The effects of energy policies in China on GDP, industrial output, and new energy profits[1]

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Abstract

Critics of environmental and energy policies often claim that such policies decrease productivity and profits. However, the effects of environmental and energy policies on productivity, GDP, output, and profits is in part an empirical question and may vary by firm, industry, sector, and type of policy. This paper examines the effects of energy policies in China on GDP, industrial output, and new energy profits using province-level data over the period 2002 to 2010. Our econometric method employs instruments to address the potential endogeneity of the policies. Consistent with the Porter hypothesis, we find that clean production policies, audit policies, energy conservation policies, and technological progress policies increase the GDP and/or industrial output value of some traditional energy industries. However, clean production policies, technological progress policies, and intellectual property rights policies decrease the GDP and/or industrial output value of some non-energy industries. None of the policies examined have any significant effect on the profits of new energy companies.

Keywords: energy policies; GDP; output; profits; Porter hypothesis; China
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1. Introduction

Energy-related concerns are serious and pervasive in today's world. In many developing countries, such as China, energy consumption continues to increase, causing energy-related problems such as power shortages and environmental pollution. These problems have severely threatened the sustainable development of these countries and have caused great concern at all levels, from the general public to national governments to international agencies. Because of their severity, the governments of many developing countries have begun to introduce energy policies and regulations to combat energy-related problems.

Ever since the 1978 reform in China to make the country more open to foreign countries, the average annual growth rate in China's gross domestic product (GDP) in real terms has been nearly 10% (Bosworth and Collins, 2007). Though speedy, the extensive economic development in China has resulted in not only economic inequality, but also high resource consumption and environmental destruction. As the world's largest energy consumer (IEA, 2010), China is facing both domestic and international pressure to deal with increasing concerns about energy security and environmental pollution.

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, enhance energy efficiency, and promote sustainable development (Political Bureau of the Central Committee, 2013).

The development of the energy industry influences the development of related industries upstream and downstream, as the energy industry provides inputs for various industries, from the agricultural industry to the national defense industry, and also requires inputs from other industries as well. Traditional energy industries, including the fossil fuel energy industries, are generally highly polluting.

The effect of energy policies on the output of firms is the subject of much debate. The conventional wisdom is that environmental and energy 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).

Jaffe et al. (1995) posits several ways in which environmental and energy 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 and energy policies may be less efficient than the original practices. Third, environmental and energy investments could crowd out other types of firm investment.

There has been some literature challenging the conventional wisdom that asserts that environmental and energy policies may stimulate growth and competitiveness. The 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 (Jaffe et al., 1995). 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, energy 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 energy 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 and energy 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 (Jaffe et al., 1995).

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).

Thus, the effects of environmental and energy 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 energy policies in China on GDP, industrial output, and new energy profits.

Previous analyses of China's energy policies have examined their evolutionary progress (Xie, Hu and Zhang, 2005), their impact on economic activities (see, e.g., Pereira and Pereira, 2010; Bojnec and Papler, 2011), their effect on energy consumption (Lu, Lin Lawell and Song, 2016), and their efficiency (Cirone and Urpelainen, 2013).

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; Greenstone, List and Syverson, 2012). There have also been studies testing the Porter hypothesis using data from OECD countries (Lanoie et al., 2011; Albrizio, Kozluk and Zipperer, 2017). 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.

This paper builds upon the existing literature by examining the effects of energy policies in China on GDP, industrial output, and new energy profits. In particular, we analyze the effects of clean production policies, audit policies, energy conservation policies, financial incentive policies, technological progress policies, and intellectual property rights policies on GDP, the industrial output of several industries, and the profits of new energy companies. We use instruments to address the potential endogeneity of the policies.

Results show that, consistent with the Porter hypothesis, clean production policies, audit policies, energy conservation policies, and technological progress policies increase the GDP and/or industrial output value of some traditional energy industries. However, clean production policies, technological progress policies, and intellectual property rights policies decrease the GDP and/or industrial output value of some non-energy industries. None of the policies examined have any significant effect on the profits of new energy companies.

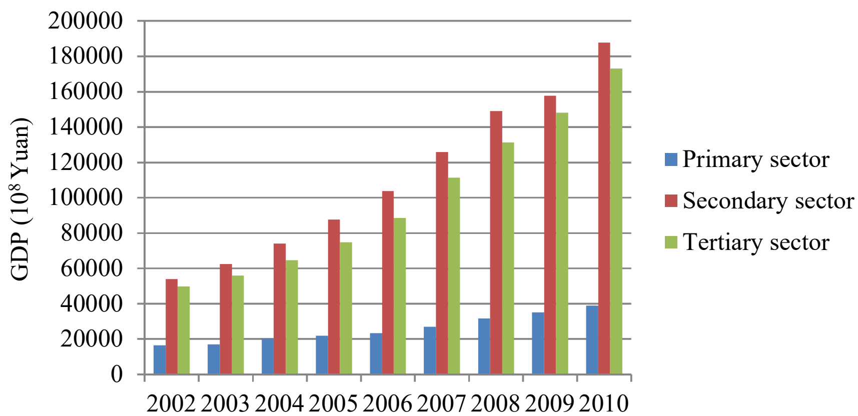
The balance of the paper proceeds as follows. Section 2 presents background information China's energy industry. Section 3 describes the energy policies we examine. Section 4 describes our data. Section 5 presents the model. Section 6 presents the results. Section 7 concludes.

