The Effects of Environmental Policies in China on GDP, Output, and Profits[1]

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Abstract

Critics of environmental policies often claim that such policies decrease productivity and profits. The effects of environmental policies on productivity, GDP, output, and profits is in part an empirical question, however, and may vary by firm, industry, sector, and type of policy. This paper examines the effects of environmental policies in China on GDP, industrial output, and new energy sector profits using province-level panel data over the period 2002 to 2013. Our econometric method employs instruments to address the potential endogeneity of the policies. We find that policies involving financial incentives or monetary awards have the potential of increasing the output and/or profits in some energy-related industries or sectors, but potentially at the cost of GDP in non-energy industries or sectors. In contrast, command and control policies and non-monetary awards appear to decrease GDP, output, and/or profits.

Keywords: environmental policies; GDP; output; profits; Porter hypothesis; China

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1. Introduction

China has achieved remarkable rates of economic growth over the past quarter century (Bosworth and Collins, 2008). Owing in part to this unprecedented economic growth that began in the 1980s, as well as to a heavy reliance on fossil fuels -- especially coal -- and inadequate environmental regulations, environmental quality has declined throughout China (Greenstone et al., 2020). To improve China's domestic environmental condition and in reaction to pressure to reduce emissions, the Chinese government has enacted a wide range of policies to protect the environment and promote sustainable development (Political Bureau of the Central Committee, 2013). These include environmental policies to increase the use of renewable energy, and policies to reduce pollution.

The effects of environmental policies on GDP, output, and profit is the subject of much debate. The conventional wisdom is that environmental regulations have a negative effect on the productivity of firms. Critics of environmental regulation often cite the temporal coincidence of the U.S economy slowdown in the 1970s with the increasing environmental regulations in the same era as a proof of the negative impact of U.S. Environmental Protection Agency (EPA) regulations (Barabera and McConnell, 1990).

There are several ways in which environmental policies could negatively affect productivity. First, because inputs will be diverted to produce an additional output -- environmental quality -- that is not included in the conventional measures of output and productivity, measured productivity will fall. Second, process and management changes induced by environmental policies may be less efficient than the original practices. Third, environmental investments could crowd out other types of firm investment (Jaffe et al., 1995).

There has been some literature challenging the conventional wisdom, asserting instead that environmental policies may stimulate growth and competitiveness. This line of argument is often called the Porter hypothesis, as it was articulated by Porter (1991). There are several levels on which the Porter hypothesis can be interpreted. First, it can be taken to mean that some sectors of private industry, namely the environmental services sector, would benefit directly from environmental regulations on their customers, because these customers would then buy their products (Jaffe et al., 1995).

Second, environmental policies can induce innovations in technology to achieve compliance (Jaffe et al., 1995). Such induced innovation effects are expected to be greater in developing countries relying on low technologies that promote both high emissions and low production performance (Tanaka, Yin and Jefferson, 2014).

Third, the Porter hypothesis can be taken to mean that some regulated firms might benefit competitively under stricter environmental policies at the expense of other regulated firms. If there are asymmetric costs to compliance that decrease competition and therefore raise prices for those firms with lower compliance costs, then these firms might benefit if the raised prices more than offset their compliance costs (Jaffe et al., 1995).

Fourth, it has also been suggested by proponents of the Porter hypothesis that the imposition of environmental policies induces firms to reconsider their production processes, and hence to discover innovative approaches not only to reduce pollution, but also to decrease costs or increase output (Porter and van der Linde, 1995; Jaffe et al., 1995; Dechezleprêtre and Sato, 2017).

Fifth, environmental regulations cause more productive firms to displace less productive ones, leading to increased productivity at the industry level (Tanaka, Yin and Jefferson, 2014). This selection mechanism may be particularly relevant for developing countries (Tanaka, Yin and Jefferson, 2014), which are plagued with productivity dispersion and resource misallocation (Banerjee and Duflo, 2005; Alfaro, Charlton and Kanczuk, 2009; Hsieh and Klenow, 2009; Banerjee and Moll, 2010; Restuccia and Rogerson, 2013).

It is possible that a negative effect of environmental regulations on productivity is an indication that firms have already become cleaner and more productive. In their analysis of countries in the European Union, for example, Marinaș et al. (2018) find that environmental policies have a negative effect on the GDP growth rate when the economy is moving towards a higher share of renewable energy. Other studies similarly suggest that a negative impact of environmental policies on economic growth might be an indication the economy is moving along the desired path towards an energy portfolio with higher clean energy shares (Dogan, 2015; Bhattacharya et al. 2016; Afonso, Marques and Fuinhas, 2017; Armeanu, Vintila and Gherghina, 2017).

Thus, the effects of environmental policies on productivity, GDP, output, and profits is in part an empirical question and may vary by firm, industry, sector, and type of policy. In this paper we empirically examine the effects of environmental policies in China on GDP, industrial output in traditional energy industries, and new energy sector profits.

Previous analyses of China's environmental policies have examined their evolutionary progress (Xie, Hu and Zhang, 2005); their efficiency (Cirone and Urpelainen, 2013); their optimal design (Lin and Zeng, 2014); how their costs are affected by market reforms (Fisher-Vanden and Ho, 2007); and their effects on economic activity (see, e.g., Pereira and Pereira, 2010; Bojnec and Papler, 2011), gasoline consumption (Lin and Zeng, 2013), mortality (Tanaka, 2015), exports of renewable technology (Groba and Cao, 2015), welfare (Li, 2018), energy consumption (Si et al., 2018), air quality (Li et al., 2019), household behavior (Barwick et al., 2020), the automobile market (Chen and Lin Lawell, 2020), the economy (Lin and Jiang, 2011; Liu and Li, 2011; Jiang and Lin, 2014; Ouyang and Lin, 2014), factor substitution (Zhang et al., 2020), and agricultural and ethanol markets (Si et al., 2020). A related literature has examined relationships between energy and GDP in different countries (Nordhaus, 1974; Stiglitz, 1974; Jorgenson, 1998; Corderi and Lin, 2011; Zhang and Lin Lawell, 2017; Jorgenson, 2018; Kerestes, Corderi Novoa and Lin Lawell, 2020; Aghaei and Lin Lawell, forthcoming).

There have been several empirical analyses of the impact of environmental regulation on firm productivity, but most have been in the U.S. context (Gray, 1987; Gollop and Roberts, 1983; Gray and Shadbegian, 1993; Berman and Bui, 2001; Gray and Shadbegian, 2002; Rassier and Earnhart, 2010; Ryan, 2012; Greenstone, List and Syverson, 2012; Fowlie, Reguant and Ryan, 2016). There have also been studies testing the Porter hypothesis using data from OECD countries (Lanoie et al., 2011; Albrizio, Kozluk and Zipperer, 2017). Zakerinia and Lin Lawell (2020) examine the effects of country-level climate change policy on GDP. Tanaka, Yin and Jefferson (2014) analyze the effect of China's Two Control Zone (TCZ) environmental regulatory policy on industrial activities for different levels of pollution and energy intensities, and find that the environmental regulations had positive effects on productivity and competitiveness. Shiu, Li and Woo (2016) examine the effects of large investments in energy and transportation infrastructure on economic growth in China. Stavropoulos, Wall and Xu (2018) find evidence for a U-shaped relationship between environmental regulations and industrial competitiveness in China.

This paper builds upon the existing literature by examining the effects of environmental policies in China on GDP, industrial output in traditional energy industries, and new energy sector profits using province-level panel data over the period 2002 to 2013. Our econometric method employs instruments to address the potential endogeneity of the policies. We find that policies involving financial incentives or monetary awards have the potential of increasing the output and/or profits in some energy-related industries or sectors, but potentially at the cost of GDP in non-energy industries or sectors. In contrast, command and control policies and non-monetary awards appear to decrease GDP, output, and/or profits.

The balance of the paper proceeds as follows. Section 2 describes our data on GDP, industrial output, and new energy sector profits in China. Section 3 describes the data we have collected and constructed on environmental policies. Section 4 presents our empirical model. Section 5 presents our results. We discuss our results in Section 6 and conclude in Section 7.

2. GDP, Industrial Output, and New Energy Sector Profits in China

To analyze the effects of environmental policies in China on GDP, industrial output in traditional energy industries, and the profits of firms in the new energy sector, we use panel data on GDP, industrial output values of several traditional energy industries, and profits of firms in the new energy sector for 30 provinces from 2002 to 2013. Tibet, Taiwan, Hong Kong, and Macao are excluded from the analysis. We begin our period of study in 2002 owing to missing data prior to 2002. We end our period of study in 2013, the last year before a substantial structural change that took place in China in 2014. In 2014, the Chinese government declared war on pollution and undertook unprecedented regulatory changes on multiple fronts to combat environmental challenges, shifting away from its long-standing strategy of prioritizing economic growth over environmental concerns (Greenstone et al., 2020). We therefore focus our analysis on the period prior to this substantial structural change.

The data we use on GDP and industrial output values of different industries come from the Chinese Statistical Yearbooks and the China Industry Economy Statistical Yearbooks. Our panel data set includes province-level data on total GDP and on the GDP for the primary, secondary, and tertiary sectors. The primary sector consists of the agriculture, forestry, animal husbandry, and fishery industries. The secondary sector consists of the mining and quarrying, manufacturing, electricity, water and gas, and construction industries. The tertiary sector consists of the all other economic activities not included in the primary or secondary sectors, including transport and other services. Our panel data set also includes province-level data on the industrial output value of the following traditional energy industries: the coal mining, smelting, and dressing industry; the petroleum and nuclear fuel processing industry;[2] and the oil and gas exploration industry.

