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Fiscal decentralization and environmental pollution: Evidence from Chinese panel data☆

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ABSTRACT

China's environmental pollution casts a shadow on its economic success. Concerning fiscal decentralization, China introduced the rule-based tax assignment system in 1994. To avoid the structural change in underlying fiscal regimes, we use the provincial panel data during the period 1995–2010. We find that fiscal decentralization has no significant effect on environmental pollution as it is measured per capita emission of wastewater, waste gas or solid waste in system GMM (Generalized method of moments) estimation. Our results are robust when we use different measures of fiscal decentralization. We further find that fiscal decentralization has a significant, positive effect on pollution abatement spending and pollutant discharge fees, which indicates possible mechanisms for fiscal decentralization to help protect the environment.

1. Introduction

It is not news that China's water and air are badly polluted following three decades of rapid growth. Fig. 1 illustrates China's wastewater pollution as measured in tons of emission of wastewater per capita for three respective provinces of Beijing, Guangdong, and Inner Mongolia. For instance, the emissions of wastewater for Inner Mongolia were 12 and 16 t per capita in 1995 and 2010, respectively. China's economic regime switched from central planning to decentralization in 1978. The fiscal decentralization initiated in 1980 is one of the most important. The goal of fiscal decentralization is to elicit a local government's initiative. Although there is still a debate (Lin & Liu, 2000; Zhang & Zou, 1998), many authors argue that China's three decades of growth can be partly explained by its fiscal federalism (e.g., Blanchard & Shleifer, 2001; Maskin, Qian, & Xu, 2000; Montinola, Qian, & Weingast, 1995; Qian & Roland, 1998; Qian & Xu, 1993). A question arises, but has not been addressed thoroughly: Is China's fiscal decentralization to blame for its environmental pollution? In this paper we focus on this central issue.

Following Oates (1972), local governments maximize the aggregate welfare of the local constituents. A decentralized system would reflect local needs (Besley & Coate, 2003; Faguet, 2004). Authors (Cutter & DeShazo, 2007; List & Gerking, 2000; Millimet, 2003) have found limited beneficial effects from decentralization for environmental protection in the U.S. Within the Chinese institutional context, local officials are not elected by local constituents. Rather, they are appointed by upper-level officials. Blanchard and

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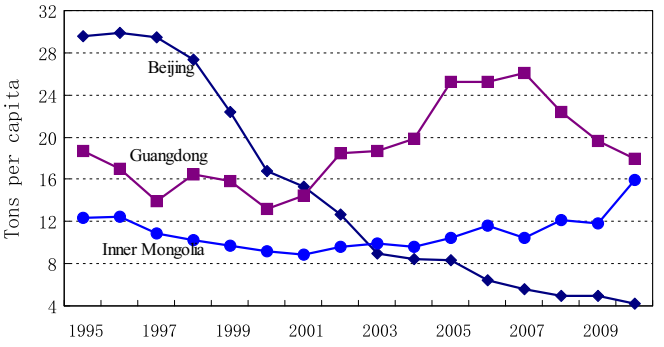

Fig. 1. Per capita wastewater emission for three representative Chinese provinces: 1995–2010.
Data source: *China Environmental Yearbook*. Beijing: China Environmental Statistical Press 1996–2011 (annual).

Shleifer (2001) highlight that under the tight control of the communist party, the central government in China has maintained a strong position to both reward and punish local administrations. Qian and Xu (1993) and Maskin et al. (2000) demonstrate that the reward mechanism is made possible by the multidivisional-form (M-form) structure of the Chinese economic system. To evaluate and promote the local officials, the central government may use the growth rates of the local economy, argued by Blanchard and Shleifer (2001) and Li and Zhou (2005), or revenue collection highlighted in Shih, Adolph, and Liu (2012). Therefore, it is more rational for the local officials to spend all investments on promoting growth, rather than spend them on controlling pollution. By so doing, their chances of promotion would be maximized. It is less likely that the preference of China's local officials would reflect local needs. It seems that the Chinese federalism would impact negatively on the environment.