2. China's Energy Industry

Figure 1 plots the GDP in the primary, secondary, and tertiary sectors in China, respectively, over the period 2002 to 2010. 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. As seen in Figure 1, the GDP for each of the three sectors has increased over the period 2002 to 2010. GDP is the highest in the secondary sector, followed by the tertiary sector. GDP is lowest in the primary sector.

The energy industry belongs to the secondary sector, which has the highest GDP among the three sectors. According to Lu, Lin Lawell and Song (2016), total energy consumption is highest in the secondary sector, followed by tertiary sector and primary sector. For the secondary sector, coal is the main energy resource consumed, followed by crude oil and electricity. Zheng and Luo (2013) show that the degree of correlation between total oil consumption and the output values of the primary and secondary sectors in China have declined over time, while those of tertiary sector have increased.

Figure 1. GDP of primary, secondary, and tertiary sectors

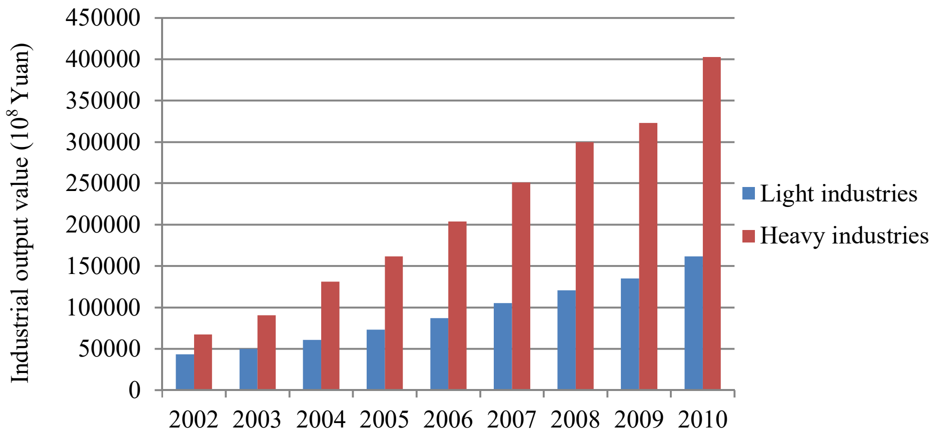


Data source: China Statistical Yearbook

Figure 2 plots the industrial output value of the light industries and the heavy industries, respectively, over the period 2002 to 2010. The light industries consist of the industries that produce consumer goods and hand tools. The heavy industries consist of a subset of the secondary sector, including mining and quarrying, electricity, water and gas, and some manufacturing. The energy industry belongs to the heavy industries.

As seen in Figure 2, the industrial output values for both the heavy industries and the light industries have increased over the period 2002 to 2010. The heavy industries have a higher industrial output value than the light industries.

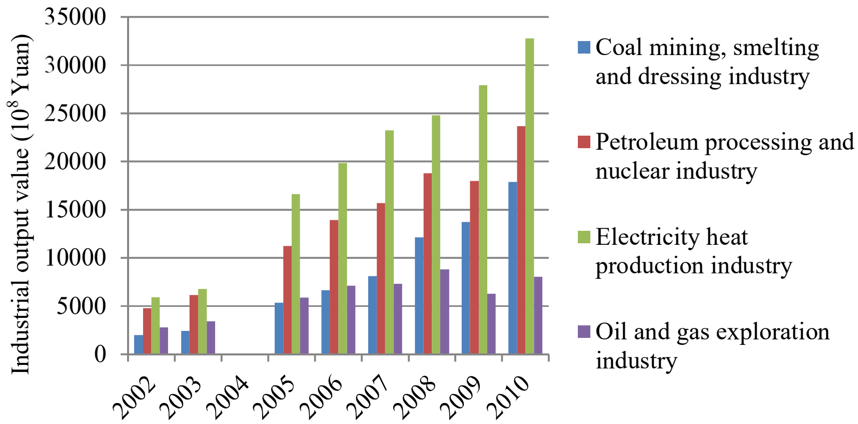
Figure 2. Industrial output value of light and heavy industries



Data source: China Statistical Yearbook

Figure 3 plots the industrial output value of the following traditional energy industries over the period 2002 to 2010: the coal mining, smelting, and dressing industry; the petroleum processing and nuclear industry; the electricity heat production industry; and the oil and gas exploration industry. According to Figure 3, the industrial output value of each of the traditional energy industries except for the oil and gas exploration industry has increased over time. Among the different energy industries, the electricity heat production industry has the highest industrial output value, followed by the petroleum processing and nuclear industry.

