the threshold for survival without any impact on firms' performances, in other words if the regulation had only the selection effect leaving only highly productive firms in the market, it would be possible to have positive coefficients here. The negative coefficient we find suggests that firms had already incurred some compliance costs with or without changes in selection threshold for survival, after which they decided to exit. Additional evidence based on alternative measures of performance shows several positive and insignificant estimates depending on variables and specifications, so the negative estimate here should not be over-emphasized.

control for various other adjustments in inputs, enhanced productivity can be attributed to residuals, most importantly technologies. The fact that changes in productive efficiency were slow and occurred over several years is supportive of our argument, especially in comparison with spuriously confounding preexisting trends. This finding highlights that induced innovation also played an important role in leading to better performance among polluting firms.

Panel B presents an interesting disparity for energy-intensive industries in the balanced panel compared with all energy intensive industries in Figure 1, Panel B. It shows that energy-intensive industries in TCZ cities performed worse, though the estimates are only marginally significant, at the beginning. However, in contrast with gradual declines in performance in Figure 1, firms in the balanced panel caught up toward the end of the period. This suggests that declining performance among energy-intensive firms can be completely attributed to new entrants (consistent with the finding in Table 4). These findings indicate that incumbent energy-intensive firms were better positioned to accommodate the environmental regulation than new entrants.

VI. Alternative Hypotheses

A. Initial Differences in Performance

Our identification strategy hinges on a similar pre-reform performance among firms with similar pollution- or energy-intensity levels in TCZ and non-TCZ cities, after controlling for mean differences across cities. The estimated effect would be spurious if, for example, highly efficient firms were located in highly developing areas, which may be correlated with the TCZ designation. Although this, in general, appears to be a plausible argument, several findings we have presented so far stand up well against such a concern in our context.

First, the similarity in performance prior to the environmental regulation is supported by graphical evidence in Figure 1 for all firms and in Figure 2 for the balanced panel. This evidence suggests that our inclusions of industry- and city-fixed effects and initial city-industry characteristics remove heterogeneities across industries and cities in the absence of the regulation, making the analytical comparisons of firms within industries and within cities valid.

Further, the superior performance of polluting firms in TCZ cities is not limited to static evidence, but is also illustrated in a dynamic setting. The analytical framework, addressing dynamic effect, is close in spirit to DDD analysis, suggesting that the polluting (or energy-intensive) firms had greater *growth* (or *declines*) over time, even after taking into account of initial heterogeneities.

While these graphical illustrations are informative, we then formally test whether there existed any *ex-ante* disparities in performance. Specifically, we assess the effect of environmental regulation on performance from when the policy was introduced in 1998. Given the plausible notion that adjustments in response to heavy environmental protection take several years, especially in China where the government often sets targets without specifying details on attaining them, the observations in 1998 are likely to offer insights on how the firms behaved in the preceding years.

It is worth noting here before presenting the results that positive estimates have mixed inferences, indicating either initial differences in performance or the immediate impact of the regulation after one year (remember our dataset observes end-of-year financial estimates). On the other hand, the similarity in characteristics (i.e., non-significant estimates or even negative estimates) provides a strong signal against concern that the main analysis is positively biased.

As it turns out, Table 5 column 1 shows an even worse performance among polluting firms in TCZ cities. Figure 2 suggests that we can expect similar estimates even for a balanced panel using the subsample of firms staying in business throughout the period and thus performing well. The finding provides added support to the identification strategy because it rejects an alternative hypothesis that polluting firms had better economic performance in TCZ cities in the first place even in the absence of the regulation. Rather, the evidence suggests that inferences from the main findings do not alter even after controlling for initial differences.

This finding helps overcome two shortcomings inherent in our analysis. One is that we do not observe performance in years prior to the policy reform. The other is that there are technically no industries that are free from regulation impacts, making us unable to formulate a counterfactual. The finding suggests, if anything, that bias arising from these two channels goes against the findings in the main analysis.

B. Price Effect

Our use of extensive profitability measures in assessing business performance offers insights on productivity effects. However, an important component embodied in these measures is idiosyncratic demand shocks within industries. For example, Foster, Haltiwanger, and Syversion (2008) argue that plant-specific prices are positively correlated with a typical measure of productivity in the literature, which they call revenue-based productivity (TFPR), leading to overstating the role of technology-based productivity, which they denote as physical productivity (TFPQ).[19]

There are two reasons to believe that price effects may not be a driving factor in our context. First, energy prices, the major commodity of pollution-intensive industries, were strictly regulated by the government in China, making them insensitive to idiosyncratic plant-level shocks. Second, even if producers have some ability to set their own prices, Foster, Haltiwanger, and Syversion (2008) find that new entrants tend to charge lower prices than incumbents. Along these lines, our findings of the substantial contribution of entrants suggest that our focus on profitability understates physical productivity growth.