We also collect data on the profits of firms in the new energy sector over the period 2002 to 2013 from Hexun.com ("Hexun.com", 2019). Hexun.com is a specialized business and finance information and news provider focusing on the mainland China financial market. Each of the new energy sector firms that we consider is publicly traded on the Chinese stock market; publicly publishes their annual financial reports, including their annual income statement; and is listed

[2] Our data for the industrial output value of the petroleum and nuclear fuel processing industry includes the industrial output value the petroleum processing and coking industry (without nuclear fuel processing) for 2002-2007 and the industrial output value for the petroleum processing and coking industry and nuclear fuel processing industry for 2008-2015.

under the new energy sector by Hexun.com. There are a total of 280 firms in the new energy sector, which comprises the combustible ice industry[3] (17 companies), low carbon industry[4] (85 companies), nuclear power industry (65 companies), shale gas industry (37 companies), and solar energy industry (116 companies). Some firms are involved in multiple industries in the new energy sector.

For each of the 280 firms in the new energy sector, we collect data on their total profit and net profit for each of for each year over 2002 to 2013 from their publicly published annual income statement. Since each one of these new energy companies are publicly traded, we assume that their annual financial reports meet the accounting standards in mainland China, and that the definition of total profit and net profit they use in their annual income statement follows the accounting standards in mainland China. Table A1 in Appendix A illustrates how total profit and net profit are calculated under the accounting standards in mainland China. We focus our analysis on total profit, which is calculated by adding up operating profit and non-business income, and then subtracting out non-business expenditure. Net profit is total profit minus income tax expense.

To create the province-level total profit observations, we sum up the total profit values across all the firms in each specific new energy industry for each specific province and for each specific year. The province-level total profit for the entire new energy sector is calculated by summing up the total profit values across all the firms in the new energy sector for each specific province and for each specific year.

Table 1 presents the summary statistics for the GDP, industrial output value, and new energy sector profit variables in our annual province-level data set, which covers 30 provinces over the period 2002 to 2013. Table A2 in Appendix A presents the within and between variation

[3] A firm is listed in the combustible ice industry if it is involved in the business related to combustible ice, including technology development, exploration, and processing. Combustible ice, also known as methane hydrate, is a frozen mixture of water and concentrated natural gas which can be lit on fire in its frozen state and is believed to comprise one of the world's most abundant fossil fuels (Brown, 2017).

[4] A firm is listed in the low carbon industry if it satisfies the definition of low carbon economy used by the China Council for International Cooperation on Environment and Development (CCICED): a new economic, technological and social system of production and consumption to conserve energy and reduce greenhouse gas emissions compared with the traditional economic system (CCICED, 2019). The low carbon industry includes firms involved in hydroelectric power, wind energy, and energy conservation.

for the GDP, industrial output value, and new energy sector profit variables.[5] Table A3 in Appendix A presents the number of firms in the new energy sector in each province for the entire new energy sector and for each of the 5 new energy industries in the new energy sector (combustible ice industry, low carbon industry, nuclear power industry, shale gas industry, and solar power industry).

We use the Chinese Statistical Yearbooks and the China Industry Economy Statistical Yearbooks to obtain data on energy prices. We use producer price indices for manufactured goods for the coal industry, the power industry, and the petroleum industry over the years 2002 to 2013. We also use the #90 gasoline retail price over the years 2002 to 2013. Table A4 in Appendix A presents the summary statistics for the energy price variables in the data set.

3. Environmental Policies in China

For our environmental policy variables, we collect and construct a novel and comprehensive data set on environmental policies at the provincial level in China by collecting data from online databases of laws and regulations from the websites of each of the provincial governments as well as from Lawtime, a website which collects laws and regulations in China ("Lawtime", 2017).

Our policy variables are constructed from the 2,656 environmental laws and regulations that are in place for at least one year over the period 2002 to 2013. These province-level laws and regulations include national laws and regulations implemented in each province, some of which may be differentiated by province. Some of the laws were implemented during the 2002-2013 time period of our data set; others were already in place. Some laws continued even after the end of our 2002-2013 time period; others expired before the end of the time period. Each of the 2,656 province-level laws and regulations has multiple clauses, and may include multiple provisions.

[5] "Within" variation is the variation in the GDP, output, or profit variable across years for a given province. "Between" variation is the variation in the GDP, output, or profit variable across provinces for a given year.

For each of the 2,656 province-level laws and regulations over the years 2002 to 2013, we categorize their provisions and features into the specific types of command and control policies; financial incentives; and awards policies, as described below. Because each province-level law and regulation has multiple clauses, provisions, and features, each law and regulation may include more than one of the following types of policies.

Our first category of environmental policies are command and control policies. We categorize the 2,656 province-level laws and regulations into whether their features or provisions include policies for the following separate types of command and control policies: (a) an ambient air quality standard for a maximum amount of pollution in air; (b) an ambient water quality standard for a maximum amount of pollution in water; (c) an emissions standard for water pollution for maximum amount of water pollution emissions; (d) a fuel mandate which mandates that a certain share of fuel be renewable, or that the carbon intensity of fuels not exceed a certain amount; and (e) a renewable electricity mandate which mandates that a certain share of electricity be renewable, or that the emissions rate from electricity not exceed a certain amount.

A second category of environmental policies are financial incentives. We consider several types of financial incentives: (a) favorable tax treatments for reducing pollution; (b) environmental taxes for water pollution emissions; (c) funding or subsidies for research and development to reduce pollution; (d) funding or subsidies for reducing pollution; (e) funding or subsidies for energy conservation; (f) loans to households for increasing energy efficiency; (g) loans to households for increasing renewable energy consumption; and (h) loans to firms for increasing renewable energy consumption.

A third category of environmental policies are awards that are given after something has been accomplished. We consider several types of awards: (a) monetary awards for having reduced pollution; (b) monetary awards for having increased energy efficiency; (c) monetary awards for having developed technology to reduce pollution; (d) monetary awards for having developed technology to reduce fossil fuel consumption; and (e) non-monetary awards for having reduced pollution.

For each type of policy, we construct a dummy variable for whether there is a policy of that particular type in province i at time t. It is difficult to quantify the policies along other dimensions, as dimensions such as the stringency of the policy or the extent of the policy are either not observable or difficult to quantify objectively in a single measure, particularly one that aggregates across the 2,656 province-level laws and regulations. Moreover, as the focus of this paper is on the marginal effects of different types of environmental policies when considering and controlling for a full and comprehensive set of all environmental policies in place, we have opted to use simple measures of each type of policy in favor of being able to include a comprehensive set of many policies. In future work we hope to develop measures to quantify the magnitude and/or stringency of the policies, particularly for policies whose effects on GDP, output, and/or profits we wish to further examine.

We streamline the set of policies we consider by eliminating those policies that have very little variation in our data set, since for these policies we do not have enough variation to identify their effects. First, we drop all policies that were in place in over 90% of the province-years of our data set, since these essentially province-invariant policies are implemented nearly nation-wide and are therefore absorbed in the year effects. This eliminates the policy variable for funding or subsidies for research and development to reduce pollution, which was in place for 97% of the province-years of our data set.

Second, we drop any policy variable that is constant (i.e., always 0 for all years or always 1 for all years) for 28 or more out of the 30 provinces, since these time-invariant policy variables are absorbed by the province fixed effects. This eliminates a number of policy variables, including the policy variable for funding or subsidies for research and development to reduce pollution also excluded because of the first criterion above.

The policy variables that are eliminated because they are always constant for 28 or more out of the 30 provinces include the policy variables for ambient air quality standards; ambient water quality standards; emissions standards for water pollution; fuel mandates; favorable tax treatment for reducing pollution; taxes on water pollution emissions; funding or subsidies for research and development to reduce pollution; funding or subsidies for reducing pollution; funding or subsidies for energy conservation; loans to households for increasing energy efficiency; loans to households for increasing renewable energy consumption; monetary awards for having increased energy efficiency; monetary awards for having developed technology to reduce pollution; and monetary awards for having developed technology to reduce fossil fuel consumption.

Tables A5-A9 in Appendix A list, for each of the policy variables we dropped, which provinces always had this type of policy and which provinces never had this type of policy over the 2002-2013 period of our data set.

The policy variables that remain are the following. The command and control policy variable that remains is the policy variable for renewable electricity mandates. The loans policy variable that remains is the policy variable for loans to firms for increasing renewable energy consumption. The monetary awards policy variable that remains is the policy variable for monetary awards for having reduced pollution. The non-monetary awards policy variable that remains is the policy variable for non-monetary awards for having reduced pollution.

Table 2 presents the summary statistics for our policy variables. Table 3 lists the years in which each type of policy was in place for each province.

4. Econometric Model

To analyze the effects of environmental policies in China on GDP, industrial output for traditional energy industries, and profits of firms in the new energy sector, we estimate the following regression for each GDP, output, or profit of type j:

$$\ln y_{ijt} = policies_{it}'\beta_{1j} + \left(\sum_{\tilde{i}\neq i} y_{\tilde{i},t-1}\right)'\beta_{2j} + \ln energyprices_{it}'\beta_{3j} + \alpha_{ij} + \tau_{tj} + \varepsilon_{ijt},$$

where the dependent variable y_{ijt} is GDP, output, or profit of type j for province i in year t; $policies_{it}$ is a vector of environmental policies; $\sum_{\tilde{i}\neq i} y_{\tilde{i},t-1}$ is a vector of time lagged spatial lagged GDP, output, and profit in province i, each component $\tilde{j}$ of which is the sum of the GDP, output, or profit of type $\tilde{j}$ of all the other provinces except province i at time *t-1*; $energyprices_{it}$ is a vector of energy prices; α_{ij} is the province effect (which is either a fixed effect or a random effect, and which varies for each type j of GDP, output, or profit y_{ijt} we use as a dependent variable); τ_{tj} is the year effect (which varies for each type j of GDP, output, or profit y_{ijt} we use as a dependent variable); and ε_{ijt} is an error term.

