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**Article**

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China Finance and Economic Review

**Provided in Cooperation with:**

Springer Nature

*Suggested Citation:* Mao, Jie; Wang, Chunhua (2016) : Tax incentives and environmental protection: Evidence from China's taxpayer-level data?, China Finance and Economic Review, ISSN 2196-5633, Springer, Heidelberg, Vol. 4, pp. 1-30,  
<https://doi.org/10.1186/s40589-016-0040-0>

This Version is available at:

<https://hdl.handle.net/10419/194310>

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# Tax incentives and environmental protection: evidence from China's taxpayer-level data

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## Abstract

**Background:** Since 2008, China has provided ITC (investment tax credit) and TID (taxable income deduction) for firms who engage in investment or business related to reducing pollution emissions and saving energy. This paper examines both incidence and effects of these tax incentives.

**Methods:** We use a unique panel dataset mainly from the NTSD (the National Tax Statistics Dataset of China) over 2007–2011, and utilize the Probit Model and the specification suggested by Greenstone (2002) to identify incidence and effects of the ITC and TID, respectively.

**Results:** We find that: (1) The two tax incentives are generally not popular. SOEs are the main beneficiaries, while regional characteristics have no impact on taxpayers' attitude to ITC or TID. The mechanism behind may be that the incentives hurt interests of firms and local governments. (2) Their effects on taxpayers' activities including capital, employment, and production are not remarkable, while growth of coal consumption significantly speeds up. These findings are robust to multiple specifications of using different empirical strategies, samples, and variables. (3) However, the results indicate that the tax incentives do serve the purpose of protecting environment by restraining coal consumption in some specific group of firms who are affiliated to the central government. This finding confirms a simple model established in the paper that emphasizes the importance of the government's executive power on tax policies and relates to the literature finding that local support can remarkably boost the efficiency of tax incentives for environmental protection.

**Conclusions:** According to the above findings, we conclude that the tax incentives such as ITC or TID can be effective tools to protect China's environment if correctly designed and adequately implemented.

**Keywords:** Tax incentives, Environmental protection, China

**JEL Classification:** H23, Q58, H30

## Introduction

Tax policy is usually more efficient or less distorted than direct regulation, for the former retains individuals' rights to choose utility-maximizing or cost-minimizing solutions (Tresch 2015, page 129). To achieve certain goals of environmental protection, many countries have used various tax policies. Besides Pigovian taxes, others such as tax

credits for specific investment on projects of limiting emissions have been widely implemented. Empirical studies on effects of these policies, however, are far from reaching consensus (see, e.g., Metcalf 2010; Murray et al. 2014; Roach 2015). This paper investigates incidence (i.e., who are beneficiaries) and effects of two environment-related tax incentives practiced in China since 2008. One is tax credit for investment on equipment for environmental protection. The other is deduction for taxable incomes from projects related to environmental protection.

After more than 30 years of extraordinarily rapid economic growth, China is facing severe environmental degradation. The combustion of fossil fuels (mainly coal) and many industrial processes release large amounts of air, water, and solid pollutants. China is now one of the world's largest emitters of sulfur dioxide (Huang et al. 2010). Major rivers are organically polluted, while major lakes are also severely polluted by total nitrogen and phosphorus. Additionally, air pollution causes dust haze across the country, especially in North China where the country's main region of coal production and consumption is. It has even caused concerns in neighboring countries such as South Korea (Jia and Ku 2016).

As a developing country, China is trying to improve environmental quality while simultaneously promoting economic growth. Like other nations such as the USA and India, tax policies play a role in the Chinese government's efforts to protect the environment. China initiated two environment-friendly tax incentives in the 2007's Amendment of China's Corporate Income Tax Law. They are investment tax credit (ITC) and taxable income deduction (TID), both of which are directly associated with pollution alleviating or energy saving. It is still an open question, however, whether or not these policies have achieved their purposes.

To that end, we construct a comprehensive and unique taxpayer-level<sup>1</sup> dataset over 2007–2011 mainly from the National Tax Statistics Dataset of China (NTSD), complemented by related data at the industry or region level. NTSD includes rich firm-level information, like beneficiary and tax break<sup>2</sup> of ITC or TID, as well as firms' basic characteristics and performance. These firms come from different sectors, including manufacturing, agricultural, building, mining, and services. We focus on manufacturing firms for they are the main producers of pollutants. This paper's main sample is a balanced panel consisting 43,000 observations from manufacturing firms in the key polluting industries. The rich data aforementioned avoid the problems or challenges in empirical analysis, such as self-selection in the sample, measurement error of tax incentives, or omitted variable bias.

The empirical strategies underlying our research are the Probit model and the method suggested by Greenstone (2002). We use the former model to figure out who are beneficiaries of the tax incentives and use the latter to check their effects on firms' activities.<sup>3</sup> We find that both incentives are generally not popular. The average probability of being a beneficiary is below 1 % over 2009–2011, the years just after the ITC and TID are in practice. State-owned enterprises (SOEs), however, are more likely to benefit from them. In addition, regional characteristics like local economic and fiscal conditions have no impact on spread of the tax incentives. We then investigate the reason why these incentives are not well welcomed by firms. We find that the incentives are negatively correlated with firm's profitability, which suggests that environmental investment may hurt its capacity of earning profits.

Furthermore, the effects of the tax incentives on taxpayers' activities, including capital accumulation, employment, and production, are not remarkable. On average, the incentives even increase coal consumption. The findings are robust to multiple specifications of the empirical model. We find that, however, one of the incentives, ITC, does serve the purpose to protecting environment by restraining coal consumption in specific group of firms which are affiliated to the central government. We build a theoretical model to explain this finding, that is, the government's executive power of taxation plays an important role in effects of tax incentives on environmental protection. As our empirical results indicate, this executive power in China mainly depends on the relationship or connection between firms and the central government. It also relates to the fact found by the literature (Greenstone and Hanna 2014) that local support can boost efficiency of tax incentives for environmental protection.

This paper is closely related to a large body of literature about tax incentives. Hall and Jorgenson (1967) present a model of user cost. They point out that the user cost of investment is a function of factors including interest rate, relative price and depreciation rate of investment goods, and tax treatment of capital income. Thus, if a tax policy such as ITC can reduce user cost, it will then encourage investment. Some researches (Abel 1982; Sen and Turnovsky 1990; Auerbach and Hassett 1991; Nielsen and Sorensen 1991; Meyer et al. 1993) find evidences supporting Hall and Jorgenson's model. In a general equilibrium model, Bovenberg and Goulder (1993) further find that for the domestic welfare, ITC should be favored over cuts in the corporate tax rate. Goolsbee (1998), however, provides a different story. Using a model based on Poterba (1984), he concludes that ITC only causes sharp increases in prices of investment goods, but the investment itself is relatively inelastic, which implies that main benefits from ITC go to capital suppliers through higher prices but rather to investing firms. More alarmingly, Murray et al. (2014) find \$10 billion per year of tax incentives, including production and investment tax credits for renewable electricity as well as tax credits for production and use of biofuels, have a tiny impact on greenhouse gas emissions, and may increase emissions in some cases.

Some papers complicate the debate on the relationship between ITC and investment. Hassett and Metcalf (1999) consider whether the uncertainty of changes in ITC influence the level of investment and find that policy uncertainty in the form of a fluctuating ITC may not reduce capital formation. Chirinko and Wilson (2008) are concerned with spillovers of ITC and find that a state's capital formation decreases with the user cost prevailing in the state but increases with those in competitive states, implying that ITC may be a zero-sum game among decentralized regions. Assibey-Yeboah and Mohsin (2011) concern macroeconomic effects of ITC, and they find that, in a developing economy who is small and open, and with external debt and sovereign risk, ITC may stimulate aggregate consumption, capital accumulation, foreign debt and output in the long run, while employment exhibits only transitional dynamics and no long-run change.

This line of literature also gives great attention to the difference between temporary and permanent ITC. Sen and Turnovsky (1990) argue that a permanent ITC should lead to a higher equilibrium capital stock, higher employment, and larger output, and a temporary ITC may have opposite effects. House and Shapiro (2008) disagree the argument above, however. Using a tax policy of bonus depreciation as external shock, House and Shapiro estimate the investment supply elasticity, and find that with a temporary ITC, investment in qualified capital increases sharply. Altug et al. (2009)'s conclusion is

quite distinctive. They find that a temporary or low policy-persistence ITC generally increases variability of investment both in the short run and in the long run, which means that a temporary ITC is not always related to higher level of investment but always leads to more volatile investment.

Some papers study other aspects of ITC's economic influence. Lyon (1989) develops a model showing that ITC should have a theoretically ambiguous effect on firm value, and his empirical tests find the changes in firm value are positively related to the expected receipt of ITC. Meyer et al. (1993) talk over how to design an ITC that can not only preserve as much of its long-run advantage but also lose the least possible federal revenue. Agrawal et al. (2014) find that small Canadian firms are quite sensitive to R&D tax credits. Huang (2014) demonstrates that tax credits used by Taiwanese firms have enhanced their productivity, especially for electronics business. Roach (2015) considers the role of market regulation, and finds that regions with deregulated electricity markets response more zealously to tax incentives than their regulated counterparts.