We formally test this hypothesis by constructing and comparing TFPR and TFPQ. Just like other studies, we do not observe price variation at the plant level. Instead, we follow Hsieh and Klenow (2009) in measuring TFPR and TFPQ using ASIP.[20] The results are presented in Table 5 column (2) for TFPQ and in column (3) for TFPR. As expected, we find a larger impact on productivity when we use physical productivity than revenue-based productivity. This is consistent with the fact that entrants (possibly other than those in the energy industry) charge lower prices, while both variables highlight enhanced productivity among pollution-intensive industries. Therefore, our quantitative estimations bolster qualitative evidence that prices at the business level should not drive the overall effect in the main analysis.

C. Unobserved Government Policies

Because our analysis is unable to address an unobservable factor correlated with both pollution intensity and the TCZ status, there is a concern that there may have been some compensating governmental policies impacting heavily affected industries to offset the negative impact on economic performance. To the best of our knowledge, we are not aware of such policies. Because the central government designated the TCZ status based on a uniform standard across the nation, it is unlikely that existing local government policies impacted the assigned status. Further, as

[19] Unlike most other studies, they can directly estimate technological efficiency by observing both producers' physical outputs and establishment-level prices.

[20] There is one difference in the construction process of these variables from Hsieh and Klenow (2009). That is, these authors use input elasticities in the United States for Chinese firms, as their objective is to measure misallocation of resources assuming that the U.S. firms are already producing at the efficient input share. In contrast, we directly compute relevant input elasticities for Chinese firms based on the observations in ASIP.

previously stated, it is historically a standard practice of the Chinese government to set goals, even quite ambitious ones, with leaving implementation mechanisms up to individual firms.

We explore whether quantitative evidence is consistent with such qualitative knowledge by investigating whether there is any difference in performance between state-owned and private firms. State-owned firms are likely to have a closer connection with government officials, which may provide them with benefits that private firms do not receive. Had there been any sort of government policy targeting regulated industries, we should find better performance among state-owned firms than private firms. The estimated results are presented in column (5) for state-owned firms and in column (6) for private firms. The point estimate is larger in magnitude for private firms and statistically different from the estimated impact on. Further, state-owned firms in energy-intensive industries suffered from even lower performance. Overall, we find no evidence that unobserved government policies confound the main finding.

D. Alternative Measure of Pollution Intensity

Lastly, we probe the robustness of the main findings to an alternative measure of pollution intensity. In particular, we use the share of SO_2 emissions by industry as of 1996 as a measurement of pollution intensity. Use of information in 1996 avoids changes in the share affected by technological progress or production efficiency driven by the regulation. As previously discussed, the main shortcoming of this measure, compared to the coal-consumption share adopted throughout the paper, is that we observe this information only at the aggregated level for some industries. The measure is still useful, as coal consumption is strongly associated with SO_2 emissions with a correlation coefficient being equal to 0.95. We present the results on sales in Table 6 and on other performance measures in Online Appendix Table A2. We find the patterns of the findings are essentially the same as the main analysis, validating our main analysis of using coal consumption as a measure of pollution intensity.

VII. Conclusions

This paper examines the effect of a stricter environmental protection regime on industrial performance in China. Despite the fact that a large fraction of pollution contributing to global climate change is emitted from developing countries, surprising little quantitative evidence is available to date. We offer some of the first evidence that pollution-intensive firms improved their performance in response to the environmental regulations. Additional evidence suggests that enhanced industrial performance is driven both by greater market dynamics via the entry of efficient firms and the exit of low-productivity firms, and by induced innovation among existing firms. The results are robust to various specifications, measures of productivity, and inclusions of city-by-year fixed effects, industry-by-year fixed effects, and pre-determined characteristics of a firm's growth at the industry-city level.