The types j of GDP, output, or profit y_{ijt} we analyze as dependent variables include total GDP; the GDP for the primary, secondary, and tertiary sectors; industrial output of the coal mining, smelting, and dressing industry; industrial output of the petroleum and nuclear fuel petroleum and nuclear fuel processing industry; industrial output of the oil and gas exploration industry; profits of firms in the new energy sector; profits of firms in the combustible ice industry in the new energy sector; profits of firms in the low carbon industry in the new energy sector; profits of firms in the nuclear power industry in the new energy sector; profits of firms in the shale gas industry in the new energy sector; and profits of firms in the solar energy industry in the new energy sector.

As explained above, after streamlining the set of policies we consider by eliminating those policies that have very little variation in our data set, since for these policies we do not have enough variation to identify their effects, the vector $policies_{it}$ of environmental policy variables that remain include renewable electricity mandates, loans to firms for increasing renewable energy consumption, monetary awards for having reduced pollution, and non-monetary awards for having reduced pollution. For each type of policy, the policy variable for that policy type for province *i* in time *t* is a dummy variable for whether there is a policy of that particular type in province *i* at time *t*.

We control for the time lagged spatial lag of all the GDP, output, and profit variables -- which, for each GDP, output, or profit of type $\tilde{j}$, we define as the sum of the GDP, output, or profit of type $\tilde{j}$ of all the other provinces except province *i* at time *t-1* -- since the GDP, output, or profit in one province may be affected by the lagged GDP, output, and profit in other provinces due to spillovers.

The vector $energyprice_{it}$ of energy prices includes gasoline price, coal price, power price, petroleum price. Broadstock et al. (2016) find that around 90 percent of Chinese firms are affected by both oil price and gasoline price.

In analyzing the effects of environmental policies on GDP, output, and new energy sector profits, one may worry that the policies are endogenous (Rehme, 2011). To address any potential endogeneity of the policies, we estimate an instrumental variables (IV) model. For each policy variable, we instrument for that policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. This instrument is therefore the number of other provinces except province *i* that had that policy type at time *t-1*.

We assume that, conditional on our covariates -- which include time lagged spatial lagged GDP, output, and profit -- the time lagged spatial lag of policies in other provinces has no effect on a province's GDP, output, or new energy sector profit except through its effect on the province's current policies. This assumption makes sense since policies of other provinces implemented in the previous year should not influence the GDP, output, or new energy sector profit in that province, except through their effect on the province's current policies.[6] Thus, the instruments are correlated with policies in province i at time t and do not affect the GDP, output, or new energy sector profit in province i at time t except through their effect on the policies in province i at time t.

We report the first-stage F-statistics for each of the endogenous policy variables in Table 4. The Angrist-Pischke first-stage F-statistics and Sanderson-Windmeijer first-stage F-statistics are tests of weak identification of individual endogenous regressors. They are constructed by "partialling-out" linear projections of the remaining endogenous regressors. The Sanderson-Windmeijer first-stage F-statistic (Sanderson and Windmeijer, 2016) is a modification and improvement of the Angrist-Pischke first-stage F-statistic (Angrist and Pischke, 2009). As seen in Table 4, the Angrist-Pischke first-stage F-statistics are all greater than 10 for each of the endogenous variables, and the Sanderson-Windmeijer first-stage F-statistics are all greater than 9 for each of the endogenous variables. Moreover, as seen in the results from the first-stage regressions for each of the endogenous policy variables in Tables B1-B4 in Appendix B, for each endogenous policy variable, there is at least one instrument that has a significant effect on that endogenous policy variable: the time lagged spatial lag of that respective policy variable. Thus, the instruments are correlated with the endogenous variables, even when controlling for all the other instruments and for the control variables.

[6] There may be a concern that policies in other provinces might affect GDP in a province if policies in other provinces cause firms shift their production to provinces with less stringent environmental policy, away from provinces with more stringent environmental policy, a phenomenon called the pollution haven effect (Levinson and Taylor, 2008; Dechezleprêtre and Sato, 2017). If this is the case, then the time lagged spatial lag policies might not be a good instrument. Even if there is a pollution haven effect, however, it is likely that the pollution haven effect operates through GDP. That is, the reason firms may move their production as a result of a policy is that that policy may have an adverse effect on GDP. Thus, if we control for the time lagged spatial lag of GDP (which we do), then, conditional on the time lagged spatial lag of GDP, the time lagged spatial lag of a policy plausibly does not affect GDP except through its effect on the policy, and therefore serves as a good instrument for the policy.

For each type j of GDP, output, or profit y_{ijt} we analyze as dependent variables, the province effect α_{ij} is either a province fixed effect or province random effect depending on whether random effects or fixed effects are more appropriate for the IV regression of that dependent variable type j, as determined by a Hausman test.

5. Results

The results of our IV regressions are presented in Tables 5-7. In particular, Table 5 presents the results of the IV regressions of province-level GDP and province-level GDP in the primary, secondary, and tertiary sectors. Table 6 presents the results of the IV regressions of the industrial output value in the following traditional energy industries: the coal mining, smelting, and dressing industry; the petroleum and nuclear fuel processing industry; and the oil and gas exploration industry. Tables 7a and 7b present the IV results for total profits for firms in the new energy sector and total profits for firms in each industry in the new energy sector (combustible ice industry, low carbon industry, nuclear power industry, shale gas industry, and solar power industry).

For each type j of GDP, output, or profit y_{ijt} we analyze as dependent variables, we conduct a Hausman test to determine whether random effects or fixed effects are more appropriate for the province effect α_{ij} for the IV regression of that dependent variable type j. The results of the Hausman tests for each IV regression are reported in Tables 5-7. We find that, for each of our IV regressions of GDP and output,[7] as well as for our IV regression of total profits in the new energy sector, we reject the null hypothesis that the random effects and regressors are uncorrelated; as a consequence, for these IV regressions, fixed effects is the more appropriate specification since

[7] We are unable to conduct a Hausman test for our IV regression of the industrial output of the coal mining, smelting, and dressing industry, as the model fitted on the data fails to meet the asymptotic assumptions of the Hausman test. Since a fixed effects estimator is consistent even if there are time-invariant province unobservables that are correlated with the regressors (Hausman, 1978), we use a fixed effects specification for our IV regression of the industrial output of the coal mining, smelting, and dressing industry.

the random effects estimator is biased and inconsistent (Hausman, 1978). In contrast, for all our new energy profit variables except the total profits in the new energy sector, we do not reject the null hypothesis that the random effects and regressors are uncorrelated; thus, for these IV regressions, both the fixed effects estimator and the random effects estimator are consistent, but a random effects specification is preferred since the random effects estimator is asymptotically efficient while the fixed effects estimator is not efficient (Hausman, 1978). We therefore report the results of IV fixed effects regressions for GDP, output, and total profits in the new energy sector in Tables 5, 6, and 7a; and the results of IV random effects regressions for all our new energy profit variables except the total profits in the new energy sector in Tables 7a and 7b.

According to our GDP results (Table 5), renewable electricity mandates, which are a command and control policy, significantly decrease GDP by 0.22%; while monetary awards for having reduced pollution significantly decrease GDP by 0.23%. Providing loans to firms for increasing renewable energy consumption significantly reduces the GDP of the primary sector by 0.12%, while providing non-monetary awards for having reduced pollution significantly decreases the GDP of the primary sector by 0.27%. Renewable electricity mandates decrease the GDP of the secondary sector by 0.71%.

In terms of output (Table 6), we find that renewable electricity mandates significantly decrease the industrial output value of the petroleum and nuclear fuel processing industry by 0.81%, while providing loans to firms for increasing renewable energy consumption significantly increases the industrial output value of the petroleum and nuclear fuel processing industry by 0.27%.

As for new energy sector profits (Tables 7a and 7b), results show that providing monetary awards for having reduced pollution significantly increases the total profits of firms in the new energy sector by 3.36% and the total profits of firms in the combustible ice industry in the new energy sector by 5.24%. In contrast, providing non-monetary awards for having reduced pollution significantly decreases the total profits of firms in the new energy sector by 3.25%; the total profits of firms in the combustible ice industry in the new energy sector by 2.43%, the total profits of firms in the low carbon economy industry in the new energy sector by 4.69%; and the total profits of firms in the shale gas industry in the new energy sector by 1.07%.

We run several alternative specifications for robustness in Appendix C. First, since a fixed effects estimator is consistent whether or not time-invariant province unobservables are correlated with the regressors (Hausman, 1978), for the first robustness check we also estimate the regressions for which random effects are preferred (but fixed effects are still consistent) using fixed effects instead. In particular, since the random effects estimator is preferred and therefore used for the IV regressions of all our new energy profit variables except the total profits in the new energy sector in Tables 7a and 7b, we report the results of IV regressions that use fixed effects instead of random effects for all the new energy sector profits variables in Tables C1a and C1b in Appendix C.[8] As expected, for those new energy sector profit variables for which random effects are preferred (but fixed effects are still consistent), a few of the coefficients that are statistically significant when we use the random effects estimator are no longer statistically significant when we use the fixed effects estimator, since the fixed effects estimator is not efficient when random effects and regressors are uncorrelated (Hausman, 1978). Nevertheless, our results that monetary awards for having reduced pollution increase profits in the new energy sector while non-monetary awards for having reduced pollution decrease profits in the new energy sector are robust to whether we use random effects or fixed effects.

For the second robustness check, we run the IV regressions for new energy sector profit using net profit instead of total profit; the results are presented in Tables C2a and C2b in Appendix C. As explained in Table A1 in Appendix A, net profit is total profit minus income tax expense. Our results that monetary awards for having reduced pollution increase profits in the new energy sector while non-monetary awards for having reduced pollution decrease profits in the new energy sector are robust to whether we use total profits or net profits.