The same prediction – Chinese federalism may harm the environment – can also be deduced from the pollution-haven hypothesis (PHH) literature (see Dean, Lovely, & Wang, 2009, and the references therein). List and Co's (2000) U.S. study finds evidence consistent with PHH. Dean et al. (2009) demonstrate that equity joint ventures from ethnically Chinese (EC) sources (Hong Kong, Macao, and Taiwan) are significantly attracted by weak environmental standards. Henley, Kirkpatrick, and Wilde (1999) demonstrate that, between 1985 and 1996, 66.4% of FDI (foreign direct investment) into China came from EC sources.[1] Therefore, given the reward structure of the Chinese institutional context, local administration would be reluctant to increase environmental policy stringency. Otherwise, higher regulatory costs would deter FDI from EC sources and therefore, hurt the growth of the local economy.

We find that fiscal decentralization has no significant effect on environmental pollution, as measured per capita emission of wastewater, waste gas or solid waste, in system GMM (Generalized method of moments) estimation. Our results are robust when we use different measures of fiscal decentralization. Our results also hold up when we include both the expenditure and revenue decentralization indicators in one regression, following Jia, Guo, and Zhang (2014). We further find that fiscal decentralization has significant, positive effects on pollution abatement spending and pollutant discharge fees, which indicates possible mechanisms for fiscal decentralization to help protect the environment.

Our study is close in spirit to List and Gerking (2000) and Millimet (2003) who find limited effects of the Reagan-era decentralization on air pollution and pollution abatement spending. In the U.S., the local officials were elected by local constituents before decentralization. Therefore, the preference of local officials already reflected local needs. The weak effect of decentralization on environmental outcomes in the U.S. can be rationalized. However, our finding is harder to rationalize. As argued above, it is less likely that the preference of local officials would reflect local needs in China without direct democracy. This suggests that Chinese federalism would hurt the environment. Our results are not supportive of this conjecture, indicating that the preference of local officials may still reflect local needs in the Chinese institutional context. Revealing the preference of local officials is clearly important because the effect of federalism on other outcomes in the process of economic development also crucially depends on the preferences of local officials. We have provided some explanation for our results in Subsection 3.6 and in the concluding Section 4.

Specifically, concerning fiscal decentralization, China introduced the tax assignment system to replace the fiscal contracting system in 1994 — detailed in Subsection 1.1. To avoid the underlying structural change in fiscal regimes, we examine how the new fiscal decentralization affects environmental pollution during the following period 1995–2010 for 27 Chinese provinces. The panel data may have many appealing features as presented below.

First, cross-country studies (e.g., Sigman, 2008) cannot adequately account for political regime, institutional and cultural effects, and other factors. As a result, they suffer from the omitted variable bias. The unobserved differences across provinces are much smaller when compared to those across countries. Moreover, our panel data allows us to control for unobserved provincial characteristics, and consequently avoid the bias from omitting such characteristics.

Second, using data solely from the new fiscal system period provides a consistent underlying fiscal regime, further controlling for policy regimes, external shocks and other unobserved province characteristics. The new fiscal system is a rule-based one of revenue-sharing between the central and local governments, while the old one is discretion-based. That is, the new fiscal system established fixed formulas by the central government in sharing the tax revenues with the provincial governments. In contrast, in the old system, the central government and the local government negotiated a percentage or amount of locally collected revenues (could change year

[1] For the FDI-regulation nexus, please also see Cole et al. (2006) and Cole et al. (2011).

from year) to be remitted to the central government. Given the substantial difference between the two fiscal systems, it is appealing to use data from one system. It is more appealing to use data from the new system because it is rule-based (not subject to negotiations).