Our findings offer two major insights on the future prospect of environmental protection in China and other developing countries. First, although the direct effect of environmental protection, measured by compliance costs, may not be trivial, changes in the industry composition and induced innovation can give rise to net positive improvements in productivity and competitiveness within domestic industries. This is particularly true when the economy initially has extensive resource misallocation. Second, when the power sector is subject to stringent environmental regulations, as is often the case with developing countries, energy-intensive firms are likely to receive negative externality effects for a given level of pollution intensity. Within this context, it would be interesting to investigate differential incentives and barriers to adopting clean and energy-efficient technologies, and/or policies promoting the development and deployment of these technologies.

Our findings may be unique to circumstances in developing countries; various studies found that the U.S. Clean Air Act depressed competitiveness of U.S. manufacturing firms. However, our finding on the selection dynamics driven by environmental regulation may still be noteworthy. For academic purposes, the overall cost of environmental protection may be overstated by focusing on an existing firm (or plant) without taking into account a firm's turnover. For the purpose of policy design, environmental standards, such as New Source Performance Standards set by the US Environmental Protection Agency, often target newly entering firms, while existing firms are exempt from the rule. In designing a policy, policymakers need to be aware of the potential roles played by new entrants when setting a standard and need to pay more attention to incentives for technology adoption among new and existing firms.

, since overtaking the United States in 2005 and produced more than 20 percent of the world's emissions in 2008. Our finding - that stringent environmental regulation may spur productivity growth - is new and striking. This study presents substantial policy implications, not only for future environmental protection in China but also for mitigating global worming.

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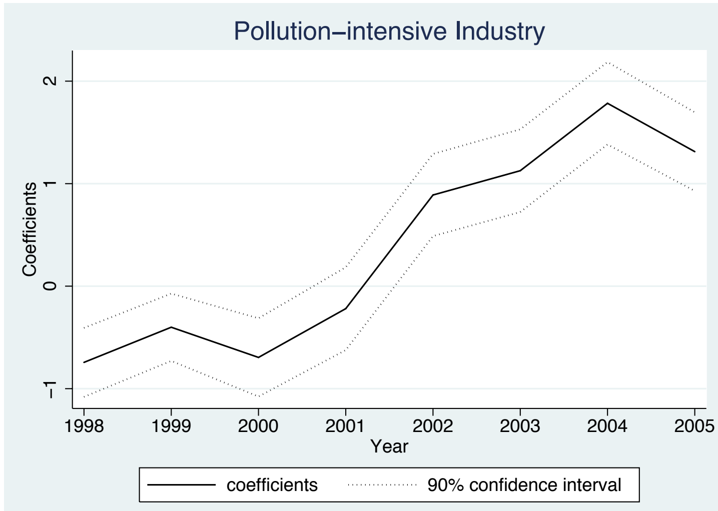
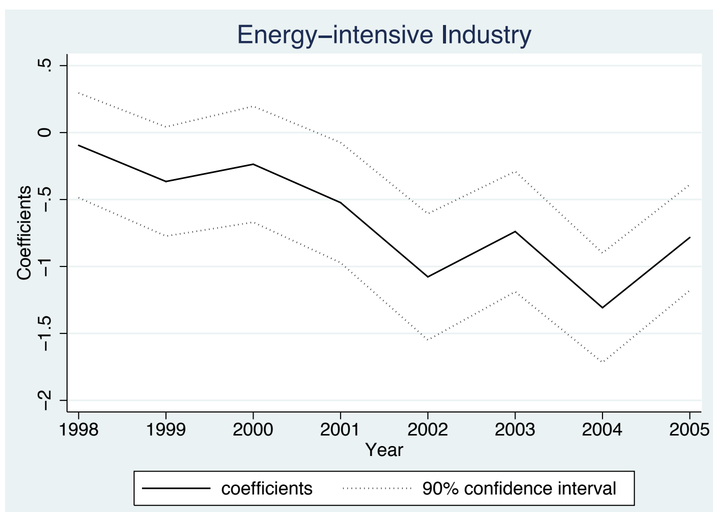
Figure 1: Dynamic Effect of Environmental Regulation