Another line of literature this paper is linked to is study on the effects of environment-related policy or regulation, especially those about tax policy. Hassett and Metcalf (1995) suggest that the energy tax credit is statistically significant in explaining the probability of investing, i.e., increasing the federal credit by 10 percentage points will increase the percentage of households claiming for the conservation investment credit from 5.7 to 7.1 %. Greenstone (2002)'s momentous work examines the impacts of a certain environment regulation implemented by the USA since the 1970s on growth of employment, capital stock, and shipments across different regions, providing a panorama of actual economic effects caused by the regulation. He finds that nonattainment counties who are strictly regulated lose more jobs, capital stock and output, compared to attainment ones, and the finding is robust to many specifications and subsamples of polluting industries. Bovenberg et al. (2008) argue that the relative advantages of the command-and-control policies and emissions taxes (like fuel taxes) depend on the extent of required abatement or compensation paid by the government to polluters. Metcalf (2010) finds that wind investment is strongly responsive to changes in tax policy like the federal production tax credit.

Our paper contributes to the above literature from four aspects as below. First, we establish a simple model to theoretically identify the effect of tax incentives such as ITC and TID on energy conservation, which has not been carefully discussed in the literature whose main attentions have been paid to the effect on investment or employment. Although it is only schematic, the model has realistic basis for related assumptions and definitely shows the conditions under which the tax incentives can slow down energy consumption.

Second, we construct a comprehensive and unique micro-level data file, to avoid the problems or challenges faced by the literature, like self-selection of sample, measurement error of tax incentives, or omitted variable bias. We merge data from various sources into a dataset to identify incidence and effects of the environment-related tax incentives in China. They include taxpayer-level information about beneficiary and tax break of ITC or TID, as well as industry-level and regional data.

Third, we adopt the empirical strategy used by Greenstone (2002) to accurately identify effects of the tax incentives. As well known, a firm or individual's response to a tax policy is usually endogenously related to its or her activities. Greenstone's method uses

information of pretreatment as key explanatory variables, removing potential circular causality in estimation. More importantly, as suggested by Greenstone, using weighted growth of dependent variables helps us control the bias caused by structural changes in the sample, like birth and death of firms or merger and acquisition among firms.

Lastly, the paper complements the literature with new and more comprehensive evidence from a developing country. It investigates both who benefit from the tax policies and what effects of these incentives on firms' activities are. The former issue is usually ignored by the literature, while the latter is studied with data mainly from developed countries. We first pin down factors determining the incidence of ITC and TID and then discuss mechanisms behind. As to their impacts, we regard capital accumulation, employment, energy consumption, and production.

The remainder of the paper is organized as follows. Section "Institutional background and theoretical discussion" introduces the institutional background about the tax incentives implemented by the Chinese government since the year 2008, and theoretically discusses their impact on energy consumption. Section "Data" describes our data. Section "Who are beneficiaries: empirical strategy and results" studies the incidence of them, as well as the related mechanism behind. Section "Effects of the tax incentives: empirical strategy and results" explores their effects on activities of taxpayers and discusses the key findings. The last section concludes the paper.

## Background

To stimulate local governments to promote economic development, China's central government adopted the FCS (fiscal contract system or *cai zheng bao gan* in Chinese) soon after the reform and opening up in the late 1970s. A decade-long history of unified state control over fiscal revenues and expenditures (*tongshou tongzhi* in Chinese) since the 1960s resulted in weak fiscal capacity of local governments, which limited the role they could play in local economic growth. Regarding the huge success of household contract responsibility system (*jiating lianchan chengbao zerenzhi* in Chinese) in rural areas, the central government made a decision to graft the experience of reform in rural to fiscal system, allowing subnational governments, including provinces, prefectures, and counties, to reserve the rest of local tax revenues after handing in a certain amount of funds to the central government (Jin et al. 2005). Under the FCS, both of firms and local governments benefited in that they were given the right to negotiate with the central government on how much they should turn in, instead of handing all profits to the central government under the old system of unified state control over fiscal revenues and expenditures. However, tax resources were often hidden by local governments, and the central government gradually lost its fiscal capacity (Zhang and Zou 1998; Qiao et al. 2008).

To avoid fiscal crisis and regain its authority in regulating economic and social development, the central government started an important tax reform in 1994, the tax-sharing reform (*fen shui zhi* in Chinese). Thousands of national tax bureaus were established to take charge of main taxes such as value-added tax and corporate income tax. Meanwhile, it became the sole tax legislative authority, laying down the laws or provisional regulations for all types of taxes.

Centralization of fiscal capacity and taxation legislation helps the central government manage to play a key role in China's economic growth during the last decades (Yang and



Yang 2012). At the same time, however, it sacrifices discretion of local governments and imposes fiscal pressure on them (Jia et al. 2014). To motivate locals to develop economy or fulfill the tasks assigned by the central government, hundreds of tax preferences are given to different regions or firms. For instance, before 2008, to attract foreign direct investments, foreign companies as well as those funded by sources from Hong Kong, Macao, and Taiwan (HMT) were once allowed to pay income taxes at a lower rate than that for domestic firms. It causes great distortion in investors' behaviors (An 2012).

In March 2007, China enacted the *Amendment of Enterprise Income Tax Law of the People's Republic of China*, which tried to unify the tax system for foreign and domestic enterprises. Most of the existing tax preferences would expire after a 5-year transition period, and some general or indiscriminative new tax policies were put into effect. Among them, there are two tax incentives related to pollution alleviating and energy saving. They are recorded in Paragraph 3, Article 27 and Article 34, respectively. It is the first time during the last decades for the Chinese government to protect environment through formal and explicit tax legislation.<sup>4</sup>

One of them is tax credit for investment on equipment for environmental protection or ITC. The law allows that 10 % of investment in specific equipment used for reducing pollution emissions or saving energy can be credited for corporate income tax. The other is deduction for taxable incomes from the projects related to environmental protection or TID. The projects include those for public wastewater treatment, public waste disposal, development and utilization of biogas, technical transformation for energy conservation and emissions reduction, and sea water desalinization.

Both incentives have been effective since January 1, 2008, and there is no deadline for expiration. Thus, we can consider them as permanent tax incentives, which are usually found by the literature to have strong impacts on economic activities. Their impacts on energy consumption, however, have not been fully examined. We develop a simple economic model in Additional file 1. It shows that, they may restrain energy consumption when the government has great executive strength of the tax incentives.<sup>5</sup> If that is the case, ITC or TID should have positive impact on environmental protection for some group of firms like central enterprises that are closely tied with the central government.

Besides, other things may also have influence. One is local support. Goals like environmental protection are usually ignored or perfunctorily treated by local firms or governments in China, who put profits or economic growth first. Jia (2012) finds some supporting evidences. ITC and TID may be also in the list, since they are made by the central government, but not by locals. The other is environment-related public services. They are usually more effective than those provided by the private sector, for the former can treat externality better (Agrawal et al. 2015). Lack of these services may weaken incentives for firms to respond to the tax incentives.<sup>6</sup>

## Data

We draw data from three sources. The first one is annual waves of the NTSD, jointly collected by the State Administration of Taxation (SAT) and the Ministry of Finance (MOF). Since 2007, the size of the sample is increased to raise representativeness of the data, and the sampling methods<sup>7</sup> and major variables are kept consistent over time. We use the data over 2007–2011 from the NTSD, a period just before and after implementation of ITC and TID.<sup>8</sup>

The representativeness of the data is discussed as below. On the one hand, as shown in Additional file 2: Table S1, the NTSD represents about 64 % of total output, 68 % of total value added, 62 % of total tax revenues, and 30 % of total urban employment, of the whole nation. The representativeness is fairly stable over time. On the other hand and more importantly, the NTSD covers firms from all sectors and regions in China and includes various categories of economic entities. The dataset includes 906 of totally 913 four-digit industries,<sup>9</sup> which belong to 95 two-digit sectors (there are totally 95 two-digit sectors). Among observations from these industries, 43.97 % belong to the manufacturing sector, 48.84 % belong to the service sector, and the rest belong to the agricultural, mining, and building sectors. Firms in the NTSD come from 31 provinces and 333 prefectures, not missing any region across the country. Furthermore, our sample consists of small, medium, and large firms. Twenty-five percent of the firms in the dataset employed no more than 10 employees, while 8.97 % had sales not exceeding 5 million Yuan a year, which is a remarkable merit compared to other datasets like the *Chinese Industrial Enterprises Dataset* that only includes above-scale manufacturing firms. Composition of ownership is also multiple, including SOEs (i.e., state-owned enterprises), foreign enterprises, HMT enterprises (i.e., owned by funds from Hong Kong, Macau, or Taiwan), incorporated companies, private firms, and other firms such as collective-owned or self-employment. Therefore, the NTSD nicely mirrors dynamic of the economy across industries and regions in China.

For later empirical investigations, we rely on the NTSD for information about the tax incentives and firm's activities. Key variables include location where a firm operates, industry that it belongs to, ITCdummy (dummy for ITC), TIDdummy (dummy for TID), ITCterm (tax break brought by ITC),<sup>10</sup> TIDterm (tax break brought by TID), ownership, age, employment size, wage, investment, capital stock, consumption of coal and fuel, return on assets (ROA), and (producing) capacity.<sup>11</sup> Some industry-level information in the data is also used to measure industry average wage and industry agglomeration. These variables are thought as important factors in evaluating effects of environmental regulation or policies (Goolsbee 1998; Greenstone 2002; House and Shapiro 2008).