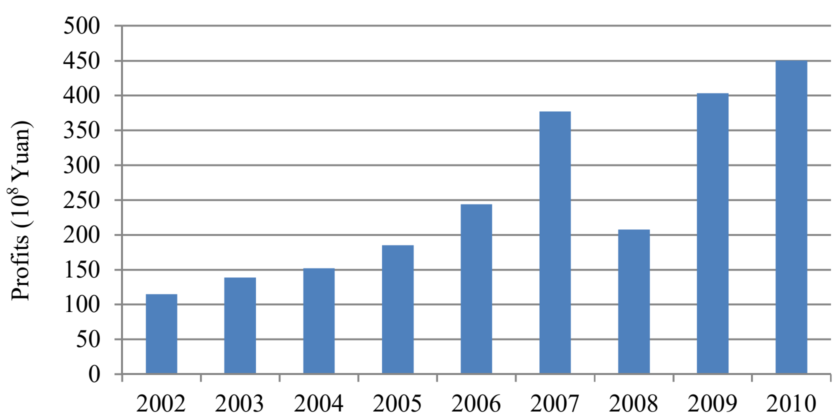
Figure 3. Industrial output value of traditional energy industries



Data source: China Industrial Economy Statistical Yearbook
Note: Data for 2004 is not available.

Figure 4 plots the profits of new energy companies in the Chinese stock market over the period 2002 to 2010. The new energy companies include renewable energy companies, biofuel companies, hydrogen fuel companies, wind companies, and solar companies traded on the Chinese stock market.

Figure 4. Profits of new energy companies in the Chinese stock market



Data source: Calculated with the data from http://stock.hexun.com/

3. Energy Policy in China

For our energy policies, we focus on six types of energy-related policies: clean production policies, audits, energy conservation policies, financial incentives, technological progress policies, and intellectual property rights policies. We choose to focus on these policies because they are among the more common types of energy policy in China. We describe each type of energy policy below.

3.1. Clean production

Clean production policies in China include measures which improve the design of clean production processes; which incentivize the use of clean energy and advanced technology in order to reduce pollution from energy consumption; which improve the efficiency of resource utilization; which reduce or avoid the emission of pollutants during production; and which encourage scientific research and technology innovation in clean production.

3.2 Audits

Audit policies are in place in a province when the province's energy conservation administrative department has the responsibility to supervise and deal with energy consumption activities. Some audit policies in some provinces are related to energy conservation evaluation and management for fixed assets investment projects; these projects are required to pass the energy conservation evaluation from the economic commission before they can be constructed. Other audit policies are for energy conservation products identification or enterprise energy supervision.

3.3 Energy conservation

In order to promote energy efficient development, a number of energy conservation policies have been issued in China. These policies provide overarching guidance for the energy conservation activities. Governments of each level have the responsibility to supervise the energy conservation activities of enterprises and departments of governments. Examples of energy conservation policies that have been implemented by various provinces in China include policies that encourage the adoption of energy conservation technology; reward enterprises which conserve resources; fine enterprises for wasting resources; and encourage water conservation.

3.4 Financial incentives

Energy policies implemented by various provinces in China that provide financial incentives include taxes and special funds.

Examples of province-level energy-related tax policies include policies that enable the corporate income tax to be deducted or exempted for energy conservation and environmental protection programs; policies that exempt investments in energy conservation and environmental protection equipment from the value-added tax; and policies that change the mode of energy resource taxation from a specific duty to an ad valorem tax. Most province-level tax policies implemented in China focus on energy conservation and on corporate income tax reduction for new energy industries.

Examples of energy-related special fund policies implemented by various provinces in China include an energy conservation special fund that is mainly used for the promotion of energy conservation technology, products, programs, and services; and a residential building energy conservation special fund that is used for the transformation of heating systems.

3.5 Technological progress

In order to promote technological progress, policies have been implemented to encourage R&D, especially by enterprises. Therefore, technological introduction, R&D and commercialization of technological research achievements in enterprises of different ownership are encouraged, particularly in private technological enterprises. Examples of technological progress policies and regulations that have been implemented by various provinces in China include regulations governing the progress of science and technology; policies to strengthen the commercialization of technological research achievements; and regulations to encourage technological introduction, absorption and innovation.

3.6 Intellectual property rights

Intellectual property rights include patents, trademarks, and copyrights as well as other intellectual property rights which are regulated by laws and regulations. The intellectual property rights policies in various provinces in China aim to protect patents and the interests of the patentee, and to promote technological progress. Examples of intellectual property rights policies and regulations implemented by various provinces in China include regulations on patent protection, patent management, intellectual property promotion, and improvements in the patent administration system.

4. Data

To analyze the effects of energy policies in China on GDP, industrial output, and the profits of new energy companies, we use panel data on GDP, industrial output values of several industries, and profits of new energy companies for 30 provinces from 2002 to 2010. Tibet, Taiwan, Hong Kong, and Macao are excluded from the analysis. Because of missing data prior to 2002, and owing to data limitations for more recent data, we limit the period of study to the period 2002 to 2010.

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. We obtained province-level data on total GDP and on the GDP for the primary, secondary, and tertiary sectors. We also obtained province-level data on the industrial output value of the light industries and the heavy industries, and the industrial output value of the following traditional energy industries: the coal mining, smelting, and dressing industry; the petroleum processing and nuclear industry; the electricity heat production and supply industry; and the oil and gas exploration industry.

Data on profits of new energy companies come from Hexun website.[2] The new energy companies include renewable energy companies, biofuel companies, hydrogen fuel companies, wind companies, and solar companies traded on the Chinese stock market. There are 162 companies in total. Owing to data limitations, we are unable to separately identify the profits

[2] http://stock.hexun.com/

an energy company earns from its new energy business from its total profit. Therefore, we use the total profits of the new energy companies to measure the output of the new energy industry. We aggregate the annual new energy profits to the province level.