Panel A



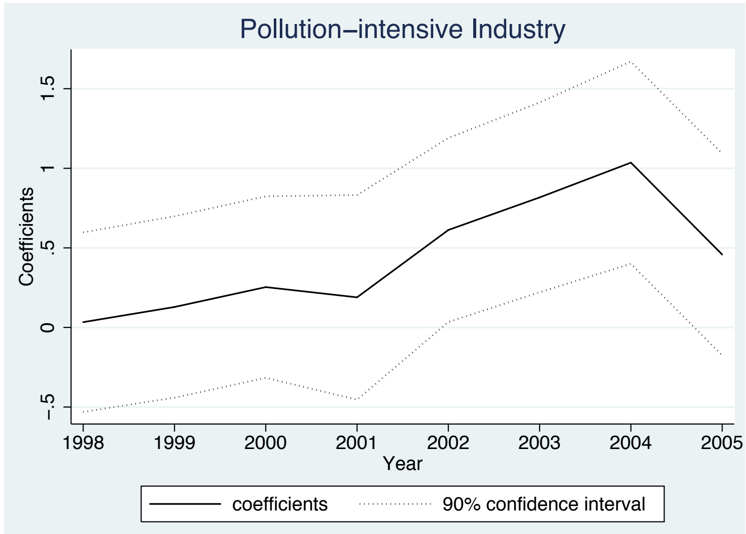
Panel B



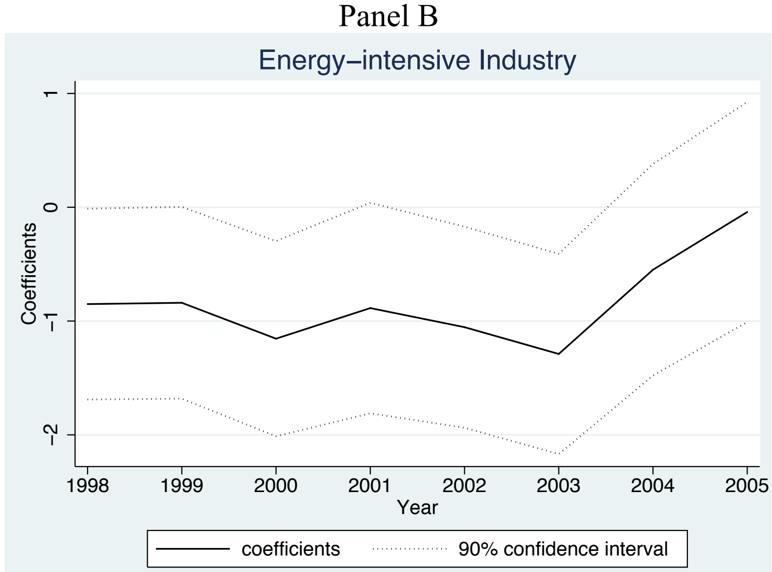
Notes: These figures present the coefficients of the interaction term based on equation 2 of pollution intensity in Panel A and of energy-intensity in Panel B and their 90% confidence interval, from separated regressions by year. The dependent variable is log of total revenues. All regressions control for initial industry-city characteristics as well firm's characteristics (capital, labor, asset, age, dummy of state ownership, leverage, and capital intensity). The sample covers the entire observations. Standard errors are clustered at the industry-city level.

Figure 2: Effect of Environmental Regulation on Induced Innovation

Panel A:



Panel B



Notes: These figures present the coefficients of the interaction term based on equation 2 of pollution intensity in Panel A and of energy-intensity in Panel B and their 90% confidence interval, from separated regressions by year. The dependent variable is log of total revenues. All regressions control for initial industry-city characteristics as well firm's characteristics (capital, labor, asset, age, dummy of state ownership, leverage, and capital intensity). The sample is the balanced panel of firms that stayed in the market throughout the period of 1998-2005. Standard errors are clustered at the industry-city level.

Table 1: Descriptive Statistics of Key Variables

Variables	Obs.	Mean	Std. Dev.
Revenues	1,133,821	56,057.18	457,823.49
Profits	1,133,839	2,429.30	41,888.42
ROA	1,136,103	0.11	0.34
ROE	1,136,103	0.22	0.77
ROCE	1,136,103	0.31	0.79
Net income	1,136,103	2,361.82	42,544.76
Capital	1,133,324	16,212.70	112,342.87
Labor	1,136,101	253.14	761.45
Asset	1,120,791	64,229.70	572,319.89
Age	1,103,556	9.41	10.51
Capital intensiveness	1,120,847	87.22	993.62
State ownership	1,136,103	0.22	0.41
Leverage	1,119,529	0.62	0.54
Firms in TCZ	1,136,103	0.69	0.46
Share of coal consumption	1,136,103	0.02	0.04
Share of SO_2 consumption	1,136,103	0.02	0.05
Share of energy consumption	1,136,103	0.03	0.04

Notes: The level of observation is at firm-by-year over the period of 1998-2005 for 138,617 firms in 1998, growing up to 250,844 firms in 2005. All monetary values are in constant thousand of 2000 RMB. ROA is returns on assets, calculated by the ratio of profits to the beginning-of-year assets, ROE is returns of equity, calculated by profits divided by equity ownership rights, ROCE is returns on capital employed, calculated by the ratio between profits and capital employed. See Online Appendix # for more details on these variable constructions.