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[8] Since the random effects estimator is biased and inconsistent for total profits in the new energy sector, we report the same IV fixed effects regression results for the total profits in the new energy sector in both Table 7a and Table C1a.

In our base-case specification, in addition to instrumenting for each endogenous policy variable using the time lagged spatial lag of that policy variable, we also instrument for each energy price using the time lag of that energy price. For the third robustness check, we instrument for the endogenous policy variables but no longer instrument for energy price; the results are presented in Tables C3, C4, C5a, and C5b in Appendix C. Our results are robust to whether we instrument for energy prices in addition to the endogenous policy variables.

6. Discussion

Our results show that renewable electricity mandates, which are a command and control policy, have significant negative effects on GDP, the GDP of the primary sector (which consists of the agriculture, forestry, animal husbandry, and fishery industries), and the industrial output value of the petroleum and nuclear fuel processing industry. Similarly, non-monetary awards for having reduced pollution have significant negative effects on the GDP of the primary sector, the total profits of firms in the new energy sector, the total profits in the combustible ice industry in the new energy sector, the total profits of firms in the low carbon industry in the new energy sector, and the total profits of firms in the shale gas industry in the new energy sector.

In contrast, policies involving financial incentives or monetary awards have mixed effects on GDP, output, or profits; with positive effects on output or profits in some energy-related industries or sectors. Loans to firms for increasing renewable energy consumption have mixed effects on GDP, industrial output, and profits, with a significant negative effect on the GDP of the primary sector, and a significant positive effect on the industrial output value of the petroleum and nuclear fuel processing industry. One possible explanation for the significant positive effect of loans to firms for increasing renewable energy consumption on the industrial output value of the petroleum and nuclear fuel processing industry is that the nuclear industry is primarily an electricity producing sector. Promoting consumption of the renewable electricity and renewable energy leads to increased sales in the nuclear industry, which in turn increases the industrial output value of the petroleum and nuclear fuel processing industry.

Similarly, monetary awards for having reduced pollution have mixed effects on GDP, industrial output, and profits, with a significant negative effect on GDP, but significant positive effects on the total profits of firms in the new energy sector and on the total profits of firms in the combustible ice industry in the new energy sector.

Thus, we find that, contrary to conventional wisdom, environmental policies do not necessarily lead to a decrease in output or profits. Consistent with the Porter hypothesis, we find that loans to firms for increasing renewable energy consumption have a significant positive effect on the industrial output values of the petroleum and nuclear fuel processing industry; and monetary awards for having reduced pollution have significant positive effects on total profits of firms in the new energy sector and on and the total profits of firms in the combustible ice industry in the new energy sector. These environment policies may be increasing productivity by inducing innovations in compliance technology; by benefiting firms with lower compliance costs; by inducing firms to reconsider their production processes, and hence to discover innovative approaches not only to reduce pollution, but also to decrease costs or increase output; and/or by more productive firms to displace less productive ones, leading to increased productivity at the industry level.

In addition to benefiting the regulated industries, environmental regulation may benefit the whole economy by benefiting the environmental services sector and by inducing innovations in compliance technology. Our results show that, on the contrary, environmental policies can decrease the GDP of some non-energy industries and sectors. Providing loans to firms for increasing renewable energy consumption and providing non-monetary awards for having reduced pollution significantly reduces the GDP of the primary sector, which consists of the agriculture, forestry, animal husbandry, and fishery industries.

One possible reason environmental policies may have a negative effect on productivity, GDP, output, and profits is that firms have already become cleaner and more productive, and that the economy is moving along the desired path towards an energy portfolio with higher clean energy shares (Dogan, 2015; Bhattacharya et al. 2016; Afonso, Marques and Fuinhas, 2017; Armeanu, Vintila and Gherghina, 2017; Marinaș et al., 2018). Since our period of analysis is prior to China's war on pollution, however, it is unlikely that firms during this period have already become cleaner and more productive.

Economists tend to favor incentive- or market-based instruments over command and control policies, including quantity-based mandates, for efficiency reasons (Auffhammer et al., 2016). Whenever unpriced emissions are the sole market failure, incentive-based instruments are more likely to achieve the social optimum and maximize social net benefits (Pigou, 1920; Coase, 1960). Our results provide an additional reason for policy-makers to use incentive- or market-based instruments as opposed to command and control policies: while command and control policies and non-monetary awards appear to decrease GDP, output, and/or profits; environmental policies involving financial incentives or monetary awards have the potential of increasing the output and/or profits in some energy-related industries or sectors, albeit potentially at the cost of GDP in other sectors.

7. Conclusion

Critics of environmental policies often claim that such policies decrease productivity and profits. The effects of environmental policies on productivity, GDP, output, and profits is in part an empirical question, however, and may vary by firm, industry, sector, and type of policy.

This paper examines the effects of environmental policies in China on GDP, industrial output, and new energy sector profits using province-level data over the period 2002 to 2013. Our econometric method employs instruments to address the potential endogeneity of the policies.

Our results suggest that policies involving financial incentives or monetary awards have the potential of increasing the output and/or profits in some energy-related industries or sectors, but potentially at the cost of total GDP and GDP in the primary sector (which consists of the agriculture, forestry, animal husbandry, and fishery industries). In contrast, command and control policies and non-monetary awards appear to decrease GDP, output, and/or profits.

Economists tend to favor incentive- or market-based instruments over command and control policies (including quantity-based mandates) because incentive- or market-based instruments are more likely to maximize social net benefits (Pigou, 1920; Coase, 1960; Auffhammer et al., 2016). Our results on the possible beneficial impact of financial incentives and monetary awards on the output and/or profits in some energy-related industries or sectors may potentially provide an additional reason for policy-makers to use incentive- or market-based instruments as opposed to command and control policies.

Our paper points to several potential avenues for future research. First, we hope in future work to quantify the stringency and extent of various environmental policies in order to further examine the relationships between environmental policies and GDP, industrial output, and new energy sector profits in China. Second, we hope in future work to further analyze and tease out the mechanisms through which various environmental policies affect GDP, industrial output, and new energy sector profits in China. Third, we hope in future work to collect and construct data to enable us to examine the relationships between environmental policies and GDP, industrial output, and new energy sector profits in China after the unprecedented environmental regulatory changes that took place when China declared war on pollution in 2014 (Greenstone et al., 2020).

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Table 1. Summary statistics for province-level GDP, industrial output, and profit variables, 2002-2013

	Obs	Mean	Std. Dev.	Min	Max
Total GDP (10^8 yuan)	360	9,326.25	8,758.71	340.65	50,143.63
GDP of primary sector (10^8 yuan)	360	923.41	725.21	44.90	3,788.68
GDP of secondary sector (10^8 yuan)	360	4,373.80	4,405.57	125.33	23,619.15
GDP of tertiary sector (10^8 yuan)	360	3,486.83	3,661.25	125.28	23,829.02
Industrial output value of coal mining, smelting, and dressing industry (10^8 yuan)	331	368.29	594.70	0.04	3,727.28
Industrial output value of petroleum processing and nuclear industry (10^8 yuan)	360	534.99	615.39	0.06	3,331.78
Industrial output value of oil and gas exploration industry (10^8 yuan)	263	297.14	360.62	0.07	1,742.65
Total profits of firms in new energy sector (10^8 yuan)	360	31.52	56.37	-49.63	500.48
Total profits of firms in combustible ice industry (10^8 yuan)	360	1.84	9.14	-14.36	108.71
Total profits of firms in low carbon industry (10^8 yuan)	360	18.36	43.47	-58.23	369.86
Total profits of firms in nuclear power industry (10^8 yuan)	360	7.89	19.85	-58.23	152.22
Total profits of firms in shale gas industry (10^8 yuan)	360	3.08	9.74	-12.31	92.76
Total profits of firms in solar energy industry (10^8 yuan)	360	5.23	12.17	-49.63	69.45

Note: The data consists of annual province-level data over the period 2002 to 2013.

Table 2. Summary statistics for province-level policy variables, 2002-2013

	Obs	Mean	Std. Dev.	Min	Mas
Command and Control					
Renewable electricity mandate	360	0.619	0.486	0	1
Financial Incentives					
Loans to firms for increasing renewable energy consumption	360	0.289	0.454	0	1
Monetary Awards					
Monetary awards for having reduced pollution	360	0.411	0.493	0	1
Non-Monetary Awards					
Non-monetary awards for having reduced pollution	360	0.475	0.500	0	1

Note: The data consists of annual province-level data over the period 2002 to 2013.

Table 3. Environmental policies in China by province, 2002-2013

Province	*Renewable electricity mandate*	*Loans to firms for increasing renewable energy consumption*	*Monetary awards for having reduced pollution*	*Non-monetary awards for having reduced pollution*
Anhui	2002 - 2013	NONE	NONE	2002 – 2013
Beijing	2005 - 2013	NONE	NONE	2005 - 2013
Chongqing	2002 - 2013	NONE	2003 - 2013	NONE
Fujian	2002 - 2013	NONE	2002 - 2013	2002 - 2013
Gansu	NONE	2004 - 2013	NONE	NONE
Guangdong	2002 - 2013	2002 - 2013	2002 - 2013	2002 - 2013
Guangxi	2002 - 2013	2002 - 2013	NONE	2011 - 2013
Guizhou	NONE	NONE	NONE	NONE
Hainan	2002 - 2013	NONE	NONE	2005 - 2013
Hebei	2004 - 2013	2011 - 2013	2002 - 2013	2002 - 2013
Heilongjiang	2010 - 2013	NONE	2006 - 2013	2009 - 2013
Henan	2002 - 2013	2002 - 2013	2004 - 2013	2002 - 2013
Hubei	2002 - 2013	NONE	NONE	NONE
Hunan	2002 - 2013	NONE	NONE	NONE
Inner Mongolia	NONE	NONE	NONE	NONE
Jiangsu	2002 - 2013	NONE	NONE	2002 - 2013
Jiangxi	NONE	NONE	NONE	2002 - 2013
Jilin	2002 - 2013	NONE	2009 - 2013	2009 - 2013
Liaoning	2010 - 2013	2002 - 2013	2004 - 2013	2002 - 2013
Ningxia	NONE	NONE	NONE	NONE
Qinghai	NONE	NONE	NONE	NONE

Shaanxi	NONE	NONE	NONE	NONE
Shandong	2002 - 2013	2002 - 2013	2002 - 2013	2002 - 2013
Shanghai	2004 - 2013	NONE	2002 - 2013	NONE
Shanxi	2006 - 2013	2004 - 2013	2006 - 2013	2006 - 2013
Sichuan	2003 - 2013	2002 - 2013	2002 - 2013	2002 - 2013
Tianjin	2002 - 2013	2002 - 2013	2002 - 2013	2002 - 2013
Xinjiang	NONE	NONE	NONE	NONE
Yunnan	NONE	NONE	NONE	NONE
Zhejiang	2003 - 2013	NONE	2002 - 2013	NONE

Notes: This table lists the years in which each type of policy was in place in each province. If a province did not have that type of policy in place for any year over 2002-2013, this is indicated with “NONE”.