Table 1 presents the summary statistics for the GDP, industrial output value, and new energy profits variables in the data set.

Table 1. Summary statistics for GDP, industrial output, and profit variables

	Obs	Mean	Std. Dev.	Min	Max
Total GDP (10^8 yuan)	270	7330	6687	329.3	38657
GDP of primary sector (10^8 yuan)	270	781.4	586.2	44.9	2948
GDP of secondary sector (10^8 yuan)	270	3651	3611	125.3	19335
GDP of tertiary sector (10^8 yuan)	270	2898	2773	125.3	17400
Industrial output value of light industries (10^8 yuan)	270	2891	4717	0	27613
Industrial output value of heavy industries (10^8 yuan)	270	6656	9069	0	54490
Industrial output value of coal mining, smelting, and dressing industry (10^8 yuan)	250	275.6	465.3	0.04	3727
Industrial output values of petroleum processing and nuclear industry (10^8 yuan)	270	449.3	528.9	0.06	3332
Industrial output value of electricity heat production and supply industry (10^8 yuan)	270	638.1	647.4	21.7	3753
Industrial output value of oil and gas exploration industry (10^8 yuan)	197	274.9	345.6	0.0725	1743
Profits of new energy companies (10^8 yuan)	270	8.421	14.44	-27.26	88.75

Note: All variables are at the province level.

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 2010. We also use the #90 gasoline retail price over the years 2002 to 2010. Table 2 presents the summary statistics for the energy prices variables in the data set.

Table 2. Summary statistics for energy prices

	Obs	Mean	Std. Dev.	Min	Max
Gasoline price (yuan) (2002 constant price)	205	5041	1178	2412	7514
Power price index (2002 constant price)	270	110.2	9.128	94.01	146.2
Coal price index (2002 constant price)	270	162.1	52.53	98.7	353.3
Petroleum price index (2002 constant price)	255	171.5	56.58	100	346.9

Note: All variables are at the province level.

We constructed a novel data set on energy 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. National energy policies are not included because their effects are absorbed in the year effects, and therefore cannot be separately identified. We focus on clean production policies, audits, energy conservation policies, financial incentives, technological progress policies, and intellectual property rights policies. We choose to focus on these six types of policies because they are among the most prevalent types of provincial energy policies in China. 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*.[3] Table 3 presents the summary statistics for our policy variables. Table 4 lists the years in which each type of policy was in place in each province.

Table 3. Summary statistics for policy variables

	Obs	Mean	Std.Dev.	Min	Max
clean production	270	0.226	0.419	0	1
audits	270	0.241	0.428	0	1
energy conservation	270	0.819	0.386	0	1
financial incentives	270	0.644	0.480	0	1
technological progress	270	0.941	0.237	0	1
intellectual property rights	270	0.596	0.492	0	1

Note: All variables are at the province level.

[3] 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. In future work we hope to develop measures to quantify the magnitude and/or stringency of the policies.

Table 4. Energy policies in China

	Clean production	Audit	Energy conservation	Financial incentives	Technological progress	Intellectual property rights
Beijing	2006-2010	none	2002-2010	2002-2010	2006-2010	2002-2010
Tianjin	2006-2010	2002-2010	2002-2010	2002-2010	2002-2010	2002-2010
Hebei	none	none	2002-2010	2002-2010	2002-2010	none
Shanxi	2005-2010	none	2002-2010	2002-2010	2002-2010	2002-2010
Inner Mongolia	none	2008-2010	2002-2010	2008-2010	2002-2010	none
Liaoning	none	none	2002-2010	2007-2010	2002-2010	2002-2010
Jilin	none	none	2002-2010	none	2002-2010	none
Heilongjiang	none	none	2002-2010	2006-2010	2002-2010	2004-2010
Shanghai	none	2002-2010	2002-2010	2002-2010	2002-2010	2002-2010
Jiangsu	none	none	2002-2010	2002-2010	2002-2010	2002-2010
Zhejiang	2002-2010	2008-2010	2002-2010	2006-2010	2002-2010	none
Anhui	none	2009-2010	2002-2010	2007-2010	2002-2010	2002-2010
Fujian	2008-2010	none	2002-2010	2008-2010	2002-2010	2004-2010
Jiangxi	2010	2009-2010	2002-2010	2007-2010	2004-2010	2010
Shandong	2010	2005-2010	2002-2010	2005-2010	2005-2010	2002-2010
Henan	none	2010	2002-2010	2002-2010	2002-2010	none
Hubei	none	2002-2010	none	2005-2010	2002-2010	2002-2010
Hunan	2010	none	2002-2010	2002-2010	2002-2010	2002-2010
Guangdong	none	none	2002-2010	2009-2010	2002-2010	2010
Guangxi	2002-2010	2007-2010	2008-2010	2002-2010	2002-2010	2002-2010
Hainan	none	none	none	2002-2010	2002-2010	2010
Chongqing	none	2008-2010	2007-2010	2005-2010	2009-2010	2007-2010
Sichuan	none	2006-2010	2002-2010	none	2002-2010	2002-2010
Guizhou	none	none	2004-2010	2002-2010	2002-2010	2003-2010
Yunnan	2004-2010	none	2002-2010	2002-2010	2002-2010	none

Shaanxi	none	none	2005-2010	2003-2010	2002-2010	2010
Gansu	none	none	2008-2010	none	2002-2010	2004-2010
Qinghai	2007-2010	2007-2010	2002-2010	2005-2010	2002-2010	2010
Ningxia	2007-2010	2006-2010	2002-2010	2007-2010	2002-2010	2003-2010
Xinjiang	2005-2010	none	none	none	2002-2010	2004-2010

Notes: This table lists the years in which each type of policy was in place in each province.