Table 2: Effect of TCZ Policy on Industrial Performance

	Dependent var: Ln(Revenue)				
	(1)	(2)	(3)	(4)	(5)
Coal Share × TCZ	1.353***	3.621***	2.761***	1.718***	1.318***
	(0.173)	(0.229)	(0.246)	(0.188)	(0.213)
Energy Share × TCZ		-4.132***	-3.574***	-1.611***	-1.405***
		(0.249)	(0.287)	(0.188)	(0.222)
Ln(Capital)				0.252***	0.252***
				(0.00204)	(0.00250)
Ln(Labor)				0.598***	0.594***
				(0.00319)	(0.00387)
Constant	10.65***	10.66***	12.82***	5.172***	6.288***
	(0.0695)	(0.0693)	(1.947)	(0.0579)	(1.307)
Observations	1,107,642	1,107,642	842,792	1,093,171	831,734
R-squared	0.224	0.225	0.245	0.591	0.596
City-by-Industry controls	No	No	Yes	No	Yes
City-by-Year FE	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE	Yes	Yes	Yes	Yes	Yes

Notes: The table presents estimated coefficients based on equation (2). All specifications include city-year fixed effects and industry-year fixed effects. City-by-Industry controls include age, dummies for firm size, and dummies for ownership type. Robust standard errors clustered at city-industry level are reported in the parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Effect of TCZ Policy on Industrial Performance using Alternative Measures

	Dependent variable				
	Profits	ROA	ROE	ROCE	Net Income
	(1)	(2)	(3)	(4)	(5)
Panel A: With no control					
Coal Share × TCZ	67,234***	0.0319	0.0533	0.0157	54,405***
	(18,630)	(0.0414)	(0.108)	(0.0880)	(16,396)
Energy Share × TCZ	-44,967***	0.0378	0.0984	0.126	-34,562***
	(15,098)	(0.0448)	(0.103)	(0.0948)	(13,253)
Panel B: With firm controls					
Coal Share × TCZ	48,208**	0.0743***	0.110**	0.0796*	36,013**
	(20,277)	(0.0219)	(0.0498)	(0.0463)	(17,759)
Energy Share × TCZ	-24,692	-0.0187	0.0393	0.0819	-15,515
	(16,538)	(0.0297)	(0.0617)	(0.0646)	(14,395)
Panel C: With city-by-industry controls					
Coal Share × TCZ	59,026**	0.0367	0.220***	0.212***	42,616**
	(23,224)	(0.0262)	(0.0536)	(0.0503)	(19,981)
Energy Share × TCZ	-38,150**	-0.0332	-0.0665	-0.0588	-24,618
	(18,751)	(0.0369)	(0.0708)	(0.0748)	(16,190)
Panel D: With all controls					
Coal Share × TCZ	48,401**	0.0534**	0.0941*	0.0438	33,695
	(24,148)	(0.0256)	(0.0549)	(0.0528)	(21,049)
Energy Share × TCZ	-29,363	-0.0163	0.0744	0.125*	-17,261
	(19,414)	(0.0351)	(0.0711)	(0.0752)	(16,969)

Notes: The table presents estimated coefficients based on equation (2). All specifications include city-year fixed effects and industry-year fixed effects. Panel A includes no additional controls, while Panel B includes additional controls of firm's characteristics (natural log of capital, natural log of labor, natural log of assets, age, a dummy for state ownership, leverage, and capital intensiveness), Panel C adds city-by-industry controls in 1998 (age, dummies for firm size, dummies for ownership types). Robust standard errors clustered at city-industry level are reported in the parentheses. The dependent variables are profits in column (1), returns on assets in column (2), returns on equity in column (3), returns on capital employed in column (4), and net income in column (5). See Online Appendix II for the definitions of each variable.