Before applying the data for estimations, we do some data cleaning. First, we unify the industry classification standard before and after the year 2011.<sup>12</sup> Second, we unify the area codes for counties, which are changing over time, to the 2007 standard code.<sup>13</sup> Third, we drop observations with zero employee, negative total assets, negative net amount of fixed assets, or negative output. Fourth, we treat<sup>14</sup> outliers of the main variables, including ROA, wage, capital stock, investment, coal input, and fuel input.

The second data source is for variables of environment regulation. The central government writes targets in the Five-Year Plans for environmental protection, and specific plans for prevention and control of major pollutants are laid out. The plans identify key regions and key polluting industries mainly for regulating sulfur dioxide (SO<sub>2</sub>) and chemical oxygen demand (COD). The information for key regions is from official documents (Huang et al. 2010).<sup>15</sup> For key polluting industries, we use information from the *Handbook on Emission Coefficients of Industrial Sources of Pollution for the First National Census on Pollution Sources*.<sup>16</sup>

The third set of data reflects region-level characteristics, extracted from administrative statistics such as *China Statistical Yearbook*, *China City Statistical Yearbook*, and *China*



**Table 1** Summary statistics of variables about the tax incentives over 2009–2011

Tax incentives	Total amount	Average amount among beneficiaries	Total number of beneficiaries	Average probability of being a beneficiary, %	Average tax break among beneficiaries
ITC					
2009					
Full sample	495,229	689.734	718	0.273	0.550
Key regions	332,516	592.720	561	0.271	0.570
Polluting industries	269,481	1024.643	263	0.716	0.468
2010					
Full sample	860,622	988.085	871	0.299	0.540
Key regions	614,566	969.347	634	0.280	0.557
Polluting industries	354,269	1150.224	308	0.821	0.474
2011					
Full sample	2,494,044	2749.773	907	0.313	0.550
Key regions	2,074,580	3206.461	647	0.286	0.564
Polluting industries	609,506	1852.602	329	0.950	0.494
TID					
2009					
Full sample	468,559	4004.778	117	0.045	0.570
Key regions	350,530	3851.978	91	0.044	0.590
Polluting industries	28,816	1600.889	18	0.049	0.489
2010					
Full sample	475,525	4135.000	115	0.040	0.549
Key regions	378,926	4457.953	85	0.038	0.566
Polluting industries	96,013	3840.520	25	0.067	0.483
2011					
Full sample	1,523,733	11,904.160	128	0.044	0.555
Key regions	1,349,565	14,830.380	91	0.040	0.570
Polluting industries	237,855	8809.444	27	0.078	0.498

*Notes:* Units of total amount and average amount are both 1000 Chinese renminbi. The probability of being a beneficiary in the table is related to ITCdummy or TIDdummy in subsequent regressions, whereas tax break equals to ITCterm or TIDterm. Full sample covers all manufacturing firms in the NTSD, while key regions and polluting industries are its subsamples, referring to manufacturing firms in the key regions or in the key polluting industries, respectively

*Statistical Yearbook for Regional Economy.* They include provincial GDP deflators, price index of investment in fixed assets, and producer price index for two-digit industries, which are used to calculate real values of GDP, investment, and output. We also collect data on GDP per capita, fiscal deficit, proportion of working population, financial development, and level of industrialization in a city or county. These regional characteristics are usually controlled by the literature (see, e.g., Chirinko and Wilson 2008; Agrawal et al. 2014).

Using information of location and four-digit industry a firm belongs to, we merge data from the three sources into one dataset. Summary statistics for main variables are presented in Tables 1 and 2. As Table 1 shows, either ITC or TID is small in amount, and it

**Table 2** Summary statistics of other variables over 2009–2011

Definition		Full sample					Benchmark sample		
		Obs.	Mean	Std.	Min	Max	Obs.	Mean	Std.
Panel A: taxpayer-level characteristics									
SOE	Indicator for state-owned firm (0 if not SOE, 1 otherwise)	947,821	0.0358	0.1859	0	1	42,919	0.0350	0.1839
Foreign	Indicator for foreign firm (0 if not foreign, 1 otherwise)	947,821	0.1148	0.3188	0	1	42,919	0.0819	0.2742
HMT	Indicator for Hong Kong, Macao or Taiwan firm (0 if not HMT, 1 otherwise)	947,821	0.0746	0.2627	0	1	42,919	0.0504	0.2188
Lshare	Indicator for incorporated firm (0 if not incorporated, 1 otherwise)	947,821	0.0243	0.1541	0	1	42,919	0.0530	0.2240
Private	Indicator for private firm (0 if not private, 1 otherwise)	947,821	0.3618	0.4805	0	1	429,19	0.3036	0.4598
ODomestic	Indicator for other domestic taxpayer (0 if not other domestic, 1 otherwise)	947,821	0.3886	0.4874	0	1	42,919	0.4761	0.4994
age	Age	947,497	9.2350	5.9772	1	112	42,901	10.8304	5.7053
size	Number of employees	946,459	184.5121	1095.4260	1	587,430	42,904	410.9350	1734.4920
Investment	Newly increased fixed assets/output	758,512	0.0636	0.1774	0	1.4138	36960	0.0640	0.1775
capital	Net value of fixed assets/output	803,062	0.6885	1.5961	0	11.9473	38,408	0.7119	1.6044
ROA	Net profits/assets	934,124	0.0067	0.1080	−0.5241	0.3853	42,717	0.0049	0.1037
wage	Total wages/output	805,700	0.2033	0.4235	0.0096	3.1505	38,594	0.1540	0.4104
capacity	Inventory/output	801,548	0.5038	1.4678	0	11.3958	38,484	0.5194	1.5035
import	Imports/output	947,827	0.0041	0.0398	0	0.6557	42,919	0.0027	0.0326
netinvest_g	1-period weighted growth of net investment	422,245	0.0083	1.6286	−2	2	19,363	0.0822	1.5412
netcapital_g	1-period weighted growth of net capital	561,613	−0.0331	0.9916	−2	2	24,516	−0.0178	0.5439
employ_g	1-period weighted growth of employees	944,106	−0.0407	0.7004	−1.9999	2	42,873	−0.0236	0.3807
coalinput_g	1-period weighted growth of coal consumption	281,669	−0.1601	1.5587	−2	2	24,456	−0.1536	1.2467
fuelinput_g	1-period weighted growth of fuel consumption	417,330	−0.1042	1.5960	−2	2	22,752	−0.1385	1.4508
output_g	1-period weighted growth of real output	820,076	−0.0260	1.1345	−2	2	38,768	0.0178	0.9219

**Table 2** Summary statistics of other variables over 2009–2011 (*Continued*)

valueadd_g	1-period weighted growth of real value added	676,813	−0.0454	1.4050	−2	2	33,006	0.0087	1.2426
Panel B: industry-level characteristics									
laborc_ind	County-industry average ratio of total wages to output	934,297	0.2043	0.2154	0.0010	3.1505	42,474	0.1631	0.2232
lnagglom	Natural logarithm of county-industry total employees excluding those in the taxpayer	895,932	7.6136	1.9994	0	13.8018	40,265	7.2046	1.7107
Panel C: region-level characteristics									
lnrealgdppc	Natural logarithm of real GDP per capita	892,501	10.2379	1.1724	6.6581	13.0234	41,440	9.7661	1.0800
fiscalauto	(Public spending-fiscal revenue)/public spending	892,882	0.3691	0.2875	−4.1491	1.0825	41,464	0.4843	0.2652
workingpop	Urban and rural employees/population	839,868	0.5652	0.4075	0.0297	4.0705	39,601	0.4636	0.1947
finance	Loan balance of financial institutions/GDP	891,966	1.4822	0.8476	0.0107	15.6464	41,400	1.2540	0.8464
indlevel	Value added of the second industry/GDP	891,772	0.4864	0.1609	0.0003	0.9906	41,348	0.5060	0.1637

*Notes:* All variables are real values, not affected by price or inflation. Units of output and GDP are 1000 Chinese renminbi and 1 Chinese renminbi, respectively. Units of coal and fuel are ton. Net investment is calculated as (newly increased fixed assets – ITC-related investment)/output, whereas net capital stock is (net value of fixed assets – net value of ITC-related investment)/output. The benchmark sample consists of incumbents or taxpayers always existing over 2007–2011 in the key polluting industries

is not highly likely for a firm to be a beneficiary. For the full sample (all manufacturing firms in the NTSD), total amount of ITC increases from 495 million in 2009 to 2494 million Chinese renminbi (RMB) in 2011.<sup>17</sup> The amount of TID is relatively smaller. So our subsequent empirical analysis is mainly focused on ITC.

Average amount of tax preferences received by the beneficiaries, however, are not negligible for them, which leads to remarkable tax breaks. For instance, in 2011, average amount of ITC among beneficiaries in the full sample is about 2.75 million Chinese renminbi. The amount of TID is 11.90 million renminbi.<sup>18</sup> As a result, average tax breaks among beneficiaries are close to 0.55, indicating that nearly half of tax burden born by a beneficiary has been offset by ITC or TID.