5. Econometric Model

To analyze the effects of energy policies in China on GDP, industrial output for several industries, and profits of new energy companies, we estimate the following fixed effects model with year effects for each GDP, output, or profit of type *j*:

$$\ln y_{ijt} = policies_{it}'\beta_1 + \beta_2 \sum_{\tilde{i} \neq i} y_{\tilde{i},j,t-1} + \ln energyprices_{it}'\beta_3 + \alpha_i + \tau_t + \varepsilon_{it},$$

where the dependent variable y_{ijt} is GDP, output, or profit of type *j* for province *i* in year *t*; $\sum_{\tilde{i} \neq i} y_{\tilde{i},j,t-1}$ is the time lagged spatial lag of the GDP, output, or profit of type *j* in province *i*, which we define as the sum of the GDP, output, or profit of type *j* of all the other provinces except province *i* at time *t-1*; $policies_{it}$ is a vector of energy policies; $energyprices_{it}$ is a vector of energy price variables; α_i is the province fixed effect; τ_t is the year effect; and ε_{it} 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 value of the light industries and the heavy industries; industrial output of the coal mining, smelting, and dressing industry; industrial output of the petroleum processing and nuclear industry; industrial output of the electricity heat production and supply industry; industrial output of the oil and gas exploration industry; and profits of new energy companies.

The vector $policies_{it}$ of energy policy variables include clean production policies, audits, energy conservation policies, financial incentives, technological progress policies, and intellectual property rights policies. We choose to focus on these six types of policies because they are among the most prevalent types of provincial energy policies in China. 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 the GDP, output or profit of type *j* in province *i*, which we define as the sum of the GDP, output or profit of type *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 in other provinces due to spillovers.

The vector $energyprice_{it}$ of energy price variables 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 government energy policies on GDP, output, and new energy 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) fixed effects model. For each policy type, we instrument for the policy variable for that policy type using the time lagged spatial lag of that policy type in province *i*, which we define as the sum of the policy variables of that policy type 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 lag of the GDP, output or profit of type *j* -- the time lagged spatial lag of policies of policies in other provinces has no effect on a province’s GDP, output or new energy 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 profit in that province, except through their effect on the province's current policies.[4] Thus, the instruments are correlated with policies in province *i* at time *t* and do not affect the GDP, output or new energy profit in province *i* at time *t* except through their effect on the policies in province *i* at time *t*.

The summary results for the first-stage regressions are presented in the bottom half of the results tables (Tables 5, 6, 7 and 8). All the first-stage F-statistics and Angrist-Pischke F-statistics are greater than 10. To test the validity of our instruments, we also conduct an under-identification test and weak-instrument-robust inference tests for each of the IV fixed effects models, and their results are presented in Tables 5, 6, 7 and 8. In all the IV fixed effects regressions, we reject under-identification as well as weak instruments. Since all equations are exactly identified, we cannot run a Sargan-Hansen test of over-identifying restrictions.

We choose to use fixed effects instead of random effects because we believe that time-invariant province unobservables are potentially correlated with the regressors; our choice was confirmed by results of Hausman tests which deemed fixed effects to be the more appropriate specification for regressions of 9 out of the 10 types of GDP, output, or profit. The p-values from the Hausman tests of the null hypothesis that the random effects and regressors are

[4] 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). If this is the case, then the time lagged spatial lag policies might not be a good instrument. 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.

uncorrelated are presented in the results tables (Tables 5, 6, 7 and 8).

6. Results

Tables 5, 6, 7, and 8 present the results from the IV fixed effects model, as well as results from a Hausman test of random effects versus fixed effects, an under-identification test, and weak-instrument-robust inference tests. As mentioned above, in all the IV fixed effects regressions, we reject under-identification as well as weak instruments.

We examine the effect of energy policies on the GDP, industrial output of several industries and profits of new energy companies in China. Table 5 presents the results of the IV fixed effects regressions of total GDP and of GDP in the primary, secondary, and tertiary sectors. Table 6 presents the results of the IV fixed effects regressions of industrial output value for light and heavy industries. Table 7 presents the results of the IV fixed effects regressions of the industrial output value for the following traditional energy industries: the coal mining, smelting, and dressing industry; the oil and gas exploration industry; the petroleum processing and nuclear industry; and the electricity heat production industry. Table 8 presents the results of the IV fixed effects regressions of the profits of new energy companies.

According to our results, clean production policies increase the GDP of the tertiary sector (which includes transport and other services) and increase the industrial output value of petroleum processing and nuclear industry; but decrease the GDP of the primary sector (which consists of the agriculture, forestry, animal husbandry, and fishery industries) and decrease the industrial output value of the light industries (which consist of the industries that produce consumer goods and hand tools). Having a clean production policy in place increases the

GDP of the tertiary sector by 9.63%; increases the industrial output value of the petroleum processing and nuclear industry by 34.5%; decreases the GDP of the primary sector by 14.9%; and decreases the industrial output value of the light industries by 28.5%.