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Effect on Firm Turnover and Selection Dynamics

Dep. Var.	Enter1	Enter2	Exit	Exit	ln(Revenue)	ln(Revenue)
Sample	All	All	All	Incumbents	Entrants	Dropouts
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Share × TCZ	-0.0993***	-0.0812***	0.0940***	0.0713**	1.643***	-0.647***
	(0.0307)	(0.0275)	(0.0246)	(0.0290)	(0.254)	(0.225)
Energy Share × TCZ	-0.0227	-0.0446	-0.170***	-0.152***	-1.161***	-0.100
	(0.0352)	(0.0332)	(0.0315)	(0.0420)	(0.237)	(0.235)
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
City-by-Industry controls	Yes	Yes	Yes	Yes	Yes	Yes
City-by-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The columns (1)-(4) report the results based on the linear probability model using the binary variables of entry and exit as dependent variables. The columns (5) and (6) use log of revenues as the depend variable. All specifications include firm controls (lnK, lnL, lnA, age, state-ownership, leverage, capital intensiveness), city-by-industry controls (age, dummies for firm sizes, dummies for ownership types), city-by-year fixed effects and industry-by-year fixed effects. Entry is defined either as firms whose observations are not reported in the previous year (denoted as enter1 in column 1) or as the first year that a firm is observed in the dataset (denoted as enter2 in column 2), while the exit is defined as the last year that the firm is observed. Robust standard errors are reported in the parentheses.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: Testing Alternative Hypotheses

Dep. Var.	Ln(Revenue)	TFPQ	TFPR	Ln(Revenue)	Ln(Revenue)	Ln(Revenue)
Sample	1998	All	All	State-owned	Private	All
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Share × TCZ	-0.620***	2.779***	0.555***	0.457***	1.261***	0.765***
	(0.212)	(0.267)	(0.201)	(0.171)	(0.205)	(0.119)
Energy Share × TCZ	-0.144	-3.559***	-1.240***	-1.416***	-0.811***	-0.870***
	(0.242)	(0.281)	(0.214)	(0.261)	(0.187)	(0.164)
Observations	97,785	870,873	870873	203,581	859,983	831,734

Notes: This table presents estimated results based on the robustness checks. Columns (1) and (2) com-pare differences in the outcomes using TFPQ and TFPR, whose definitions are described in Online Appendix. Column (3) presents estimates using only sample in 1998. Columns (4) and (5) compares samples in all years between state-owned firms and private firms. All specifications include city-year fixed effects and industry-year fixed effects. In column (6), we use SO2 share instead of Coal share. The robust standard errors clustered as the city-industry level are reported in the parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Robustness Check with Using SO_2 Share for Pollution Intensity

	Dependent var: Ln(Revenue)				
	(1)	(2)	(3)	(4)	(5)
SO_2 Share × TCZ	1.426***	1.983***	1.505***	0.993***	0.765***
	(0.117)	(0.127)	(0.136)	(0.105)	(0.119)
Energy Share × TCZ		-2.584***	-2.387***	-0.911***	-0.870***
		(0.190)	(0.227)	(0.137)	(0.164)
Ln(Capital)				0.252***	0.252***
				(0.00204)	(0.00249)
Ln(Labor)				0.598***	0.594***
				(0.00319)	(0.00387)
Constant	10.64***	10.65***	12.85***	5.162***	6.297***
	(0.0694)	(0.0692)	(1.969)	(0.0579)	(1.312)
Observations	1,107,642	1,107,642	842,792	1,093,171	831,734
R-squared	0.224	0.225	0.245	0.591	0.597
City-by-Industry controls	No	No	Yes	No	Yes
City-by-Year FE	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE	Yes	Yes	Yes	Yes	Yes

Notes: This table repeats the same analysis as in Table 3 except that we use SO_2 share at the industry level as a measure of pollution intensity. The remaining comments are the same.
*** p<0.01, ** p<0.05, * p<0.1