Table 2 presents summary statistics for other variables. We choose incumbents or existing manufacturing firms over 2007–2011 in the key polluting industries as benchmark sample, while use the full sample as reference. The reasons for it are as follows. First, some firms may respond to the tax policies through entry to or exit of the market, causing self-selection bias to estimation. It is solved by using a strictly balanced panel of incumbents. Second, firms in the key polluting industries are the main producers of pollutants and thus main beneficiaries of ITC and TID,<sup>19</sup> so we can drop irrelevant observations. After treating outliers and dropping observations with missing values, there are about 43,000 observations in the benchmark sample.<sup>20</sup>

Panel A of Table 2 summarizes firm-level characteristics. The difference between the full and benchmark sample is not large. As for ownership, about 3.5 % of taxpayers are SOEs, while less than 20 % are foreign or HMT firms. A large part in the sample is other domestic firms, such as private-owned, collective, or cooperative ones. On average, the firms are about 9–10 years old and have 185–411 employees. Investment is 6 % of the output, while the net value of capital stock is about 70 % of the output. One-period weighted growth of net investment is 8 % annually in the benchmark sample, while net capital stock<sup>21</sup> slightly shrinks in both the full sample and benchmark sample. Growth of employment or energy consumption also declines in the two samples over time.<sup>22</sup>

Panel B presents summary statistics for industry-level variables, and there seems no systematic gap between the two samples. Panel C reports summary statistics of regional characteristics. Real GDP per capita is close to 20,000 Chinese renminbi (about 3000 USD). On average, local governments in China have no fiscal autonomy, indicated by the fact that public spending is 37 to 48 % larger than fiscal revenues.<sup>23</sup>

### Method and Result A - Who are beneficiaries

We estimate a Probit model to understand the determinants for incidence of ITC or TID. The econometric equation is as follows.

$$\text{Policydummy}_{it} = \alpha + X'_{i,t-1}\beta + Z'_{jt}\gamma + v_t + \mu_{pt} + \varepsilon_{it}, \quad (1)$$

where (Policydummy) is dummy for ITC or TID. It equals one if the firm is a beneficiary of ITC (or TID). ( $X$ ) and ( $Z$ ) are vectors of firm-level and region-level characteristics,<sup>24</sup> and ( $\beta$ ) and ( $\gamma$ ) are their coefficients. Subscripts  $i$ ,  $j$ , and  $t$  refer to firm, region, and year. We also control year fixed effects and province-year trends,<sup>25</sup> i.e.,

$(v_t)$  and  $(\mu_{pt})$ , respectively.  $(\alpha)$  is constant term, while  $(\varepsilon)$  is random error. To account for endogeneity, we use one-period lagged values of firm-level characteristics,  $(X_{i,t-1})$ .

We try three sets of samples as follows. (1) The benchmark sample. (2) Incumbents in the polluting industries without those who have investment related to ITC or income required for TID in the last year but have no such investment or income in the current year or subsamples A and C of the benchmark sample. (3) Incumbents in the polluting industries without those who have investment related to ITC or income required for TID in the last 2 years but have no such investment or income in the current year or subsamples B and D of the benchmark sample.<sup>26</sup>

### Who are ITC beneficiaries?

Table 3 presents the results about incidence of ITC by estimating Eq. (1), using the different samples aforementioned. Columns 1, 3, and 5 control province-year trends, while industry-year trends are controlled in the other columns.

Since the results from different samples are quite similar, we look at those using the benchmark sample, as reported by columns 1 and 2. They show that several firm characteristics have significant impacts on the probability of being an ITC beneficiary. First, ownership does matter. Compared to SOEs, private enterprises (indicated by *lagPrivate*) are less likely to benefit from ITC. Incorporated enterprises (indicated by *lagLshare*) seem to express more positive attitude to ITC than SOEs, but the difference between them is not significant. This finding is consistent with the literature (see, e.g., Greenstone and Hanna 2014) that emphasize the importance of local support for good performance of government regulations on environment. In China, SOEs are tightly connected with the government, in terms of both personnel and finance. It is therefore more likely for SOEs to reduce pollution and save energy, as a response to the request from the government.<sup>27</sup> As to incorporated enterprises, some of them are listed in stock markets, who are responsible for both shareholders and the public. They may trade off between profits required by current investors and environmental protection favored by the public or potential investors.

Second, factors like age, size and profitability also have remarkable influence. Older firms, who may be relatively conservative in operation, seem to be more reluctant to apply for ITC. Taxpayers with more employees or larger capital stock are more likely to be beneficiaries.<sup>28</sup> Meanwhile, taxpayers of stronger profitability are also more likely to be beneficiaries.<sup>29</sup>

Third, parameters of coal inputs are positive and significant, while those of fuel inputs are negative but not significant. It indicates that a firm who performs worse in alleviating pollution may be more likely to be a beneficiary.

Lastly, it is beyond our expectation that the impacts from regional characteristics such as real GDP per capita and fiscal autonomy are not significant or not robust. It indicates that a better economic or fiscal condition does not encourage more taxpayers to use ITC. With guide of the literature (Agrawal et al. 2015), it is not a surprise given that China is lack of environment-related public services from local governments, who occupy numerous economic resources (Xu 2011).

**Table 3** Factors determining probability of being ITC beneficiary

Dependent variable: ITCdummy	Benchmark sample		Subsample A of benchmark sample		Subsample B of benchmark sample	
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Ownership						
lagForeign	−0.101 (0.176)	−0.151 (0.172)	−0.117 (0.177)	−0.168 (0.173)	−0.122 (0.177)	−0.174 (0.173)
lagHMT	−0.188 (0.183)	−0.210 (0.180)	−0.201 (0.184)	−0.218 (0.181)	−0.206 (0.184)	−0.223 (0.182)
lagLshare	0.098 (0.158)	0.084 (0.156)	0.091 (0.159)	0.079 (0.157)	0.089 (0.159)	0.075 (0.157)
lagPrivate	−0.353** (0.160)	−0.331** (0.159)	−0.371** (0.161)	−0.345** (0.160)	−0.378** (0.161)	−0.350** (0.160)
lagODomestic	−0.039 (0.144)	−0.078 (0.143)	−0.053 (0.144)	−0.088 (0.144)	−0.058 (0.144)	−0.092 (0.144)
Taxpayer's other features						
lagInage	−0.113* (0.059)	−0.168*** (0.060)	−0.116** (0.059)	−0.171*** (0.060)	−0.117** (0.059)	−0.171*** (0.060)
lagInsize	0.373*** (0.027)	0.399*** (0.030)	0.379*** (0.027)	0.405*** (0.030)	0.382*** (0.027)	0.408*** (0.030)
lagcapital	0.063*** (0.021)	0.055*** (0.020)	0.061*** (0.021)	0.054*** (0.020)	0.060*** (0.021)	0.053*** (0.020)
lagROA	3.027*** (0.333)	2.863*** (0.339)	3.074*** (0.335)	2.910*** (0.341)	3.084*** (0.335)	2.919*** (0.342)
lagwage	−0.096 (0.104)	−0.098 (0.100)	−0.098 (0.105)	−0.101 (0.101)	−0.095 (0.105)	−0.099 (0.101)
lagIncoalinput	0.042*** (0.014)	0.022* (0.013)	0.043*** (0.015)	0.023* (0.014)	0.042*** (0.015)	0.023* (0.014)
lagInfuelinput	−0.006 (0.015)	−0.012 (0.014)	−0.005 (0.015)	−0.012 (0.014)	−0.005 (0.015)	−0.012 (0.014)
Region's features						
lnrealgdppc	−0.015 (0.059)	−0.031 (0.048)	−0.014 (0.060)	−0.028 (0.048)	−0.013 (0.060)	−0.028 (0.048)
fiscalauto	−0.072 (0.252)	−0.353* (0.190)	−0.078 (0.256)	−0.343* (0.193)	−0.082 (0.257)	−0.348* (0.193)
workingpop	0.284 (0.227)	0.291* (0.177)	0.288 (0.228)	0.301* (0.176)	0.282 (0.228)	0.300* (0.176)
finance	0.030 (0.050)	0.036 (0.037)	0.032 (0.051)	0.040 (0.037)	0.031 (0.052)	0.040 (0.038)
indlevel	−0.235 (0.214)	−0.202 (0.136)	−0.271 (0.244)	−0.221 (0.147)	−0.283 (0.255)	−0.231 (0.155)
Constant	−4.082*** (0.781)	−3.445*** (0.920)	−4.088*** (0.789)	−3.523*** (0.927)	−4.094*** (0.791)	−3.559*** (0.929)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Province fixed effect	Yes	No	Yes	No	Yes	No



**Table 3** Factors determining probability of being ITC beneficiary (*Continued*)

Province-year fixed effect	Yes	No	Yes	No	Yes	No
Industry fixed effect	No	Yes	No	Yes	No	Yes
Industry-year fixed effect	No	Yes	No	Yes	No	Yes
Observation	11644	11664	11563	11580	11532	11548
Pseudo R-square	0.234	0.208	0.238	0.213	0.240	0.214

Notes: Superscript symbols “\*”, \*\*, and \*\*\*” represent 10 %, 5 %, and 1 % significant level respectively. The values in parentheses are robust standard errors. Wald  $\chi^2$ 's  $p$  values are all below 0.01. Subsample A of the benchmark sample consists of incumbents in the polluting industries without those who have investment related to ITC in the last year but have no such investment in the current year. Subsample B of the benchmark sample consists of incumbents in the polluting industries without those who have investment related to ITC in the last 2 years but have no such investment in the current year

### Who are TID beneficiaries?

Additional file 2: Table S2 reports the results about incidence of TID using the same data and specifications as those in Table 3 for ITC. Because there are more missing values in TID, the sample becomes smaller in this case.<sup>30</sup> Some coefficients that are significant in Table 3 become insignificant here. They include those for capital stock, ROA, and coal inputs. The parameters of age become positive but are neither very significant nor robust.<sup>31</sup> The impact of ownership is statistically significant at higher level, suggesting that all firms but SOEs are less possible to benefit from TID. Economic and fiscal conditions still have no influence on incidence of TID.