Table 4. Angrist-Pischke and Sanderson-Windmeijer First-Stage F-statistics

	Angrist-Pischke First-Stage F-Statistic	Sanderson-Windmeijer First-Stage F-statistic
Command and Control		
Renewable electricity mandate	22.20	11.11
Financial Incentives		
Loans to firms for increasing renewable energy consumption	241.64	48.58
Monetary Awards		
Monetary awards for having reduced pollution	29.37	10.67
Non-Monetary Awards		
Non-monetary awards for having reduced pollution	51.25	9.20

Note: For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province i, which we define as the sum of the values of that policy variable over all the other provinces except province i at time $t-1$.

Table 5. Results for total GDP and GDP of the primary, secondary, and tertiary sectors

	Dependent variable is:			
	Log GDP	*Log GDP of the primary sector*	*Log GDP of the secondary sector*	*Log GDP of the tertiary sector*
	(1)	(2)	(3)	(4)
<u>Policy Variables</u>				
Command and Control				
Renewable electricity mandate	-0.2206**	0.1614	-0.7069**	-0.1437
	(0.0836)	(0.0968)	(0.2455)	(0.0995)
Financial Incentives				
Loans to firms for increasing renewable energy consumption	0.0377	-0.1181**	0.1053	0.0136
	(0.0491)	(0.043)	(0.115)	(0.0838)
Monetary Awards				
Monetary awards for having reduced pollution	-0.2323*	0.2463	-0.5155	-0.2127
	(0.1173)	(0.1361)	(0.3234)	(0.1549)
Non-Monetary Awards				
Non-monetary awards for having reduced pollution	0.1979	-0.2742*	0.6349	0.2228
	(0.1197)	(0.1358)	(0.3543)	(0.1409)
<u>Energy Prices</u>				
Log gasoline price	-0.0391	-0.0521	-0.3548	-0.0769
	(0.1713)	(0.1664)	(0.4744)	(0.2211)
Log power price	-0.2802	-0.0617	-1.286	-0.4625
	(0.3336)	(0.5077)	(0.8701)	(0.6338)
Log coal price	0.5795***	-0.3718	1.3510**	0.058
	(0.1662)	(0.2477)	(0.4323)	(0.2983)

Log petroleum price	0.1547	-0.0726	-0.0546	-0.15
	(0.129)	(0.1553)	(0.3306)	(0.2087)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y	Y
Province fixed effects	Y	Y	Y	Y
Province random effects	N	N	N	N
Year effects	Y	Y	Y	Y
IVs for policy variables	Y	Y	Y	Y
IVs for energy prices	Y	Y	Y	Y
Hausman test (H0: random effects and regressors are uncorrelated)				
chi2	3,102.29	707.56	102.38	159.51
p-value (Pr>chi2)	[0.0000]****	[0.0000]****	[0.0000]****	[0.0000]****
Observations	161	161	161	161
R-squared	0.9834	0.9552	0.889	0.9593

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. Significance codes: *5% level, **1% level, and ***0.1% level.

Table 6. Results for industrial output value of traditional energy industries

	Dependent variable is log industry output value of:		
	Coal mining, smelting, and dressing industry	*Petroleum and nuclear fuel processing industry*	*Oil and gas exploration industry*
	(5)	(6)	(7)
Policy Variables			
Command and Control			
Renewable electricity mandate	-0.7	-0.8098*	-0.3628
	(0.3774)	(0.3349)	(0.4484)
Financial Incentives			
Loans for firms for increasing renewable energy consumption	0.2323	0.2732*	-0.4533
	(0.1705)	(0.1267)	(0.3118)
Monetary Awards			
Monetary awards for having reduced pollution	-0.9187	-0.245	-1.399
	(0.5195)	(0.3861)	(0.8037)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	0.8349	0.524	0.9954
	(0.5186)	(0.4782)	(0.7357)
Energy Prices			
Log gasoline price	-0.0327	0.4688	-0.8021
	(0.6243)	(0.6134)	(0.9103)
Log power price	2.2355	-1.8991	0.1371
	(1.9503)	(1.2524)	(2.5416)
Log coal price	-0.469	0.8186	-0.071
	(1.0436)	(0.7487)	(1.6079)

Log petroleum price	-0.8907	-2.6487***	0.6774
	(0.6872)	(0.625)	(1.0624)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Province random effects	N	N	N
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	Y	Y	Y
Hausman test (H0: random effects and regressors are uncorrelated)			
chi2	N/A	543.22	137.53
p-value (Pr>chi2)	N/A	[0.0000]****	[0.0000]****
Observations	160	161	159
R-squared	0.9234	0.8951	0.5259

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. We are unable to conduct a Hausman test for our IV regression of the industrial output of the coal mining, smelting, and dressing industry, as the model fitted on the data fails to meet the asymptotic assumptions of the Hausman test. Significance codes: *5% level, **1% level, and ***0.1% level.

Table 7a. Results for total profits of firms in new energy sector

	Dependent variable is log total profits of firms in:		
	New energy sector	*Combustible ice industry in new energy sector*	*Low carbon industry in new energy sector*
	(8)	(9)	(10)
Policy Variables			
Command and Control			
Renewable electricity mandate	2.0072	-0.9332	3.2403
	(1.134)	(2.4975)	(1.7193)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	-0.6057	0.3564	-1.0840
	(0.7067)	(1.4744)	(1.326)
Monetary Awards			
Monetary awards for having reduced pollution	3.3587*	5.2411**	1.7309
	(1.4558)	(1.6251)	(1.7796)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	-3.2496*	-2.4324*	-4.6880*
	(1.4541)	(1.1434)	(1.8311)
Energy Prices			
Log gasoline price	1.4721	-4.0243	2.2063
	(1.398)	(5.3296)	(2.831)
Log power price	-0.1359	4.7141	2.0636
	(4.4001)	(11.4612)	(6.2423)
Log coal price	-4.5934**	13.0159	-7.0391
	(1.7502)	(10.8656)	(3.7349)
Log petroleum price	-2.0164	4.3465	1.6444

	(1.6066)	(5.1297)	(2.2132)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	N	N
Province random effects	N	Y	Y
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	Y	Y	Y
Hausman test (H0: random effects and regressors are uncorrelated)			
chi2	125.81	14.00	0.00
p-value (Pr>chi2)	[0.0000]****	[0.8697]	[1.0000]
Observations	148	72	148
R-squared	0.569	0.9075	0.0198

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. Significance codes: *5% level, **1% level, and ***0.1% level.

Table 7b. Results for total profits of firms in new energy sector

	Dependent variable is log total profit of firms in:		
	Nuclear power industry in new energy sector	*Shale gas industry in new energy sector*	*Solar energy industry in new energy sector*
	(11)	(12)	(13)
Policy Variables			
Command and Control			
Renewable electricity mandate	-1.446	-0.5038	-0.9963
	(0.8425)	(0.6978)	(2.2487)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	-0.1603	-0.2581	1.9746
	(0.9193)	(0.6787)	(569.4897)
Monetary Awards			
Monetary awards for having reduced pollution	0.1048	0.8952	-1.4965
	(0.6944)	(0.5094)	(1.7039)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	0.9203	-1.0705*	0.3223
	(0.6878)	(0.4917)	(2.3176)
Energy Prices			
Log gasoline price	11.276	-1.6105	-2.0886
	(11.6543)	(4.3862)	(2.7689)
Log power price	10.3726	2.6588	2.535
	(6.9872)	(4.0933)	(6.1946)
Log coal price	-0.7865	1.2537	3.1196
	(2.2015)	(1.1884)	(4.8198)
Log petroleum price	0.0712	1.1945	-2.5979

	(1.7232)	(0.9024)	(2.498)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	N	N	N
Province random effects	Y	Y	Y
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	Y	Y	Y
Hausman test (H0: random effects and regressors are uncorrelated)			
chi2	37.28	23.80	0.00
p-value (Pr>chi2)	[0.0543]	[0.4151]	[1.0000]
Observations	118	99	118
R-squared	0.4660	0.7386	0.0316

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. Significance codes: *5% level, **1% level, and ***0.1% level.

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Appendix A:

Supplementary Tables Describing Data

Table A1. Definition of Profit According to China's Accounting Rules

Operating Profit	
	Gross Revenue
less	Operating Cost
less	Business Tax and Surcharges
less	Marketing Cost
less	Management Cost
less	Financing Cost
adjust	Change in Fair Value
adjust	Investment Income
Total Profit	
	Operating Profit
plus	Non-Business Profit
less	Non-Business Cost
Net Profit	
	Total Profit
less	Income Tax Expenditure

Note: Table illustrates how total profit and net profit are calculated under the accounting standards in mainland China.