Third, the degree of rule-based fiscal decentralization still has substantial variations cross provinces and time, due to the gradual approach to reform in China. Following previous literature (e.g., Fiva, 2006; Jin & Zou, 2002), one of our measures of fiscal decentralization is the ratio of provincial budgetary and extra-budgetary revenues to the budgetary revenues of the central government, expressed in per capita terms, denoted *REVALL*, detailed in Subsection 2.5. Fig. 2 illustrates the substantial variations in *REVALL* across the three representative provinces in China mentioned above (see Subsection 1.2 for more elaboration). Our analysis exploits the substantial variations.

Fourth, the panel data specification allows us to deal with the potential endogeneity of fiscal decentralization that arises because of, for instance, reverse causality, by the system GMM estimation. In so doing, we can establish a causal relationship between fiscal decentralization and pollution in China.

The potential endogeneity of fiscal decentralization is one reason why we do not use the standard instrumental variable (IV) approach. The standard IV approach – fiscal decentralization is used as an instrumental variable for pollution abatement spending or the stringency of environmental policy – suffers from the blunt instrument problem (Bazzi & Clemens, 2013). First, we will always have omitted variable bias in the standard IV approach unless we include both channels (pollution abatement spending and the stringency of environmental policy). Second, fiscal decentralization may also influence environmental pollution via other channels. Third, fiscal decentralization may be endogenous. Therefore, we study the direct cause effect of fiscal decentralization on pollution and then identify the intermediate channels. Our two-step identification strategy is more robust.

Our finding contradicts He, Pan, and Yan (2012) who have found that decentralization increases air pollution with city-level data in China. First, our indicator of fiscal decentralization is more suitable and commonly used (see Fiva, 2006; Jin et al., 2005; Jin & Zou, 2002; Zhang & Zou, 1998). Second, Dean et al. (2009, p. 2) highlight: "[The] lack of evidence for PHH in earlier studies may be due to a failure to account for endogeneity and measurement error." Similarly, without accounting for endogeneity, He et al.'s finding cannot be taken as robust and causal. Third, the city level data may overlook the whole picture. The federalism literature emphasizes the competition among state/provincial administrations. However, at the city level, the cities are located in different provinces, and, hence, the direct competition among the thousands of cities in different provinces may not be a big concern for each city. Moreover, He et al.'s study fails to account for the fact that the cities within one province may differ fundamentally from those within another province. A study similar to ours may use city level data within one province, but such a study would significantly decrease the number of observations. Such a study would also fail to capture the essence of federalism. This is because the cities within one province not only compete with one another, but also have to compete with other cities within the whole country. Such a concern would not be an issue with state-level data.

The rest of the paper proceeds as follows. After we introduce the institutional background, in Section 2 we describe the data and the estimation strategy. Section 3 presents the regression results. Section 4 concludes.

1.1. Fiscal decentralization in China

A comprehensive description of China's fiscal decentralization is beyond the scope of this paper (see Montinola et al., 1995; Wang, 1995, for details). Here, we give a brief summary.

In 1978, China initiated market-oriented reform and opening-up. One important aspect of the market-oriented reform is the initiation of fiscal decentralization in 1980. That is, China adopted a fiscal contracting system between the central and provincial governments (and between any two adjacent levels of governments). The provincial government negotiates with the central government on the total amount (or share) of tax and profit revenue (negative values mean subsidies) to be remitted to the central government for the next several years (see Ma, 1995; Zhang & Zou, 2001, for discussions on the pre-1994 fiscal system in China). In 1994, a new fiscal system – the tax assignment system – was introduced to replace the old discretion-based system of revenue-sharing (the fiscal

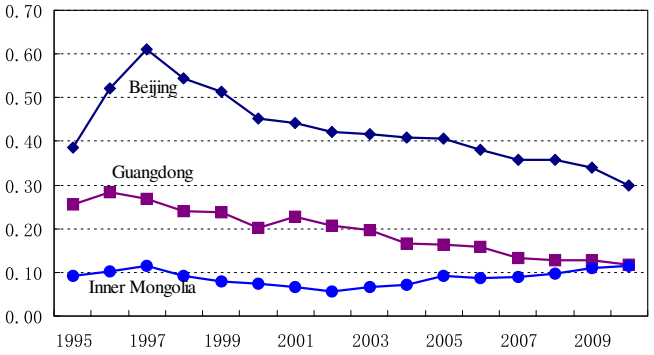

Fig. 2. Degree of fiscal decentralization (*REVALL*) for three representative Chinese provinces: 1995–2010. Notes: *REVALL* is calculated as the sum of budgetary and extra-budgetary revenues of a province divided by the budgetary revenue of the central government, weighted by the provincial population.
Data sources: *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