### Robustness checks

We try some sensitivity tests as follows: (1) using two different samples, i.e., incumbents in the key regions and incumbents in the full sample and (2) controlling different sets of variables, such as using dummies for age and size instead of log of them, dropping some of regional characteristics correlated to others.<sup>32</sup> We find that the coefficients of interest are similar. In sum, these findings confirm that factors such as ownership and scale play important role in spread of ITC and TID, while regional characteristics are not relevant.<sup>33</sup>

### Discussion on mechanisms behind unpopularity of ITC and TID

As mentioned earlier, there are two factors that may explain unpopularity of the tax incentives. One is lack of support from taxpayers; the other is short of related public services from local governments. With regard to Jia (2012), mechanism behind the second factor is clear. Under a system of official promotion that emphasizes economic index, public spending, or budget of the government has been inevitably inclined to affairs about economic growth, rather than protecting environment. The question why firms are poorly responsive, however, remains open.

Our interpretation is that investment or projects related to environmental protection may hurt profitability of taxpayers. Using the econometric equation mentioned in the next section, we estimate effect of the tax incentives (as indicators for related investment or projects) on firm's ROA. Table 4 reports the results.

As columns 3 and 4 show, once biases caused by structural changes in the sample are concerned,<sup>34</sup> and the errors are clustered at province-industry level,<sup>35</sup> we find that ITC has a significantly negative impact on ROA, especially for the sample without SOEs. Since non-SOEs like foreign and private domestic enterprises or even incorporated firms mainly pursue maximization of profits rather than social welfare, they are reluctant to be beneficiaries of the tax policies that may erode their capacity of making profits.

This finding is consistent with Table 3 and Additional file 2: Table S2, i.e., compared to SOEs who have to consider some social goals, other firms are less likely to apply for ITC or TID. It gives us an important policy implication about how to design a tax policy that can efficiently protect environment, that is, it should better be profit-neutral, bringing no decline of profitability to its beneficiaries.

**Table 4** Analysis on mechanism: effect of being beneficiaries of ITC and TID on profitability

Dependent variable: ROA	Original value		Weighted growth	
Independent variables	(1)	(2)	(3)	(4)
Part A: benchmark sample				
Lagged ITCdummy	−0.008 (0.008)	−0.008 (0.008)	−0.041 (2.413)	−1.384* (0.743)
lagged TIDdummy	−0.011 (0.012)	−0.010 (0.013)	4.773 (5.487)	2.680 (6.098)
Taxpayer-level control variables	Yes	Yes	Yes	Yes
Taxpayer fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Province and province-year fixed effect	Yes	No	Yes	No
Industry and industry-year fixed effect	No	Yes	No	Yes
Within R-square	0.013	0.010	0.005	0.001
Observation	25003	25003	24814	24814
Part B: benchmark sample without SOEs				
Lagged ITCdummy	−0.014 (0.009)	−0.014 (0.009)	−1.472** (0.727)	−1.510** (0.663)
Lagged TIDdummy	−0.011 (0.015)	−0.011 (0.015)	4.869 (6.040)	3.340 (6.372)
Taxpayer-level control variables	Yes	Yes	Yes	Yes
Taxpayer fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Province and province-year fixed effect	Yes	No	Yes	No
Industry and industry-year fixed effect	No	Yes	No	Yes
Within R-square	0.014	0.011	0.002	0.003
Observation	22903	22903	23939	23939

Notes: Superscript symbols \*\*, \*, and \*\*\*\* represent 10 %, 5 %, and 1 % significant level respectively. The two coefficients in *italics* should be emphasized for they indicate that ITC hurts firms' profitability. In all columns, we use specifications similar to Eq. (2), and residuals are clustered at province-industry level. In columns 1–2, the dependent variable is ROA, while that for columns 3–4 is weighted growth of ROA. Taxpayer-level control variables include age and size. We also try adding other factors like ownership, wage, capacity and import, and industry-level characteristics, and the results are quite similar. Meanwhile, we try adding region-level variables like real GDP per capita and some others but find that their coefficients are not significant, and the key results experience no difference. The within R-square is relatively small, for we have controlled many fixed effects in estimation. For other notes, see Table 3

### Method and Result B - Effects of the tax incentives

In what follows, we use the fixed effects model for panel data to estimate effects of ITC and TID. Following Greenstone (2002), we estimate the model as below.

$$\Delta Y_{it} = (Y_{it} - Y_{i,t-1}) / [(Y_{it} + Y_{i,t-1}) / 2] = X'_{i,t-1} \beta + Z'_{jt} \gamma + \alpha_i + v_t + \mu_{pt} + u_{it}, \quad (2)$$

where  $(\Delta Y_{it})$  is identified as weighted growth or percentage change of outcomes we are interested in between the year  $t$  and  $t - 1$ . The reason why we introduce this variable but not ordinary growth rate is that structural changes in the sample may cause bias to our estimation.<sup>36</sup> They include entry and exit of firms or merger and acquisition among firms. It will lead to huge variation in  $(\Delta Y_{it})$ , while the variation may have no connection with the policies we study on. It will then cause bias in the results of our estimation, which may be driven by changes in composition of the sample but not the tax incentives per se.<sup>37</sup> Weighted  $(\Delta Y_{it})$ , with an interval of values limited between minus two and positive two, can greatly reduce the scale of variation caused by unrecorded changes in the sample and thus control the bias.<sup>38</sup>

( $Y$ ) represents firm's activities including investment, capital stock, employment, consumption of coal and fuel, output, and value added. ( $X_{i,t-1}$ ) is a vector of firm-level variables, whose pretreatment values at the last year are used here.<sup>39</sup> ( $Z_{jt}$ ) refers to the industry-level characteristics for the present period, including county-industry average wage ratio and agglomeration of industry.<sup>40</sup> ( $\beta$ ) and ( $\gamma$ ) are coefficients of ( $X$ ) and ( $Z$ ). ( $\alpha_i$ ) is firm-level fixed effect, while ( $\nu_t$ ) and ( $\mu_{pt}$ ) are year and province-year fixed effects.<sup>41</sup> ( $u_{it}$ ) is random error, clustered at province-industry level.

Two points are worth mentioning here. One is that the coefficient of extensive margin effect should be opposite in sign to that of intensive margin effect.<sup>42</sup> The reason is that ( $\beta$ ) of ITCterm or TIDterm is the effect of tax break or one minus tax incentives<sup>43</sup> but not direct impact of tax incentives. For the results of intensive margin effect therefore, a negative ( $\beta$ ) means a positive effect. The other is that ( $\beta$ ) or ( $\gamma$ ) should be carefully interpreted, for they are not elasticity or quasi-elasticity usually presented in the literature.<sup>44</sup> We will provide discussions later.

### The baseline results

Table 5 reports our baseline results about the effects of ITC and TID on firm's activities, using Eq. (2). Model specifications are the same across columns 1, 3, 5 and 7, in which province-year trends are controlled. Specifications in the other columns are similar, while industry-year trends are concerned. Other factors like the firm-level and industry-level characteristics are considered in all of the regressions. There are two parts in Table 5. Part A presents the extensive margin effects, using ITCdummy and TIDdummy as the key independents, while part B shows the intensive margin effects by regressing on ITCterm and TIDterm.

Since the majority of the parameters of interest are not statistically significant, we provide discussions for part of the results here and leave the rest in the Additional file 2: Table S3. Main findings are as follows. First, ITC stimulates consumption of coal, both extensively and intensively. The parameters of lagged ITCdummy are 0.404 and 0.407 when we control different sets of fixed effects, implying elasticities of 0.0064 and 0.0065, respectively. The coefficients of lagged ITCterm are  $-1.437$  and  $-1.305$ , equal to elasticities of 0.0030 and 0.0027 to ITC, respectively. These results indicate that more ITC firms receive, more coal, though not large in growth according to the small elasticities above, will be consumed. It can be explained by the mechanism we discuss in Subsection "Discussion on mechanisms behind unpopularity of ITC and TID" of Section "Who are beneficiaries: empirical strategy and results", that is, investment for protecting environment hurts profitability and firms thus use more coal that is cheaper<sup>45</sup> than other energies like fuel and hydraulic to save costs and keep profits. Second, the tax incentives restrain to some extent growth of net investment and output. The coefficients, however, are statistically significant at low levels. These results are consistent with previous studies in the literature (see, e.g., Goolsbee 1998; Greenstone 2002; Altug et al. 2009; Assibey-Yeboah and Mohsin 2011) who find that regulations or tax policies do no good for expansion of the targeted industries. Third, other effects of the tax incentives are not remarkable. The parameters of employment, net capital stock, fuel inputs, and value added are generally insignificant.