Table A2. Within and between variation of GDP, output, and profit variables

		Mean	Std. Dev.	Min	Max	Obs.
Total GDP	overall	9326.25	8758.71	340.65	50143.63	360
	between		7324.85	795.98	30376.25	30
	within		4970.46	-7547.59	30088.05	12
GDP of primary sector	overall	923.41	725.21	44.90	3788.68	360
	between		641.96	81.97	2433.58	30
	within		355.58	-120.18	2278.50	12
GDP of secondary sector	overall	4373.80	4405.57	125.33	23619.15	360
	between		3686.72	335.76	14235.53	30
	within		2496.72	-3926.09	14113.49	12
GDP of tertiary sector	overall	3486.83	3661.25	125.28	23829.02	360
	between		2853.19	260.90	12153.26	30
	within		2348.08	-3865.12	15162.59	12
Industrial output value of coal mining, smelting, and dressing industry	overall	472.73	876.27	0.04	6805.46	332
	between		601.80	0.04	2725.72	30
	within		635.64	-1975.59	4552.47	11.0667
Industrial output values of petroleum processing and nuclear industry combined	overall	659.40	877.42	0.06	6847.55	360
	between		660.95	13.32	2810.74	30
	within		588.55	-1708.26	4696.20	12
Industrial output value of oil and gas exploration industry	overall	341.52	444.16	0.07	2174.51	264

	between		384.22	0.13	1413.23	24
	within		226.42	-338.01	1344.73	11
Total profits of firms in new energy sector	overall	31.52	56.37	-49.63	500.48	360
	between		46.36	-3.00	232.36	30
	within		33.07	-133.18	299.65	12
Total profits of firms in combustible ice industry in new energy sector	overall	1.84	9.14	-14.36	108.71	360
	between		7.24	0.00	39.27	30
	within		5.72	-35.90	71.28	12
Total profits of firms in low carbon industry in new energy sector	overall	18.36	43.47	-58.23	369.86	360
	between		37.64	-3.14	189.74	30
	within		22.73	-113.42	198.48	12
Total profits of firms in nuclear power industry in new energy sector	overall	7.89	19.85	-58.23	152.22	360
	between		15.01	-3.14	59.44	30
	within		13.26	-47.20	107.30	12
Total profits of firms in shale gas industry in new energy sector	overall	3.08	9.74	-12.31	92.76	360
	between		7.36	-1.35	39.14	30
	within		6.51	-36.06	56.70	12
Total profits of firms in solar energy industry in new energy sector	overall	5.23	12.17	-49.63	69.45	360
	between		8.81	-3.00	30.86	30
	within		8.54	-41.40	46.16	12

Note: Table presents the within and between variation for the GDP, industrial output value, and new energy sector profit variables. "Within" variation is the variation in the GDP/output/profit variable across years for a given province. "Between" variation is the variation in the GDP/output/profit variable across provinces for a given year.

Table A3. Number of firms in new energy sector by province, 2002-2013

Province	New Energy Sector (All Industries)	Combustible Ice Industry	Low Carbon Industry	Nuclear Power Industry	Shale Gas Industry	Solar Energy Industry
Anhui	3-6	0-1	2	0-1	0	1-2
Beijing	8-21	1-4	6-8	1-5	0-4	1-5
Chongqing	4-6	0	1-2	1-2	2	2
Fujian	3-7	0	1	2	0-1	0-3
Gansu	3-7	0-1	1-2	2-4	0-2	0
Guangdong	14-35	0	6-9	0-5	0	10-24
Guangxi	2	0	2	0	0	0
Guizhou	2	0	1	0	1	0
Hainan	0	0	0	0	0	0
Hebei	4	0	1	1	0	4
Heilongjiang	3-5	0	1	2-4	0	1
Henan	3-10	0	1-2	0	1-2	1-6
Hubei	6	1	1	1	2	3
Hunan	4-6	0	2	1	2	0-2
Inner Mongolia	4	0	2	1	0	1
Jiangsu	9-34	0-1	4-6	2-7	1-4	3-19
Jiangxi	3-4	0	1	2	0	0-1
Jilin	3	0	1	0	2	0
Liaoning	3-6	0	1-2	1	1	0-2
Ningxia	3	0	1	0	0	3
Qinghai	0-1	0-1	0	0	0	0
Shaanxi	2-8	0	1-2	0-3	0-1	1-2

Shandong	8-16	1-2	5-7	0-2	0-3	3-6
Shanghai	9-15	0-1	5-6	3-6	0-1	3-5
Shanxi	8	0	5	1	2	0
Sichuan	8-11	1	4	2-4	1	3-4
Tianjin	2-5	1-3	1	0	0	0-1
Xinjiang	5-7	0-1	3-4	1	2	3
Yunnan	2	0	2	0	0	0
Zhejiang	17-35	0	6-7	3-11	3-4	6-16

Notes: This table lists the number of firms that claim they are operating in a specific province in their annual financial report in any year over the period 2002-2013. If the number of firms in the new energy sector never changes for that province over 2002-2013, then only one number is reported, which is the number of firms in the new energy sector in that province each year over 2002-2013. If the number of firms in the new energy sector changes for that province over 2002-2013, then the table presents the range between the number of firms in the new energy sector in the year that had the lowest number of firms in the new energy sector, and the number of firms in the new energy sector in the year that had the highest number of firms in the new energy sector for that province over 2002-2013.

Table A4. Summary statistics for province-level energy prices, 2002-2013

	Obs	Mean	Std. Dev.	Min	Max
Gasoline price (yuan) (2002 constant price)	295	5594.86	1312.19	2412.20	8023.27
Power price index (2002 constant price)	360	112.43	7.49	100.00	120.15
Coal price index (2002 constant price)	360	170.42	47.34	100.00	221.44
Petroleum price index (2002 constant price)	360	170.39	44.07	100.00	215.43

Note: The data consists of annual province-level data over the period 2002 to 2013.

Table A5. Command and control policy variables that we dropped from the empirical analysis because they constant for at least 28 out of the 30 provinces

	Command and control			
	Ambient air quality standard	Ambient water quality standard	Emissions standard for water pollution	Fuel mandate
Anhui	1	1	1	1
Beijing	1	1	1	
Chongqing	1	1		
Fujian	1	1	1	1
Gansu	0	0	1	1
Guangdong	1	1	1	1
Guangxi	1	1	1	1
Guizhou	0	0	1	1
Hainan	1	1	1	1
Hebei	1	1	1	0
Heilongjiang		0	0	0
Henan	1	1	1	1
Hubei	1	1	1	1
Hunan	1	1	1	1
Inner Mongolia	0	0	0	0
Jiangsu	1	1	1	1
Jiangxi	1	1	1	0
Jilin	0	0	1	0
Liaoning	1	1	1	0
Ningxia	0	0	0	1

Qinghai	0	0	0	1
Shaanxi	0	0	1	1
Shandong	1	1	1	1
Shanghai	1	1	1	1
Shanxi				0
Sichuan	1	1	1	1
Tianjin	1	1	1	1
Xinjiang	0	0	1	1
Yunnan	0	0	0	1
Zhejiang	1	1	1	1

Notes: For each type of policy, provinces that have that type of policy for every year during the 2002-2013 period are indicated with “1”; provinces that never have that type of policy for any year during the 2002-2013 period are indicated with “0”; and provinces that have that type of policy for some years but not others during the 2002-2013 period are indicated with a blank cell.

Table A6. Tax variables that we dropped from the empirical analysis because they constant for at least 28 out of the 30 provinces

	Financial incentives: Taxes	
	Favorable tax treatment for reducing pollution	Tax on water pollution emissions
Anhui	0	0
Beijing	0	0
Chongqing	0	0
Fujian	0	0
Gansu	0	1
Guangdong	1	1
Guangxi	1	0
Guizhou	0	1
Hainan	1	0
Hebei	0	0
Heilongjiang	0	0
Henan	1	1
Hubei	1	0
Hunan	0	0
Inner Mongolia	0	0
Jiangsu	0	0
Jiangxi	1	0
Jilin	0	0
Liaoning	1	0
Ningxia	0	1

Qinghai	0	1
Shaanxi	0	1
Shandong	1	1
Shanghai	1	0
Shanxi	0	0
Sichuan	1	0
Tianjin	1	
Xinjiang	0	1
Yunnan		1
Zhejiang	1	0

Notes: For each type of policy, provinces that have that type of policy for every year during the 2002-2013 period are indicated with “1”; provinces that never have that type of policy for any year during the 2002-2013 period are indicated with “0”; and provinces that have that type of policy for some years but not others during the 2002-2013 period are indicated with a blank cell.

Table A7. Funding or subsidies policy variables that we dropped from the empirical analysis because they constant for at least 28 out of the 30 provinces

	Financial incentives: Funding or subsidies		
	Funding or subsidies for research and development to reduce pollution	Funding or subsidies for reducing pollution	Funding or subsidies for energy conservation
Anhui	1	1	1
Beijing	1	1	1
Chongqing	1	0	1
Fujian	1	1	1
Gansu	1	0	0
Guangdong	1	1	1
Guangxi	1	1	1
Guizhou	1	1	0
Hainan	1	1	1
Hebei	1		0
Heilongjiang	1	0	0
Henan	1	1	1
Hubei	1	0	0
Hunan	1	0	0
Inner Mongolia	0	0	0
Jiangsu	1	1	1
Jiangxi	1	0	0
Jilin	1	0	0
Liaoning	1	0	0
Ningxia	1	0	0

Qinghai	1	0	0
Shaanxi	1	0	0
Shandong	1	1	1
Shanghai	1		
Shanxi	1	0	
Sichuan	1		1
Tianjin	1	1	1
Xinjiang	1	0	0
Yunnan	1	0	0
Zhejiang	1	0	0

Notes: For each type of policy, provinces that have that type of policy for every year during the 2002-2013 period are indicated with “1”; provinces that never have that type of policy for any year during the 2002-2013 period are indicated with “0”; and provinces that have that type of policy for some years but not others during the 2002-2013 period are indicated with a blank cell.