contracting system). We follow He and Sun (2014) and Wang (1995) to summarize the main characteristics of the new rule-based system of revenue-sharing below.

First, taxes now are divided into three distinct categories: central, local, and shared. Central taxes concern those with national interests and macroeconomic management. Before 2002, examples of central taxes include tariffs, corporate income taxes and the remitted profits of state-owned enterprises. Local taxes include corporate income taxes and the remitted profits of local enterprises as well as personal income tax, and many others related to local economic activities. The shared taxes include the value added tax (VAT), resource tax, and securities exchange tax. However, the classification was subjected to a substantial change in 2002 as elaborated in the next paragraph. As a result, central taxes and local taxes would go into the central budget and local budget, respectively. As for shared taxes, they are to be split between the central and provincial governments according to some established formulas. The established formulas are fixed (i.e., not subject to negotiation) and apply to all the provinces. For instance, 75% of the revenue from the VAT goes to the central government and the remaining 25% to the provincial governments; 50% of the revenue from securities exchange tax belongs to the central government and the other half to the provincial governments.

As discussed, China's new rule-based fiscal system has also been subjected to changes in sharing-rules between the provinces and the central government. Before 2002, local taxes included all corporate income taxes and remitted profits of local enterprises, personal income tax, and many others related to local economic activities. However, since 2002, both corporate income taxes and personal income taxes became the central-local sharing taxes: The central government owned 50% of income taxes in 2002 and 60% thereafter. We will use data during the period 1995–2010 to cover the impact of the reform on the sharing of income taxes in 2002.

Second, tax administration has been centralized. Before 1994, local tax offices were tasked with collecting virtually all taxes. After 1994, the center established its own revenue collection agency (i.e., the national tax service). Under the two parallel systems of tax administration, the national system collects central taxes and the local system collects local taxes. Shared taxes are collected by the national system first, but the proceeds from these taxes would be divided between the central and subnational governments according to the formulas mentioned above. Third, tax rates have been standardized and the tax structure has been simplified. Some taxes, such as product tax, have been abolished. A universal tax rate of 33% has been imposed on all enterprises. Moreover, local governments are no longer allowed to grant tax breaks.

1.2. The provincial variation in fiscal decentralization

To test the effects of fiscal decentralization on environmental pollution, we need to exploit their provincial variations. However, after 1994 the rules for revenue-sharing are fixed and apply to all provinces. Why would there be substantial provincial variations in the degree of fiscal decentralization? Moreover, is our measure of fiscal decentralization closely related to the share of locally collected tax revenues kept by the local province? We use the expenditure decentralization, denoted *EXPALL*, to answer these two questions. China's fiscal decentralization has two important characteristics. The first is that central government transfers have been of a relatively large volume, mainly to support the development of poor regions. The second is the existence and expansion of extra-budgetary funds (Montinola et al. describe them as certain categories of revenues collected by the local governments and ministries, including some retained profits of state-owned enterprises). We rely on these two features for the answers.

The Finance Yearbook of China (FYC) contains the complete data on the budgetary income and expenditure of all provincial governments. It has the inter-governmental transfers (i.e., bilateral transfers between the central government and the provincial governments), and the extra-budgetary income and expenditure for all provincial governments. The provincial data provided by the FYC allows us to identify the source of the substantial variations in the degree of fiscal decentralization. Table 1 presents the data for the three representative provinces mentioned above, namely Beijing, Guangdong and Inner Mongolia. The three provinces are representative of their respective group (the municipalities, the rich coastal provinces, and the poor interior provinces) because of the abovementioned two features of China's fiscal federalism: China's central government favors the poorer provinces in allocating its central transfers, and therefore, the rich provinces would expand their extra-budgetary funds more to avoid predation from the central government (the common-pool problem of China's fiscal federalism has been discussed in Jia et al., 2014).