**Table 5** Baseline effects of ITC and TID on activities of taxpayers

Dependent variable: weighted growth in Eq. (2)	Net investment		Employment		Coal inputs		Output	
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Part A								
Lagged ITCdummy	−0.430* (0.228)	−0.410* (0.226)	−0.007 (0.026)	−0.009 (0.026)	0.404** (0.199)	0.407** (0.204)	0.020 (0.053)	0.034 (0.053)
Lagged TIDdummy	0.215 (0.476)	0.171 (0.516)	0.017 (0.088)	0.031 (0.088)	−0.330 (0.442)	−0.360 (0.442)	−0.162 (0.195)	−0.135 (0.200)
Taxpayer-level control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Taxpayer fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province and province-year fixed effect	Yes	No	Yes	No	Yes	No	Yes	No
Industry and industry-year fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Within R-square	0.021	0.014	0.546	0.548	0.044	0.038	0.522	0.519
Observation	16584	16584	20907	20907	13821	13821	20810	20810
Part B								
lagged ITCterm	0.149 (0.558)	0.114 (0.575)	0.090 (0.069)	0.108 (0.068)	−1.437** (0.683)	−1.305** (0.636)	−0.080 (0.152)	−0.073 (0.155)
Lagged TIDterm	−0.284 (0.446)	−0.273 (0.432)	0.078 (0.132)	0.083 (0.125)	0.911 (0.720)	0.952 (0.743)	0.358* (0.199)	0.344* (0.176)
Taxpayer-level control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Taxpayer fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province and province-year fixed effect	Yes	No	Yes	No	Yes	No	Yes	No

**Table 5** Baseline effects of ITC and TID on activities of taxpayers (*Continued*)

Industry and industry-year fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Within R-square	0.021	0.014	0.551	0.552	0.044	0.040	0.524	0.522
Observation	15953	15953	20070	20070	13207	13207	19976	19976

Notes: Superscript symbols \*, \*\*, and \*\*\* represent 10 %, 5 %, and 1 % significant level respectively. The coefficients in *Italics* should be emphasized for they indicate that the tax incentives stimulate coal consumption. In all columns, we use the specification in Eq. (2), and residuals are clustered at province-industry level. Taxpayer-level control variables include ownership, age, size, ROA, wage, capacity, import, and output, and we use their pretreatment or 1-year lagged values. Industry-level characteristics include county-industry average wage ratio and agglomeration of industry, and we use their current values. For other notes, see Tables 3 and 4



**Table 6** Heterogeneity in effects of ITC: regarding taxpayer's affiliation

Dependent variable: weighted growth in Eq. (2)	Subsample E of benchmark sample		Subsample F of benchmark sample		Subsample A of full sample	Subsample B of full sample
	(1)	(2)	(3)	(4)	(5)	(6)
Independent variables	Coal inputs	Net investment	Coal inputs	Net investment	Coal inputs	Coal inputs
Part A						
Lagged ITCdummy	<i>-7.614** (3.738)</i>	<i>-3.951*** (1.220)</i>	<i>1.659** (0.629)</i>	0.099 (0.835)	-0.172 (1.223)	-0.252 (0.980)
Taxpayer-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Taxpayer fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Province and province-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
within R-square	0.795	0.702	0.180	0.174	0.225	0.209
Observation	144	201	3048	3693	799	1198
Part B						
Lagged ITCterm	<i>81.460*** (14.892)</i>	<i>2.897*** (1.044)</i>	-2.167 (1.433)	<i>-2.572* (1.547)</i>	<i>17.988** (7.592)</i>	<i>16.433** (7.901)</i>
Taxpayer-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Taxpayer fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Province and province-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Within R-square	0.859	0.925	0.193	0.180	0.109	0.095
Observation	126	178	2998	3645	724	1067

Notes: Superscript symbols \*, \*\*, and \*\*\* represent 10 %, 5 %, and 1 % significant level respectively. The coefficients in Italics should be emphasized for they indicate that ITC constrains coal consumption of firms affiliated to the central government. Columns 1–2 use subsample E of the benchmark sample or firms attached to the central government in the benchmark sample, while columns 3–4 use subsample F of the benchmark sample, that is, those attached to subnational governments including provinces, prefectures and counties in the benchmark sample. Column 5 uses subsample A of the full sample, that is, incumbents or existing firms affiliated to the central government in the full sample. Column 6 uses subsample B of the full sample or firms affiliated to the central government in the full sample. We do not report the results for TID due to lack of TID-related observations. We try controlling industry and industry-year fixed effects instead of province and province-year ones and find the results are similar to those in this table. We also try estimations on other dependent variables like net capital stock, employment, fuel inputs, output, and value added and find no significant differences in the results between the two subsamples. For other notes, see Table 5

In sum, the baseline results indicate two findings. One is that economic effects of the tax incentives are weak in that they only slightly deter investment and output of the beneficiaries. The other and more important is that the incentives increase coal consumption, which means negative impacts on environmental quality and is contrary to their initial purpose.

### Robustness checks

We do several robustness checks for the baseline results. First, we add regional characteristics in the regression. Second, we use dummies for age and size, instead of logs of them. The new results are reported in Additional file 2: Table S4.<sup>46</sup> They are quite similar to the baseline results, regarding the impacts of the tax incentives. Third, we try different definitions of the dependent variable, including ordinary growth rate and natural log of it. For the results, see Additional file 2: Table S5. The parameters become very large in value and are all insignificant when we use ordinary growth rate. It implies the necessity to follow Greenstone's method, for ignoring structural changes in the sample like merger or acquisition will conceal the impact of ITC on coal consumption. When logs of the dependent variables are used, the results are similar to those in Table 5.

### Heterogeneity analyses

First, we check whether the results vary across regions.<sup>47</sup> To do this, we classify locations of firms into three regions: eastern, central, and western.<sup>48</sup> We re-estimate the baseline regressions by using the interactions of region dummies with tax incentives as main explanatory variables. The interested parameters of the interactions, however, are not significant.

Second, we try sensitivity tests regarding ownership, size, and region-specific characteristics like fiscal spending for environmental protection, whether a key regulated area and whether a county of ethnic minorities.<sup>49</sup> The regressions include the interactions of related dummies with tax incentives. None of the above tests show statistically significant impacts of the tax incentives on firm's activities.

Third, we use subsamples which consist of only SOEs and (or) incorporated enterprises. The parameters of interest, however, are either insignificant or indifferent from those in Table 5. These firms per se, however, should be cautiously analyzed. As to the state-owned economy, SOEs are only part of it, while other firms like incorporated enterprises, collective enterprises, and public-private joint ventures are also affiliated to different levels of governments.<sup>50</sup> For the state-owned economy, therefore, affiliation may be a better indicator than ownership.

As to those attached to the central government, most of them are central enterprises<sup>51</sup> (*yang qi* in Chinese) who are very closely tied to the central government. They are usually regarded as part of the public sector but not ordinary profit-seeking enterprises. Supporting evidence is that senior executives or managers of these enterprises have administrative rank or title.<sup>52</sup> Regarding the model in Additional file 1, the literature (Greenstone and Hanna 2014), and Subsection "Discussion on mechanisms behind unpopularity of ITC and TID" of Section Who are beneficiaries: empirical strategy and results, the tax incentives should have some good impact on these special enterprises. For one thing, the central government has a stronger executive power of taxation on them<sup>53</sup> and gets more support from them, compared to others like those attached to

subnational governments. For another, receiving billions of subsidies from the central government annually,<sup>54</sup> these firms care less about profits and may better comply with the tax policies.

We use subsamples of firms affiliated to the central or subnational governments and redo the baseline estimations. The results are reported in Table 6. To save space, we report only the results that have significant difference between the subsamples. Columns 1–2 use subsample E of the benchmark sample (i.e., enterprises affiliated to the central government), while columns 3–4 use subsample F of the benchmark sample (i.e., firms attached to subnational governments). By enlarging the scale of sample, columns 5–6 are robustness checks for the results in column 1 which are the key finding and are the basis for our later discussion on policy implications.

We find that signs of the parameters of ITC in columns 1–2 are exactly opposite to those in columns 3–4, implying that impacts of ITC on enterprises affiliated to the central government are systemically different from effects on those attached to subnational governments. Regarding columns 1 and 2, ITC slows down coal consumption and restrains growth of net investment. Take the effect on coal consumption as an example. The coefficient for extensive margin effect is  $-7.614$  or elasticity of  $-0.5018$ . It is quite significant. That for intensive margin effect is  $81.460$  or elasticity of  $1.5093$ .<sup>55</sup> It is very significant and robust. For their counterparts attached to subnational governments, ITC increases coal consumption and net investment, as shown in columns 3 and 4. Our theoretical model and the literature are supported by these results.

Combining the results in Tables 4 and 6, we can confirm a conjecture that close relationship between firms and the central government enhances the restraining impact of ITC on coal consumption, while worry for losing profits weakens it.<sup>56</sup>

### Discussion on the results from heterogeneity analyses

First, although the results may suggest that close relationship between firms and the central government is crucial, it by no means supports that firms creating pollution or wasting resources should all be nationalized for the sake of environmental protection. Instead, we should emphasize the importance of information transparency and adequate regulations. On the one hand, without necessary and high-quality information, it is difficult for tax policies or incentives to be efficient (Pomeranz 2015). Departments of the central government should do better on collecting and using data about firms' energy consuming and their efforts on pollution alleviation. With these, the government is able to design tax policies that are more incentive compatible or at least profit-neutral and to better implement them as well. On the other hand, the central government who less concerns about profits of a certain firm should take more responsibility in the practice of the tax incentives.