Table A8. Loans to households policy variables that we dropped from the empirical analysis because they constant for at least 28 out of the 30 provinces

	Financial incentives: Loans to households	
	Loans to households for increasing energy efficiency	Loans to households for increasing renewable energy consumption
Anhui	0	0
Beijing		0
Chongqing	0	0
Fujian	0	0
Gansu	1	0
Guangdong	1	1
Guangxi	1	1
Guizhou	1	0
Hainan		
Hebei	0	0
Heilongjiang	0	0
Henan	1	1
Hubei	0	0
Hunan	0	1
Inner Mongolia	0	0
Jiangsu	0	0
Jiangxi	0	0
Jilin	0	0
Liaoning	0	1
Ningxia	0	0

Qinghai	0	0
Shaanxi	0	0
Shandong	1	1
Shanghai	0	0
Shanxi	0	0
Sichuan	0	1
Tianjin	0	0
Xinjiang	0	0
Yunnan	1	0
Zhejiang	0	0

Notes: For each type of policy, provinces that have that type of policy for every year during the 2002-2013 period are indicated with "1"; provinces that never have that type of policy for any year during the 2002-2013 period are indicated with "0"; and provinces that have that type of policy for some years but not others during the 2002-2013 period are indicated with a blank cell.

Table A9. Monetary awards policy variables that we dropped from the empirical analysis because they constant for at least 28 out of the 30 provinces

	Monetary awards		
	Monetary awards for having increased energy efficiency	Monetary awards for having developed technology to reduce pollution	Monetary awards for having developed technology to reduce fossil fuel consumption
Anhui	0	0	0
Beijing	0	0	0
Chongqing	0	1	0
Fujian	1	0	
Gansu	0	0	0
Guangdong	1	1	1
Guangxi		0	0
Guizhou	0	0	0
Hainan		0	0
Hebei	0	0	0
Heilongjiang	0	0	0
Henan	1	0	0
Hubei	0	0	0
Hunan	1	0	0
Inner Mongolia	0	0	0
Jiangsu	0	0	0
Jiangxi	0		0
Jilin	0	0	0
Liaoning	0	0	0

Ningxia	0	0	0
Qinghai	0	0	0
Shaanxi	0	0	0
Shandong	1	1	1
Shanghai	1	1	0
Shanxi	1	0	0
Sichuan	1	1	1
Tianjin	1		
Xinjiang	0	0	0
Yunnan	0	0	0
Zhejiang	1	1	0

Notes: For each type of policy, provinces that have that type of policy for every year during the 2002-2013 period are indicated with “1”; provinces that never have that type of policy for any year during the 2002-2013 period are indicated with “0”; and provinces that have that type of policy for some years but not others during the 2002-2013 period are indicated with a blank cell.

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Appendix B:
First-Stage Regressions

Table B1. First-stage regressions for command and control policy variable

	Dependent variable is: Renewable electricity mandate
Instruments	
Time lagged spatial lag of:	
Command and Control	
Renewable electricity mandate	-0.5253**
	(0.1636)
Financial Incentives	
Loans to firms for increasing renewable energy consumption	0.0638
	(0.0694)
Monetary Awards	
Monetary awards for having reduced pollution	-0.0310
	(0.0645)
Non-Monetary Awards	
Non-monetary awards for having reduced pollution	-0.2499
	(0.1984)
Economic variables	Y
Province fixed effects	Y
Year effects	Y
Observations	161

Notes: For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. Economic variables include energy prices and the time lagged spatial lag of GDP, output, and profit. Significance codes based on robust standard errors: * 5% level, ** 1% level, and *** 0.1% level.

Table B2. First-stage regressions for financial incentive policy variable

	Dependent variable is: Loans to firms for increasing renewable energy consumption
Instruments	
Time lagged spatial lag of:	
Command and Control	
Renewable electricity mandate	0.0145
	(0.0444)
Financial Incentives	
Loans to firms for increasing renewable energy consumption	-0.8352***
	(0.1169)
Monetary Awards	
Monetary awards for having reduced pollution	-0.0117
	(0.0318)
Non-Monetary Awards	
Non-monetary awards for having reduced pollution	0.0124
	(0.0430)
Economic variables	Y
Province fixed effects	Y
Year effects	Y
Observations	161

Notes: For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. Economic variables include energy prices and the time lagged spatial lag of GDP, output, and profit. Significance codes based on robust standard errors: * 5% level, ** 1% level, and *** 0.1% level.

Table B3. First-stage regressions for monetary awards policy variable

	Dependent variable is: Monetary awards for having reduced pollution
Instruments	
Time lagged spatial lag of:	
Command and Control	
Renewable electricity mandate	0.1162
	(0.0704)
Financial Incentives	
Loans to firms for increasing renewable energy consumption	-0.0277
	(0.0310)
Monetary Awards	
Monetary awards for having reduced pollution	-0.4537*
	(0.1762)
Non-Monetary awards	
Non-Monetary awards for having reduced pollution	-0.1958
	(0.1112)
Economic variables	Y
Province fixed effects	Y
Year effects	Y
Observations	161

Notes: For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. Economic variables include energy prices and the time lagged spatial lag of GDP, output, and profit. Significance codes based on robust standard errors: * 5% level, ** 1% level, and *** 0.1% level.

Table B4. First-stage regressions for non-monetary awards policy variable

	Dependent variable is: Non-monetary awards for having reduced pollution
Instruments	
Time lagged spatial lag of:	
Command and Control	
Renewable electricity mandate	0.0169
	(0.0477)
Financial Incentives	
Loans to firms for increasing renewable energy consumption	0.0304
	(0.0500)
Monetary Awards	
Monetary awards for having reduced pollution	-0.1288
	(0.0892)
Non-Monetary Awards	
Non-monetary awards for having reduced pollution	-0.7080***
	(0.1606)
Economic variables	Y
Province fixed effects	Y
Year effects	Y
Observations	161

Notes: For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. Economic variables include energy prices and the time lagged spatial lag of GDP, output, and profit. Significance codes based on robust standard errors: * 5% level, ** 1% level, and *** 0.1% level.

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Appendix C:
Robustness Checks

Table C1a. Robustness 1: Results for total profits of firms in new energy sector using fixed effects

	Dependent variable is log total profits of firms in:		
	New energy sector	*Combustible ice industry in new energy sector*	*Low carbon industry in new energy sector*
	(8)	(9')	(10')
Policy Variables			
Command and Control			
Renewable electricity mandate	2.0072	-3.2473	3.2404
	(1.134)	(2.7609)	(1.8289)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	-0.6057	1.9969	-1.084
	(0.7067)	(2.6008)	(1.0535)
Monetary Awards			
Monetary awards for having reduced pollution	3.3587*	(omitted)	1.731
	(1.4558)	N/A	(1.7463)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	-3.2496*	(omitted)	-4.6882*
	(1.4541)	N/A	(1.9593)
Energy Prices			
Log gasoline price	1.4721	-0.4869	2.2064
	(1.398)	(2.8904)	(1.9568)
Log power price	-0.1359	6.6353	2.0635
	(4.4001)	(15.3581)	(5.2265)
Log coal price	-4.5934**	4.9948	-7.0393
	(1.7502)	(6.6342)	(3.1028)
Log petroleum price	-2.0164	8.1808*	1.6444

	(1.6066)	(3.5552)	(1.9074)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Province random effects	N	N	N
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	Y	Y	Y
Hausman test (H0: random effects and regressors are uncorrelated)			
chi2	125.81	14.00	0.00
p-value (Pr>chi2)	[0.0000]****	[0.8697]	[1.0000]
Observations	148	71	147
R-squared	0.569	0.8449	0.1938

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. Since the random effects estimator is biased and inconsistent for total profits in the new energy sector, the IV fixed effects regression results for the total profits in the new energy sector are also reported in Table 7a in the paper. Significance codes: *5% level, **1% level, and ***0.1% level.

Table C1b. Robustness 1: Results for total profits of firms in new energy sector using fixed effects

	Dependent variable is log total profit of firms in:		
	Nuclear power industry in new energy sector	*Shale gas industry in new energy sector*	*Solar energy industry in new energy sector*
	(11')	(12')	(13')
Policy Variables			
Command and Control			
Renewable electricity mandate	4.0512	-3.4396	-0.9934
	(4.012)	(6.2454)	(1.5008)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	-0.9611	0.8907	(omitted)
	(1.6107)	(3.2558)	N/A
Monetary Awards			
Monetary awards for having reduced pollution	4.8359	-3.9309	-1.4934
	(2.5657)	(13.5796)	(1.2508)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	-5.7345	-1.8688	0.3177
	(4.7526)	(6.2373)	(1.7182)
Energy Prices			
Log gasoline price	3.0822	-3.6427	-2.0857
	(3.0175)	(10.7771)	(2.6328)
Log power price	10.7439	-5.8059	2.5339
	(10.4821)	(8.1733)	(4.7103)
Log coal price	-12.9145	4.7774	3.1134
	(8.3126)	(7.0403)	(3.0001)
Log petroleum price	-4.8635	5.6475	-2.5974

	(4.4496)	(13.5553)	(2.3655)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Province random effects	N	N	N
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	Y	Y	Y
Hausman test (H0: random effects and regressors are uncorrelated)			
chi2	37.28	23.80	0.00
p-value (Pr>chi2)	[0.0543]	[0.4151]	[1.0000]
Observations	116	99	117
R-squared	0.4944	0.4916	0.6384

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. Significance codes: *5% level, **1% level, and ***0.1% level.