Audit policies increase the industrial output value of petroleum processing and nuclear industry. Having an audit policy in place increases the industrial output value of petroleum processing and nuclear industry by 46.9%.

Energy conservation policies increase the GDP of the secondary sector, which consists of the mining and quarrying, manufacturing, electricity, water and gas, and construction industries. Having an energy conservation policy in place increases the GDP of the secondary sector by 20.9%.

Financial incentive policies do not have a significant effect on any of the GDP or industrial output measures we examined, nor do they have a significant effect on new energy profit.

Technological progress policies increase the industrial output value of the electricity heat production and supply industry and increase the industrial output value of the oil and gas exploration industry; but decrease the GDP of the primary sector (which consists of the agriculture, forestry, animal husbandry, and fishery industries), decrease the GDP of secondary sector (which consists of the mining and quarrying, manufacturing, electricity, water and gas, and construction industries), and decrease the industrial output value of the light industries (which consist of the industries that produce consumer goods and hand tools). In particular, having a technological progress policy in place increases the industrial output value of electricity heat production and supply industries by 24.7%; increases the industrial output value of oil and gas exploration industries by 151.5%; decreases the GDP of the primary sector by 13.1%; decreases the GDP of secondary sector by 19.1%; and decreases the industrial output value of the light industries by 40.4%.

Intellectual property rights policies decrease GDP. Having an intellectual property rights policy in place decreases GDP by 16.8%.

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)
Policy Variables				
clean production	0.0703	-0.149**	0.0327	0.0963*
	(0.0378)	(0.0525)	(0.0487)	(0.0463)
audits	0.0500	0.0671	0.0907	0.0509
	(0.0362)	(0.0497)	(0.0491)	(0.0439)
energy conservation	0.0744	0.00125	0.209**	-0.0719
	(0.0601)	(0.0838)	(0.0796)	(0.0723)
financial incentives	0.0611	0.101	0.0744	0.0457
	(0.0429)	(0.0579)	(0.0548)	(0.0520)
technological progress	-0.0160	-0.131*	-0.191**	0.0375
	(0.0515)	(0.0621)	(0.0624)	(0.0596)
intellectual property rights	-0.168*	-0.0550	-0.107	-0.129
	(0.0750)	(0.112)	(0.102)	(0.0904)
Economic Variables				
gasoline price	-0.0534	-0.0539	0.0112	-0.130*
	(0.0541)	(0.0742)	(0.0710)	(0.0641)
power price by region	0.433	0.842*	0.574	0.186
	(0.300)	(0.418)	(0.393)	(0.375)
coal price by region	0.199**	0.213*	0.183*	0.178*
	(0.0675)	(0.0912)	(0.0863)	(0.0809)
petroleum price by region	-0.00275	-0.0513	-0.0722	0.0338
	(0.0680)	(0.0931)	(0.0889)	(0.0810)

time lagged spatial lag of dependent variable	-14.24***	-12.20**	-17.66***	-10.16***
	(2.314)	(3.698)	(2.287)	(1.801)
Province fixed effects	Y	Y	Y	Y
Year effects	Y	Y	Y	Y
p-value from Hausman test of random effects vs. fixed effects	[0.0004]***	[0.0366]*	[0.0000]***	[0.0012]**
p-value from under-identification test	[0.0000]***	[0.0000]***	[0.0000]***	[0.0000]***
Angrist-Pischke first-stage F-statistics:				
clean production	58.02	55.92	59.96	54.85
audits	85.33	82.19	84.22	83.30
energy conservation	84.81	87.85	81.17	81.39
financial incentives	39.64	40.89	42.04	38.27
technological progress	83.02	97.93	91.31	88.32
intellectual property rights	33.62	28.10	31.29	32.81
p-values from weak instrument-robust inference tests:				
Anderson-Rubin Wald F test	[0.0029]**	[0.0001]***	[0.0000]***	[0.0055]**
Anderson-Rubin Wald Chi-sq test	[0.0004]***	[0.0000]***	[0.0000]***	[0.0011]**
Stock-Wright LM test	[0.0020]**	[0.0001]***	[0.0000]***	[0.0038]**
Observations	164	164	164	164
R-squared	0.978	0.893	0.964	0.972

Notes: Robust standard errors in parentheses. For each policy type (clean production, audits, energy conservation, financial incentives, technological progress, intellectual property rights), we instrument for the policy variable for that policy type using the time lagged spatial lag of that policy type in province i, which we define as the sum of the policy variables of that policy type over all the other provinces except province i at time $t-1$. We define the time lagged spatial lag of the GDP, output or profit of type j in province *i* as the sum of the GDP, output or profit of type *j* of all the other provinces except province *i* at time *t-1*. Significance codes: *5% level, **1% level, and ***0.1% level.