NOT FOR PUBLICATION

Environmental Regulation and Industrial Performance: Evidence from China

Gary Jefferson Shinsuke Tanaka Wesley Yin

Online Appendix

Online Appendix I

Table A1: Pollution and Energy Intensity, by industry

Code	Industry	SO_2	Coal	Energy
13	Agricultural byproduct processing	0.00%	1.27%	1.50%
14	Food industry / manufacturing of food	3.05%	0.88%	0.92%
15	Beverage industry/ manufacture of beverage	3.05%	0.71%	0.76%
16	Tobacco industry / manufacture of tobacco	3.05%	0.14%	0.17%
17	Textile industry	2.02%	1.84%	2.69%
18	Textile garments, footwear and headgear industry/ manufacturing of textile garments, footwear, footwear and headgear	0.00%	0.09%	0.25%
19	Leather, fur, down and its related manufacturing	0.12%	0.17%	0.22%
20	Processing of timbers and manufacture of wood, bamboo, cane, palm, and straw	0.00%	0.26%	0.29%
21	Manufacture of furniture	0.00%	0.05%	0.08%
22	Manufacture of paper and paper products	2.13%	1.55%	1.63%
23	Printing, reproduction of recording media	0.05%	0.06%	0.16%
24	Manufacture of goods for culture and education, and sports wear	0.00%	0.02%	0.05%
25	Processing of petroleum, coking, processing of nucleus fuel	1.06%	5.83%	4.24%
26	Manufacture of chemical raw material and chemical materials	7.94%	7.85%	12.06%
27	Medical and pharmaceutical manufacturing	0.81%	0.66%	0.92%
28	Chemical fiber manufacturing	1.07%	0.60%	0.97%
29	Manufacture of rubber	0.49%	0.41%	0.49%
30	Manufacture of plastic	0.16%	0.23%	0.41%
31	Manufacture of nonmetal minerals	7.30%	9.75%	9.95%
32	Smelting and pressing of ferrous metals	6.25%	9.38%	14.13%
33	Smelting and pressing of nonferrous metals	4.69%	0.98%	2.17%
34	Metal manufacturing	0.16%	0.34%	0.76%
35	General purpose equipment manufacturing	0.00%	0.60%	1.26%
36	Special purpose equipment manufacturing	0.00%	0.47%	0.83%
37	Transport equipment manufacturing	0.00%	0.62%	1.05%
39	Electrical machinery and equipment manufacturing	2.28%	0.25%	0.48%
40	Communication equipment, computer and other electronic equipment	0.00%	0.10%	0.25%
41	Measuring instrument and machinery for culture and educational activity and office work	0.00%	0.05%	0.11%
42	Art work and other manufacturing	0.00%	0.66%	0.94%
43	Recycling and disposal of waste	0.00%	0.00%	0.00%
44	Production and supply of electric power and heating power	55.85%	31.81%	5.38%
45	Production and supply of gas	0.00%	0.55%	0.26%
46	Production and supply of water	0.00%	0.03%	0.37%
	Manufacturing and power sectors total	95.41%	78.23%	65.75%
	National total	13,098,346	137,676.5	131,175.6

Notes: Each entry, except the last row, indicates the share to the national total for SO2 emissions (in ton), coal consumption (10,000 tons), and energy consumption (in 10,000 tons of SCE). The readings are based on the baseline observations in 1995,

except for SO_2 in 1996 since SO_2 emissions are not available in 1995. SO_2 emission is not disaggregated between industry codes 14, 15, and 16, and thus the reported estimates are the total of these three industries. Industries whose SO_2 emissions are not reported are considered to have zero emission to reflect their negligible levels. The original data report the aggregated SO_2 emissions for the production and supply of electric, gas, and water, yet we take the number as the emissions of electric industry. Further, among the electric industry, SO_2 emissions and coal consumptions are set to be zero for hydro, nuclear, and other energy generations, and supply of electricity and heat production and supply.
Source: Data from National Bureau of Statistics of China

Online Appendix II

Data Appendix

This appendix provides the variable definitions and construction used in the main paper.

Revenues – Product sales revenue (the main business income). *Source*: ASIP.

Profits – Total profits, which includes product sales profits, other operating profits, investment income, subsidy income, and others. *Source*: ASIP.

Assets – Total assets, which includes total current(flow) asset, total fixed assets, and intangible and deferred assets. Source: ASIP.

Labor – Complete staff (jobholders average population). *Source*: ASIP.

Capital – Paid-in-capital, the capital contributed to a corporation by investors. This includes state capital, collective capital, corporate capital, personal capital, Hong Kong, Macao, Taiwan capital, and foreign capital. *Source*: ASIP.