Table C2a. Robustness 2: Results for net profits of firms in new energy sector

	Dependent variable is log net profit of firms in:		
	New energy sector	*Combustible ice industry in new energy sector*	*Low carbon industry in new energy sector*
	(14)	(15)	(16)
Policy Variables			
Command and Control			
Renewable electricity mandate	1.392	-5.1367*	3.363
	(1.5067)	(2.3389)	(1.7773)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	-0.7042	3.7127	-1.6344
	(0.986)	(2.4284)	(1.1176)
Monetary Awards			
Monetary awards for having reduced pollution	4.072	(omitted)	1.7924
	(1.8102)	N/A	(1.7167)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	-2.7581	(omitted)	-4.3157*
	(1.6863)	N/A	(1.9221)
Energy Prices			
Log gasoline price	2.1333	-0.7678	2.0997
	(1.9364)	(3.5657)	(1.8401)
Log power price	-0.1508	12.5634	4.1044
	(5.3971)	(16.526)	(5.1903)
Log coal price	-4.1368	8.0238	-6.4598*
	(2.0887)	(6.6201)	(3.0076)
Log petroleum price	-2.6117	10.1844**	1.2514

	(2.1432)	(3.2131)	(1.8677)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Province random effects	N	N	N
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	Y	Y	Y
Observations	148	70	147
R-squared	0.529	0.8201	0.2183

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. Significance codes: *5% level, **1% level, and ***0.1% level.

Table C2b. Robustness 2: Results for net profits of firms in new energy sector

	Dependent variable is log net profit of firms in:		
	Nuclear power industry in new energy sector	*Shale gas industry in new energy sector*	*Solar energy industry in new energy sector*
	(17)	(18)	(19)
Policy Variables			
Command and Control			
Renewable electricity mandate	5.3661	-4.1188	-1.7659
	(4.78)	(6.8791)	(3.0097)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	-2.1585	1.2435	(omitted)
	(2.0724)	(3.5948)	N/A
Monetary Awards			
Monetary awards for having reduced pollution	6.5742*	-4.421	-3.2722
	(3.2687)	(15.1079)	(2.6839)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	-6.7331	-2.0953	1.8297
	(5.4717)	(6.9468)	(3.3045)
Energy Prices			
Log gasoline price	5.1142	-4.0701	-7.283
	(3.9823)	(11.9096)	(5.5072)
Log power price	8.7013	-6.4942	4.3774
	(12.0645)	(9.0866)	(7.6351)
Log coal price	-12.9776	5.721	3.6072
	(9.4223)	(7.7611)	(5.3809)
Log petroleum price	-6.5231	6.9395	-1.6791

	(5.3317)	(15.0787)	(3.6805)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Province random effects	N	N	N
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	Y	Y	Y
Observations	115	99	116
R-squared	0.3681	0.4027	0.2032

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. For each energy price, we instrument for that energy price using the time lag of that energy price. Significance codes: *5% level, **1% level, and ***0.1% level.

Table C3. Robustness 3: Results for total GDP and GDP of the primary, secondary, and tertiary sectors

	Dependent variable is:			
	Log GDP	*Log GDP of the primary sector*	*Log GDP of the secondary sector*	*Log GDP of the tertiary sector*
	(1")	(2")	(3")	(4")
Policy Variables				
Command and Control				
Renewable electricity mandate	-0.1437*	0.088	-0.5167*	-0.1515
	(0.0731)	(0.0894)	(0.2016)	(0.0918)
Financial Incentives				
Loans to firms for increasing renewable energy consumption	-0.0003	-0.1049**	0.0318	0.0111
	(0.045)	(0.0401)	(0.0964)	(0.0727)
Monetary Awards				
Monetary awards for having reduced pollution	-0.1348	0.1738	-0.2772	-0.2269
	(0.0893)	(0.1186)	(0.2392)	(0.1265)
Non-Monetary Awards				
Non-monetary awards for having reduced pollution	0.1094	-0.2008	0.405	0.2616*
	(0.09)	(0.1079)	(0.2677)	(0.1212)
Energy Prices				
Log gasoline price	0.0493	-0.1375*	-0.0105	-0.1077
	(0.0579)	(0.0638)	(0.1173)	(0.0675)
Log power price	0.1581	-0.1621	-0.1661	-0.2077
	(0.2031)	(0.3139)	(0.5012)	(0.3515)
Log coal price	0.2341**	-0.1853	0.6995**	0.1038
	(0.089)	(0.1461)	(0.2454)	(0.1349)
Log petroleum price	0.0369	-0.0874	-0.1645	-0.1615

	(0.0906)	(0.1045)	(0.2127)	(0.1509)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y	Y
Province fixed effects	Y	Y	Y	Y
Year effects	Y	Y	Y	Y
IVs for policy variables	Y	Y	Y	Y
IVs for energy prices	N	N	N	N
Observations	176	176	176	176
R-squared	0.9892	0.9581	0.9209	0.9588

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. Significance codes: *5% level, **1% level, and ***0.1% level.

Table C4. Robustness 3: Results for industrial output value of traditional energy industries

	Dependent variable is log industry output value of:		
	Coal mining, smelting, and dressing industry	*Petroleum and nuclear fuel processing industry*	*Oil and gas exploration industry*
	(5”)	(6”)	(7”)
Policy Variables			
Command and Control			
Renewable electricity mandate	-0.7986*	-0.6167*	-0.2836
	(0.3927)	(0.2895)	(0.4997)
Financial Incentives			
Loans for firms for increasing renewable energy consumption	0.2987*	0.2154*	-0.4224
	(0.1475)	(0.1068)	(0.238)
Monetary Awards			
Monetary awards for having reduced pollution	-0.8679	-0.2977	-1.2633
	(0.5489)	(0.3446)	(0.7133)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	0.7897	0.2851	0.7262
	(0.5302)	(0.379)	(0.6765)
Energy Prices			
Log gasoline price	0.4422	-0.0561	0.4343
	(0.3313)	(0.1815)	(0.3692)
Log power price	1.1819	-1.6932*	-0.1155
	(1.2732)	(0.8463)	(1.9737)
Log coal price	0.2765	0.3983	0.7189
	(0.5313)	(0.4123)	(0.8164)

Log petroleum price	-0.8203	-1.6092***	1.1886
	(0.6484)	(0.4577)	(0.7445)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	N	N	N
Observations	175	176	174
R-squared	0.9284	0.9116	0.5548

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. Significance codes: *5% level, **1% level, and ***0.1% level.

Table C5a. Robustness 3: Results for total profits of firms in new energy sector

	Dependent variable is log total profits of firms in:		
	New energy sector	*Combustible ice industry in new energy sector*	*Low carbon industry in new energy sector*
	(8”)	(9”)	(10”)
Policy Variables			
Command and Control			
Renewable electricity mandate	1.8567	-1.5589	2.2159
	(0.9496)	(1.7019)	(1.2416)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	-0.6244	1.8282	-1.1602
	(0.6566)	(2.1055)	(1.0231)
Monetary Awards			
Monetary awards for having reduced pollution	2.7162*	(omitted)	0.4466
	(1.3615)	N/A	(1.3058)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	-2.7734*	(omitted)	-2.9966*
	(1.2271)	N/A	(1.1642)
Economic Variables			
Log gasoline price	0.5523	0.8027	0.1094
	(0.5027)	(0.9128)	(0.5652)
Log power price	1.1267	3.6378	-2.9685
	(2.6392)	(4.9696)	(3.2818)
Log coal price	-4.1825***	3.195	-3.4089*
	(1.1064)	(2.8909)	(1.4905)
Log petroleum price	-1.5632	4.2108	2.1393

	(1.3344)	(2.7742)	(1.6482)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	N	N	N
Observations	163	76	159
R-squared	0.5870	0.8098	0.3739

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. Significance codes: *5% level, **1% level, and ***0.1% level.

Table C5b. Robustness 3: Results for total profits of firms in new energy sector

	Dependent variable is log total profit of firms in:		
	Nuclear power industry in new energy sector	*Shale gas industry in new energy sector*	*Solar energy industry in new energy sector*
	(11”)	(12”)	(13”)
Policy Variables			
Command and Control			
Renewable electricity mandate	0.427	-3.8115	0.8718
	(2.2103)	(4.2795)	(0.897)
Financial Incentives			
Loans to firms for increasing renewable energy consumption	1.0214	1.8562	(omitted)
	(1.384)	(2.7948)	N/A
Monetary Awards			
Monetary awards for having reduced pollution	2.0922	-4.8713	-0.7462
	(1.6223)	(8.5302)	(0.9675)
Non-Monetary Awards			
Non-monetary awards for having reduced pollution	-1.7407	-3.5544	-1.5447
	(2.5583)	(3.6167)	(0.964)
Energy Prices			
Log gasoline price	-1.0635	-1.053	-0.5027
	(0.6277)	(1.5611)	(0.7521)
Log power price	11.6875**	-0.2244	1.9304
	(3.713)	(5.7324)	(2.5337)
Log coal price	-3.3752	3.4883	-0.5248
	(2.5362)	(5.1009)	(0.9842)
Log petroleum price	-0.1428	6.1039	-2.481

	(2.4907)	(8.9816)	(1.428)
Time lagged spatial lag of GDP, output, and profit	Y	Y	Y
Province fixed effects	Y	Y	Y
Year effects	Y	Y	Y
IVs for policy variables	Y	Y	Y
IVs for energy prices	N	N	N
Observations	126	105	126
R-squared	0.7460	0.2259	0.7324

Notes: Robust standard errors in parentheses. For each policy variable, we instrument for the policy variable using the time lagged spatial lag of that policy variable in province *i*, which we define as the sum of the values of that policy variable over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the dependent variable in province *i* as the sum of the values of the dependent variable of all the other provinces except province *i* at time *t-1*. Significance codes: *5% level, **1% level, and ***0.1% level.