Second, the results from Subsection "Discussion on the results from heterogeneity analyses" have important implications, especially for the elasticities ( $0.5018$  and  $-1.5093$ ) that we derive from column 1 in Table 6. The benchmark sample indicates that, on average, a firm consumes 23,907 t of coal annually. If the firms respond to ITC like those affiliated to the central government, then 1 % of increase in probability of being beneficiary (or 430 more ITC beneficiaries) would lead to a 120-ton decrease in

coal consumption for each firm, whereas 1 % of increase in tax incentives (or about 5200 Chinese RMB more ITC for each beneficiary)<sup>57</sup> would save 361 tons of coal for every taxpayer. If the impact could be extended to the whole group of above-scale manufacturing firms,<sup>58</sup> and given that 1 % of them would benefit from ITC, then each 20 million Chinese RMB used for tax incentives could save 1.4 million tons of coal.<sup>59</sup> This is a big bang for the buck. So if better designed and implemented, the tax incentives put into practice since 2008 may become one of the ideal tools for environmental protection in China.

## Conclusions

This paper studies both incidence and influence of two tax incentives for protecting environment in China. Based on a taxpayer-level dataset from various sources, we find that the incentives are not well welcomed by firms, with the exception of SOEs. In addition, we find that their effects on firms' activities are below expectation. They even increase coal consumption. These findings are robust to multiple specifications of using different empirical strategies, samples, and explanatory or dependent variables. Further analyses, however, show that one of the tax incentives, ITC, works well—restraining growth of coal consumption—in some manufacturers which are affiliated to the central government. Our theoretical and empirical studies suggest that less negative impact on profitability and closer firm-government relationship will promote positive impact of the tax incentives on environmental protection.<sup>60</sup>

The empirical findings point to policy implications. If well designed and implemented, tax incentives such as ITC may be an efficient tool for saving energy and limiting emissions. A feasible measurement may be setting up a complete system of tax expenditures management. In developed countries such as the USA, Australia, and Canada, tax expenditures are important part of public budget, providing detailed information about incidence and effects of various types of tax incentives or preferences. With a system of tax expenditures management, we can know better about how the two tax incentives studies in the paper have been implemented in each firm and then find ways to promote efficiency of the tax incentives.

Although the dataset used by us is from a single country, China, the situations documented in this paper, such as lack of local support and poor executive power of taxation, might befall in other developing countries. So for the governments of these countries to redesign the institutions related with environmental protection, our research is also meaningful.

## Endnotes

<sup>1</sup>. "Taxpayer" and "firm" are exchangeable in this paper.

<sup>2</sup>. Explanation for tax break is as follows. Given that statutory tax rate is  $t$ , tax base is  $M$ , and tax incentives are  $xM$  ( $0 < x < 1$ ), we can get that the net-of-incentive tax rate is  $(1 - x)t$ . Tax break refers to  $(1 - x)$ , similar to the term of *net-of-tax rate* used by the literature. In empirical studies, net-of-tax rate is generally used as independent variable, rather than tax rate or tax burden per se (see, e.g., Feldstein 1995, 1999; Saez 2001; Fack and Landais 2016). Following the literature, we use tax breaks but not tax incentives in subsequent estimations. It is unnecessary to consider net-of-tax rate or combine it with

tax break in this paper, for the statutory tax rate of corporate income tax in China keeps at 25 percent nationwide since 2008.

<sup>3</sup>. As well known, a firm or individual's response to a tax policy is usually endogenously related to its or her activities. Greenstone uses information of pretreatment as key explanatory variables, removing potential reverse causality in estimation. More importantly, as suggested by Greenstone (in his NBER Working Paper No. 8484, which is a complete vision of Greenstone (2002)), using weighted growth of dependent variables helps us control the bias caused by structural changes in the sample, like birth (entry) and death (exit) of firms.

<sup>4</sup>. Before 2008, there were once some temporary tax preferences for comprehensive resource utilization. Meanwhile, charges for disposing pollutants are levied before and after the 2008's tax reform. None of these policies, however, are laws, but provisional regulations or administrative rules. Additionally, there are also some tax preferences for environmental protection in other taxes like value-added tax, but their incidence and effects are not yet available for empirical study due to lack of data. In the estimations below, we consider some variables including fixed effects to control potential impact from these tax preferences.

<sup>5</sup>. We build a schematic model, in which we consider a three-factor production function and two types of tax incentives, i.e., ITC and TID. We then get comparative static effects of these tax incentives on energy consumption. Here, the executive strength depends on two factors, information transparency and strictness of the implementation. The former is usually determined by quality of corporate governance in firms, while the latter is connected to relationship between firms and the government. For details of the model and relevant evidences for assumptions in it, see Additional file 1 and Additional file 2: Table S6.

<sup>6</sup>. Using the data from the National Bureau of Statistics of China, we find that during 2007–2014, the ratio of public spending used for environmental protection to total public expenditures is averagely 2.41 %, lower than that for education (14.89 %), social security (10.37 %), health care (5.40 %), and science and technology (4.06 %). The real fiscal spending per capita on environmental protection in our benchmark sample over 2009–2011 is only 149 Chinese RMB per capita. It is lower (118.20 Chinese RMB) over 2007–2011. Its distribution is shown by Additional file 2: Figure S1. It is apparently left skewed, implying that most of the taxpayers in the sample locate in regions with low public spending on environmental protection.

<sup>7</sup>. The firms in the NTSD are sampled through two methods. One is direct statistics, suitable for firms who pay a large amount of taxes. The other is stratified sampling, dividing the taxpayers nationwide to deciles according to their sales and then randomly sampling certain firms from each decile.

<sup>8</sup>. We mainly use the data over 2009–2011, for the values of ITC and TID are unavailable until 2009. Part of the data over 2007–2008 are also used to create the benchmark sample on which our main empirical results depend.

<sup>9</sup>. Seven four-digit industries that are not involved are all economic-trivial or non-profit ones, including 0340 (animal hunting), 9032 (archives), 9422 (foreign affairs), 9431 (courts), 9432 (procuratorates), 9520 (political parties), and 9612 (women federation).

<sup>10</sup>. According to footnote 3, the value of ITCterm is from zero to one. When it is close to zero, ITC is very bountiful because the tax credit is nearly equal to income tax payable. TIDterm is alike.

<sup>11</sup>. We consider the following types of ownership: SOE, private, limited liability or incorporated, foreign, HMT, and other domestic company. For definitions of other variables, see Table 2.

<sup>12</sup>. We unify the new standard beginning in 2011 to that before 2011. In 2011, the four-digit industry codes of China were changed. It will certainly result in misidentification of industries if not unified.

<sup>13</sup>. About 670 among nearly 3000 county-level regions in China experience changes in area code.

<sup>14</sup>. We use the order *winsor* in STATA to treat 0.5 % in upper and lower limits respectively.

<sup>15</sup>. China's environmental regulation efforts in recent years mainly focus on these regions where have been severely polluted. One is the three rivers (Huai, Hai, and Liao) and three lakes (Tai, Chao, and Dianchi), where COD emissions have caused severe organic pollution in the rivers and lakes. Another is the two control zones, which have heavy air pollution by SO<sub>2</sub> and acid rain. Related government plans clearly list the key regions (at county or prefecture level).

<sup>16</sup>. It allows us to determine whether a four-digit industry can be classified as a key polluting industry.

<sup>17</sup>. The extremely quick growth of total amount in the full sample is due to several outliers in the year 2011, while growth in the benchmark sample (manufacturing firms from the key polluting industries) is relatively normal and acceptable. This is one of the reasons why our estimations below are focused on the benchmark sample.

<sup>18</sup>. It should be mentioned that ITC is directly the amount of tax preference, while the benefit from TID is the number of multiplying TID by statutory tax rate (25 %). See equation (A2) in Additional file 1, which is helpful to understand the difference between ITC and TID.

<sup>19</sup>. Firms from the key polluting industries are more responsive to the incentives, and they also receive more generous preferences. As Table 1 shows, average probability of being a beneficiary in the sample of key polluting industries is higher than that in the full sample. Take ITC for example, in 2011, the possibility of receiving it is 0.950 % for key polluting industries, obviously higher larger than that for the full sample (0.313 percent). As far as tax break is concerned, we have similar finding. ITC and TID are not more generous in key regions, however. One possible reason is that too many regions are chosen as key regulation areas, resulting in a fact that regulated regions cannot explicitly target main polluters at micro level.

<sup>20</sup>. What is worth mentioning is that it may be more preferred that the benchmark sample be focused on some concrete industries such as environmental protection, energy and water saving, and production safety. However, according to the industry classification codes (i.e., GB/T 4754-2002 or GB/T 4754-2011) issued by the National Bureau of Statistics of China, we cannot find codes for these kinds of industries and thus cannot define related firms.



<sup>21</sup>. Here, net capital stock is the value after we subtract ITC-related investment from the net value of fixed assets. Net investment is similar. So the dependent variables in what follows will not be overlapped with some key independent variables such as ITC-term, which avoids estimation bias. For explanation for weighted growth, see Section V.

<sup>22</sup>. It is consistent with the fact that the Chinese economy has been severely shocked by the 2008's subprime mortgage crisis.

<sup>23</sup>. Local governments depend highly on transfers (4.65 trillion Chinese RMB in 2014 or nearly 60 of total local fiscal revenues) from the central government.

<sup>24</sup>. Firm-level characteristics include ownership, age, size, capital, ROA, wage, inputs of coal, and fuel, while regional control variables are real GDP per capita, fiscal autonomy, working population, finance development, and level of industrialization. For definitions of these variables, see panels A and C in Table 2.

<sup>25</sup>. They are used to account for potential effects of factors such as other tax preferences or cyclic economic fluctuations. We also try industry-year trends instead of province-year ones. As shown by Table 3, the key results using different sets of fixed effects are similar. We prefer province-year to industry-year, for there exists large trade barriers among provinces due to the Chinese-style decentralization (see Young 2000; Xu 2011), and time-varying policies from provincial governments should have greater impact on firms' activities.