Net Income – Operating profits – taxes – interests. *Source*: Author's calculation

ROA (returns of assets) – Net income divided by the beginning of total assets. Because our dataset report the end-of-year values, we computed the beginning of total assets by subtracting total profits from end-of-year total assets. *Source*: Author's calculation

ROE (returns on equity) – Net income divided by average shareholder's equity, which is an arithmetic mean of end-of-year equity last year and end-of-year equity this year. *Source*: Author's calculation

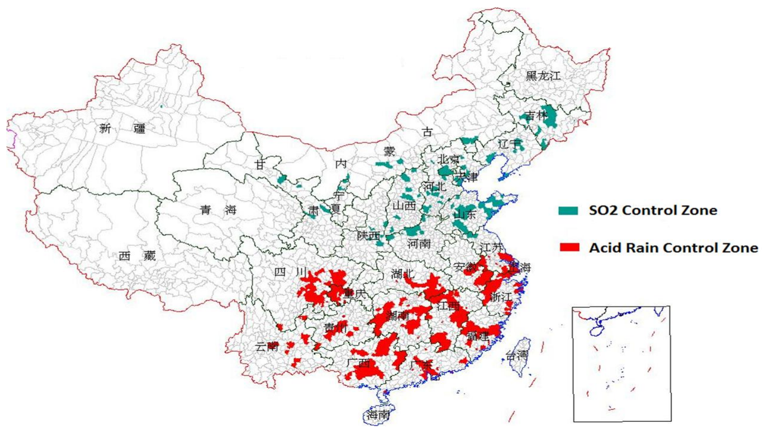
ROCE (returns on capital employed) – Earnings before interest and taxes (EBIT) divided capital employed. EBIT = operating profits + non-operating profits. Capital employed = total assets − current liabilities. *Source*: Author's calculation

Capital Intensiveness – Capital divided by Labor. *Source*: Author's calculation

Leverage – Total assets minus shareholder's equity, and then divided by the total assets. *Source*: Author's calculation

Online Appendix III

Figure A1: Distribution of Two Control Zones



Notes: The green shaded prefectures represent SO_2 Control Zone, and the red shaded prefectures represent Acid Rain Control Zone, designated by the Two Control Zone policy in 1998.
Source: China Atlas of Population and Environment (1990-1999).

Online Appendix IV

Table A2: Effect of TCZ Policy on Industrial Performance using SO_2 Emission as Pollution Intensity

	Dependent variable				
	Profits	ROA	ROE	ROCE	Net Income
	(1)	(2)	(3)	(4)	(5)
Panel A: With no control					
SO_2 Share × TCZ	41,565***	0.0399*	0.0880	0.0529	34,147***
	(10,359)	(0.0232)	(0.0611)	(0.0494)	(9,109)
Energy Share × TCZ	-19,428**	0.0364	0.0818	0.103	-14,239**
	(7,780)	(0.0353)	(0.0707)	(0.0727)	(6,736)
Panel B: With firm controls					
SO_2 Share × TCZ	30,419***	0.0567***	0.0959***	0.0792***	23,373**
	(11,271)	(0.0119)	(0.0276)	(0.0252)	(9,880)
Energy Share × TCZ	-6,757	0.00242	0.0621	0.0921*	-2,550
	(8,470)	(0.0263)	(0.0511)	(0.0560)	(7,267)
Panel C: With city-by-industry controls					
SO_2 Share × TCZ	40,510***	0.0266	0.0680	0.0354	33,117***
	(12,207)	(0.0279)	(0.0724)	(0.0593)	(10,657)
Energy Share × TCZ	-22,599***	0.0382	0.115	0.142	-16,877**
	(8,757)	(0.0426)	(0.0854)	(0.0868)	(7,668)
Panel D: With all controls					
SO_2 Share × TCZ	30,499**	0.0417***	0.0800***	0.0546*	22,063*
	(13,382)	(0.0140)	(0.0305)	(0.0288)	(11,670)
Energy Share × TCZ	-11,337	-0.00183	0.0955	0.123*	-5,272
	(9,477)	(0.0305)	(0.0596)	(0.0648)	(8,311)

Notes: The table presents estimates analogous to Table 6 in the main paper but using alternative measures of productivity. All specifications include city-year fixed effects and industry-year fixed effects. Panel A includes no additional controls, while Panel B includes additional controls of firm's characteristics (natural log of capital, natural log of labor, natural log of assets, age, a dummy for state ownership, leverage, and capital intensiveness), Panel C adds city-by-industry controls in 1998 (age, dummies for firm size, dummies for ownership types). Robust standard errors clustered at city-industry level are reported in the parentheses. The dependent variables are profits in column (1), returns on assets in column (2), returns on equity in column (3), returns on capital employed in column (4), and net income in column (5). See Online Appendix II for the definitions of each variable.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$