Table 6. Results for industrial output value of light and heavy industries

	Dependent variable is log industrial output value of:	
	Light industries	*Heavy industries*
	(5)	(6)
Policy Variables		
clean production	-0.285**	-0.0664
	(-0.0898)	(0.0860)
audits	0.140	0.139
	(0.108)	(0.0993)
energy conservation	-0.103	-0.0201
	(0.113)	(0.114)
financial incentives	0.0583	0.127
	(0.118)	(0.106)
technological progress	-0.404*	-0.242
	(0.194)	(0.172)
intellectual property rights	-0.0553	-0.140
	(0.160)	(0.141)
Economic Variables		
gasoline price	0.277	-0.0469
	(0.796)	(0.742)
power price by region	-0.991	1.088
	(0.702)	(0.663)
coal price by region	0.469**	0.391*
	(0.177)	(0.161)
petroleum price by region	-0.0992	-0.316*
	(0.147)	(0.146)
time lagged spatial lag of dependent variable	-15.72***	-13.79***
	(3.186)	(3.055)
Province fixed effects	Y	Y
Year effects	Y	Y
p-value from Hausman test of random effects vs. fixed effects	[0.0000]***	[0.0000]***
p-value from under-identification test	[0.0002]***	[0.0000]***
Angrist-Pischke first-stage F-statistics:		
clean production	36.22	40.47
audits	102.06	100.91
energy conservation	33.79	40.67
financial incentives	21.65	26.58
technological progress	29.44	37.38

intellectual property rights	34.65	44.22
p-values from weak instrument-robust inference tests:		
Anderson-Rubin Wald F test	[0.0005]***	[0.2039]
Anderson-Rubin Wald Chi-sq test	[0.0000]***	[0.1056]
Stock-Wright LM test	[0.0004]***	[0.1496]
Observations	121	121
R-squared	0.959	0.977

Notes: Robust standard errors in parentheses. For each policy type (clean production, audits, energy conservation, financial incentives, technological progress, intellectual property rights), we instrument for the policy variable for that policy type using the time lagged spatial lag of that policy type in province i, which we define as the sum of the policy variables of that policy type over all the other provinces except province i at time $t-1$. We define the time lagged spatial lag of the GDP, output or profit of type j in province i as the sum of the GDP, output or profit of type j of all the other provinces except province i at time $t-1$. Significance codes: *5% level, **1% level, and ***0.1% level.

Table 7. Results for industrial output value of traditional energy industries

	Dependent variable is log industrial output value of:			
	Coal mining, smelting, and dressing industry	*Petroleum processing and nuclear industry*	*Electricity heat production and supply industry*	*Oil and gas exploration industry*
	(7)	(8)	(9)	(10)
Policy Variables				
clean production	0.549	0.345*	-0.0601	0.187
	-0.299	(0.142)	(0.0722)	(0.286)
audits	-0.178	0.469**	0.0154	-0.335
	(0.277)	(0.154)	(0.0705)	(0.282)
energy conservation	0.0580	0.125	0.00712	0.513
	(0.466)	(0.240)	(0.120)	(0.552)
financial incentives	-0.281	-0.168	-0.0448	-0.133
	(0.307)	(0.165)	(0.0794)	(0.299)
technological progress	-0.140	-0.216	0.247**	1.515***
	(0.365)	(0.185)	(0.0890)	(0.394)
intellectual property rights	0.514	0.275	-0.141	0.697
	(0.583)	(0.295)	(0.157)	(0.595)
Economic Variables				
gasoline price	0.374	0.0404	0.0226	0.427
	(0.427)	(0.211)	(0.104)	(0.403)
power price by region	2.673	-1.768	-0.521	3.966
	(2.850)	(1.153)	(0.574)	(2.325)
coal price by region	0.0382	0.315	0.00130	1.255*
	(0.586)	(0.256)	(0.126)	(0.517)

petroleum price by region	-0.386	-1.371***	-0.00788	0.682
	(0.545)	(0.266)	(0.130)	(0.494)
time lagged spatial lag of dependent variable	-1.470	-5.773*	-13.25***	-8.449**
	(2.129)	(2.804)	(1.904)	(2.731)
Province fixed effects	Y	Y	Y	Y
Year effects	Y	Y	Y	Y
p-value from Hausman test of random effects vs. fixed effects	[0.1201]	[0.0000]***	[0.0019]**	[0.0028]**
p-value from under-identification test	[0.0000]***	[0.0000]***	[0.0000]***	[0.0000]***
Angrist-Pischke first-stage F-statistics:				
clean production	51.48	64.55	58.10	59.08
audits	78.95	81.21	79.26	31.73
energy conservation	81.60	70.78	82.35	64.84
financial incentives	51.63	40.62	42.91	30.59
technological progress	83.36	90.80	93.96	46.80
intellectual property rights	46.55	32.61	27.91	23.08
p-values from weak instrument-robust inference tests:				
Anderson-Rubin Wald F test	[0.3552]	[0.0017]**	[0.1566]	[0.0000]***
Anderson-Rubin Wald Chi-sq test	[0.2506]	[0.0002]***	[0.0903]	[0.0000]***
Stock-Wright LM test	[0.2873]	[0.0012]**	[0.1189]	[0.0000]***
Observations	151	164	164	127
R-squared	0.732	0.865	0.964	0.637

Notes: Robust standard errors in parentheses. For each policy type (clean production, audits, energy conservation, financial incentives, technological progress, intellectual property rights), we instrument for the policy variable for that policy type using the time lagged spatial lag of that policy type in province *i*, which we define as the sum of the policy variables of that policy type over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the GDP, output or profit of type *j* in province *i* as the sum of the GDP, output or profit of type *j* of all the other provinces except province *i* at time *t-1*. Significance codes: *5% level, **1% level, and ***0.1% level.