<sup>26</sup>. The reason why we use these subsamples is that some investment or income connected to environmental protection may be one-time or lumpy and will not recur in the following years. For instance, a firm who has purchased some equipments for alleviating pollution in 2009 may not need to continue such investments in 2010 or 2011. If we keep the 2010–2011 observations of this firm in our benchmark sample, we may underestimate the possibility of benefiting from ITC or TID. Subsamples A and B are used in Table 3, while subsamples C and D in Additional file 2: Table S2.

<sup>27</sup>. However, what deserves mention is that SOEs per se are heterogeneous. In China, they belong to different levels of governments, some of which mainly emphasize economic growth that is essential for promotion, rather than environmental protection (Jia 2012). Our later estimations verify it.

<sup>28</sup>. It implies that the view of financial repression (see, e.g., Agrawal et al. 2014) on environment-related investment may not hold in China. Otherwise, small firms should respond more actively to ITC, for ITC reduces financial constraints on them.

<sup>29</sup>. One explanation is that limiting emissions and saving energy are activities consuming profits. So firms with stronger profitability are more capable to involve themselves in green investment. It is supported by the evidences from Subsection "Discussion on mechanisms behind unpopularity of ITC and TID" of Section "Who are beneficiaries: empirical strategy and results".

<sup>30</sup>. The variable *lagHMT* is dropped in estimations due to lack of related observations.

<sup>31</sup>. The parameters of age become insignificant when we control industry-year trends. Compared to the results in Table 3, it may imply that the effect of age on ITC is different from its impact on TID. For two things, however, we do not dwell on it. One is that it is not our main interest; the other is that the results for TID are not robust.

<sup>32</sup>. Details are as follows. Age is divided to three categories, zero-five, six-nine, ten and older. We use zero-five as reference. Size is divided quarterly according to the distribution of sizes in same industry, and we use smallest 25 percentage as reference. Some region-level control variables like financial development and industrial structure are correlated with real GDP per capita or fiscal autonomy.

<sup>33</sup>. To save space, we do not report these results in the paper. The results are available from the authors upon request.

<sup>34</sup>. Unrecorded behaviors like merger and acquisition between firms will cause bias in the parameters of interest, and this problem can be lessened by using weighted growth but not original level of ROA. For related explanation, see Section “Effects of the tax incentives: empirical strategy and results”.

<sup>35</sup>. We also try clustering the errors at firm, province, and industry, respectively and find that the results are very close. With regard to the reason mentioned in Section “Effects of the tax incentives: empirical strategy and results”, we choose clustering errors at province-industry level as baseline specification.

<sup>36</sup>. As our data of ITC and TID cover only 3 years of 2009–2011, we do not try weighted growth with 2-year gap, in that the dataset will then be cross sectional but not panel. We try using the ordinary growth rate as defined by  $(\Delta Y_{it} = (Y_{it} - Y_{i,t-1})/Y_{i,t-1})$  in robustness checks.

<sup>37</sup>. Using the benchmark sample ensures that our results will not be bothered by entry or exit of taxpayers. They may still be biased, however, by merger and acquisition among firms. Since the NTSD provides no information about these activities, we have reasons to suspect whether an incumbent firm is still the one it was in the last year or years. For instance, a taxpayer in the benchmark sample, who has not any change in firm code or name, may in fact have been merged with a firm never in our sample.

<sup>38</sup>. It can be thought as an extension of Greenstone’s consideration, in that merger or acquisition is qualitatively similar to entry or exit, all of which will cause great changes in activity or performance of a firm. Greenstone (2002) has paid attention to entry and exit but neglects those like merger and acquisition. Thus, weighted growth of the dependent variable should still be used here, even in a sample of balanced panel data.

<sup>39</sup>. Pretreatment values of the key independent variables are believed to be less endogenously correlated with the dependent variable (Greenstone 2002). We also try using  $X_{it}$  and find the results are similar. To save space, we do not report them in the paper. They are available from the authors upon request. For definitions of these variables, see panel A in Table 2.

<sup>40</sup>. For definitions of these variables, see panel B in Table 2. We also try adding region-level variables like real GDP per capita and fiscal autonomy but find that their coefficients are not significant, and the results of key variables experience no difference. So, in the baseline specification, we do not control these factors. But, we consider them in robustness check (see Additional file 2: Table S4).

<sup>41</sup>. We also try controlling industry-year fixed effects, and as reported by Table 5, the main results are similar.

<sup>42</sup>. Here, the extensive and intensive margin effects refer to impact of being a beneficiary and that of the benefits received, respectively.

<sup>43</sup>. As to the reason for that, see footnote 3.

<sup>44</sup>. Since  $(\Delta Y_{it})$ , weighted growth but not log of value or normal annual growth, is used in Eq. (2), there needs some calculations for shifting  $(\beta)$  or  $(\gamma)$  to elasticity (see Additional file 3).

<sup>45</sup>. Coal is one of the cheapest energy in China, which provides over 80 % of the total electricity power and is the main resource of air pollution (Vennemo et al. 2009; Wang 2011; Jia 2012).

<sup>46</sup>. We also try specifications with industry-year fixed effects, as well as estimations on the other variables of interest, including net capital stock, fuel consumption, and value added. We find that the results are similar to the baseline.

<sup>47</sup>. Some of the empirical results mentioned in this subsection are not reported, for almost all of them are not significant. They are available from the authors upon request.

<sup>48</sup>. The eastern includes the following provinces: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central covers Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western consists of Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

<sup>49</sup>. According to the information from the National Bureau of Statistics of China, there are 634 counties of ethnic minorities among nearly 3000 county-level administrative areas. They are relatively autonomous in social and economic development. Thus, it deserves attention that whether or not firms in these regions behave differently when they face to the tax incentives.

<sup>50</sup>. An example is Baosteel Group Corporation, who is located in Shanghai and is one of Chinese steel giants. Although it is an incorporated enterprise, the power of appointing chairman of the board is in hand of the central government. For relevant discussions, see Hsieh and Song (forthcoming).

<sup>51</sup>. In our sample, 85 % of the firms attached to the central government are central enterprises or SOEs attached to the central government. In the rest, 3 % are incorporated enterprises and 12 % are other firms.

<sup>52</sup>. For instance, board chairman of CNPC (China National Petroleum Corporation), who is directly appointed by the central government, is an entrepreneur equal to ministers in administrative hierarchy.

<sup>53</sup>. For related evidences, see Additional file 2: Table S6.

<sup>54</sup>. In our sample, the ratio of fiscal subsidies to total sales for SOEs is averagely four to five times higher than that for other firms.

<sup>55</sup>. We will discuss policy implications based on these elasticities in Subsection “Discussion on the results from heterogeneity analyses” of this section.

<sup>56</sup>. We also try other specification using interactions of ITC with dummies for the subsamples. The main results are qualitatively close to those in Table 6. Furthermore, we repeat estimations using subsamples of listed and unlisted firms, and fail to find significant difference. Those listed as well as affiliated to the central government, however, response like central enterprises. What does matter, therefore, is the relationship with the central government, but not being public enterprises. The related results are available from the authors upon request.

<sup>57</sup>. A beneficiary in the benchmark sample receives 522,143 Chinese RMB of ITC, averagely. And we assume that the payable tax will not change when ITC is increased.

<sup>58</sup>. There are 0.38 million firms in China that are above-scale manufacturing enterprises. See the website of the National Bureau of Statistics of China, <<http://data.stats.gov.cn/easyquery.htm?cn=C01>>. The figure is for the year 2014.

<sup>59</sup>. The figures are those under intensive margin effect. They are calculated by multiplying 3800 by 361 and multiplying 3800 by 5221. The figures under extensive margin effect, however, are less cost-benefit efficient.

<sup>60</sup>. There may be some other micro-level mechanisms behind the correlation of tax incentives with environmental protection. Due to availability of data, however, now we can just give evidence about the mechanisms of profitability and firm-government relationship. We will continue our study on other mechanisms in future research.

## Additional files

**Additional file 1:** A schematic model explaining effect of the tax incentives on energy use. (DOC 151 kb)

**Additional file 2:** Auxiliary tables and figures. (DOC 295 kb).

**Additional file 3:** A note for calculating elasticity. (DOC 57 kb)

## Abbreviations

FCS: Fiscal contract system; GDP: Gross domestic production; HMT: Hong Kong, Macao, and Taiwan; ITC: Investment tax credit; MOF: Ministry of Finance; NTSD: National Tax Statistics Dataset; ROA: Return on assets; SAT: State Administration of Taxation; SOE: State-owned enterprises; TID: Taxable income deduction

## Acknowledgements

Jie Mao acknowledges financial support from the National Natural Science Foundation of China (grant number: 71573038). We are grateful to advices from Roger Gordon, Michael Greenstone, Ruixue Jia, and David Victor, and thank Chong-en Bai for providing us with the data.

## Availability of data and materials

The dataset and dofiles of STATA used in this paper's empirical analysis are available from the authors upon request (please send email to [zjumilesark@126.com](mailto:zjumilesark@126.com)).

## Authors' contributions

JM is the main contributor to this paper. Both authors read and approved the final manuscript.

## Competing interests

The authors declare that we have no competing interests.

Received: 18 August 2016 Accepted: 25 October 2016

Published online: 09 November 2016

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