Table 8. Results for profits of new energy companies

	Dependent variable is *log profits of new energy companies* (11)
Policy Variables	
clean production	-0.960
	(0.571)
audits	-0.794
	(0.479)
energy conservation	0.339
	(1.133)
financial incentives	-0.0573
	(0.558)
technological progress	-0.239
	(0.688)
intellectual property rights	-0.439
	(1.293)
Economic Variables	
gasoline price	-0.468
	(0.692)
power price by region	0.0979
	(4.828)
coal price by region	0.0717
	(0.923)
petroleum price by region	-0.0772
	(0.994)
time lagged spatial lag of dependent variable	-3.673*
	(1.825)
Province fixed effects	Y
Year effects	Y
p-value from Hausman test of random effects vs. fixed effects	[0.0950]
p-value from under-identification test	[0.0008]***
Angrist-Pischke first-stage F-statistics:	
clean production	29.02
audits	32.81
energy conservation	51.97

financial incentives	25.57
technological progress	47.35
intellectual property rights	15.57
p-values from weak instrument-robust inference tests:	
Anderson-Rubin Wald F test	[0.0977]
Anderson-Rubin Wald Chi-sq test	[0.0408]*
Stock-Wright LM test	[0.0667]
Observations	138
R-squared	0.365

Notes: Robust standard errors in parentheses. For each policy type (clean production, audits, energy conservation, financial incentives, technological progress, intellectual property rights), we instrument for the policy variable for that policy type using the time lagged spatial lag of that policy type in province *i*, which we define as the sum of the policy variables of that policy type over all the other provinces except province *i* at time *t-1*. We define the time lagged spatial lag of the GDP, output or profit of type *j* in province *i* as the sum of the GDP, output or profit of type *j* of all the other provinces except province *i* at time *t-1*. Significance codes: *5% level, **1% level, and ***0.1% level.

7. Conclusion

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

This paper examines the effects of energy policies in China on GDP, industrial output, and new energy profits. In particular, we analyze the effects of clean production policies, audit policies, energy conservation policies, financial incentive policies, technological progress policies and intellectual property rights policies on GDP, the industrial output of several industries and the profits of new energy companies. We use instruments to address the potential endogeneity of the policies.

According to our results, clean production policies increase the GDP or industrial output value of the transport, services, petroleum processing, and nuclear industries; but decrease the GDP or industrial output value of the agriculture, forestry, animal husbandry, fishery industries, and consumer goods and hand tools industries.

Audit policies increase the industrial output value of petroleum processing and nuclear industry. Energy conservation policies increase the GDP of the secondary sector, which consists of the mining and quarrying, manufacturing, electricity, water and gas, and construction industries. Financial incentive policies do not have a significant effect on any of the GDP or industrial output measures we examined, nor do they have a significant effect on new energy profit.

Technological progress policies increase the GDP or industrial output value of the electricity heat production, electricity heat supply, oil exploration, and gas exploration industries; but decrease the GDP or industrial output value of the agriculture, forestry, animal husbandry, fishery, manufacturing, water and gas, construction, consumer goods, and hand tools industries. Intellectual property rights policies decrease GDP.

We find that, contrary to conventional wisdom, energy and environmental policies do not necessarily lead to a decrease in GDP or output. Consistent with the Porter hypothesis, our results show that clean production policies, audit policies, energy conservation policies, and technological progress policies increase the GDP and/or industrial output value of some traditional energy industries, suggesting that these policies do not necessarily decrease the output of traditional energy industries. Environmental regulation may increase 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 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, energy policies can decrease the GDP and/or industrial output value of some non-energy industries. Clean production policies decrease the GDP or industrial output value of the agriculture, forestry, animal husbandry, fishery industries, and consumer goods and hand tools industries. Technological progress policies decrease the GDP or industrial output value of the agriculture, forestry, animal husbandry, fishery, manufacturing, water and gas, construction, consumer goods, and hand tools industries. Intellectual property rights policies decrease GDP.

None of the policies we examined has a significant effect on the profits of new energy companies. There are two possible explanations why the energy policies examined in this paper do not have a positive effect on the profits of new energy companies. First, most of the new energy companies we examine engage in other forms of production as well, and the new energy business profit is only a small fraction of the companies' total profits. The other sources of profit for these companies might come from energy-intensive activities. Since we only observe the total profits of new energy companies, we are unable to separate out the new energy portion of the profits from the profits from other activities that new energy companies engage in. It is therefore possible that the energy policies do not increase the profits of new energy companies because they decrease the profits from the new energy companies' other energy-intensive activities.

A second possible reason why the energy policies examined in this paper do not have a positive effect on the profits of new energy companies is that the production process of new energy products is not environmental friendly (CCTV, 2008). For example, the production process of polysilicon, an important raw material of the photovoltaic industry, forms a large amount of high pollution by-product, such as four chlorinated silicon trichlorosilane and hydrogen chloride. Thus, energy and environment policies that regulate the pollution from the production of new energy may decrease the profits of new energy companies.

In future work, we hope to quantify the stringency and extent of various energy policies in order to further examine the relationships between energy policies and GDP, industrial output, and new energy profits in China. We also hope to further analyze and tease out the mechanisms through which various energy policies affect GDP, industrial output, and new energy profits in China.

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