The fiscal data in Table 1 substantiates the two features of China's fiscal federalism. The budgetary expenditure of a province roughly equals the sum of its budgetary income, extra-budgetary income, and net transfer from the central government. The net transfer from the central government equals the subsidies from the central government minus the remittance to the central government. That is, the funding of the budgetary expenditure of a province mainly comes from three sources: budgetary income, extra-

Table 1
Data on China's fiscal system 1995–2010.
Data source: Finance Yearbook of China, Beijing: China Finance Press 1996–2011 (annual).

	Average (mean) over the period 1995–2010			
	Beijing	Guangdong	Inner Mongolia	China
Budgetary expenditure	981.1	2083.0	699.0	6447.9
Extra-budgetary expenditure	102.0	367.8	42.8	
Budgetary income	821	1691.0	288.9	15,628
Extra-budgetary income	123.6	484.5	63.12	
Subsidies from the central government	195.8	694.0	393.6	
Remittance to the central government	47.1	1.5	58.1	

Note: the income, expenditure and transfers data are in 100 million Yuan.

budgetary income, and net transfer from the central government. Based on the transfer payments data, all the provinces have positive net transfers from the central government. Therefore, the central government subsidizes the provincial governments, which are financed by tax-revenues from the central taxes, shared taxes, and remittances from the provincial governments. For instance, over the sample period 1995–2010, the central government had an average annual budgetary income of 1562.8 billion yuan, while its average annual budgetary expenditure was only 644.8 billion yuan. Therefore, more than 50% of central revenues were transferred back to the provinces.

The poorer province of Inner Mongolia has received more subsidies from the central government. During 1995–2010, on average Inner Mongolia received an annual transfer of 39.4 billion yuan from the central government, which consisted of 56% of its average annual budgetary income. By contrast, the ratios for Beijing and Guangdong were 20% and 33%, respectively. As a result, the rich provinces would think that they have subsidized the poorer provinces. Therefore, as Montinola et al. state, that the local governments want to prevent predation by the central government. In China, the extra-budgetary revenue is wholly retained by the local government. Therefore, the expansion of extra-budgetary revenues enhances local government security from predation by the central government. Table 1 demonstrates the faster expansion of the extra-budgetary income of the rich provinces. During 1995–2010, the extra-budgetary income of the rich province Guangdong was around 29% of its budgetary income, while the ratio for Inner Mongolia was 22%.

Now we can identify the substantial variations in our measure of fiscal decentralization (*EXPALL*). The provincial variations mainly come from two sources: the transfer from the central government and the extra-budgetary expenditure.

Moreover, the fiscal decentralization data patterns show that the extra-budgetary income/expenditure is closely related to the share of locally collected tax revenues kept by the local province under the rule-based fiscal system. Therefore, *EXPALL* is a suitable measure of fiscal autonomy at the provincial level. Nonetheless, it may not be perfect. Although *EXPALL* takes account of the fiscal autonomy of the rich provinces, it tends to over-estimate that of the poor provinces because the poor provinces receive more subsidies from the central government, as illustrated in Fig. 3 for the period 2003–2010. Therefore, to check the robustness of our results, we will also use revenue decentralization indicators, following the previous literature (see, e.g., Fiva, 2006; Jin & Zou, 2002).

2. The data

2.1. The empirical specification and the empirical strategy

Before we construct the data, we present the empirical specification:

$$\ln(EP)_{i,t} = \beta_0 + \beta_1 \ln(EP)_{i,t-1} + \beta_2 \ln(\mathrm{FDC})_{i,t} + \beta_3(\mathrm{Control\ Variables})_{i,t} + u_1 + T_t + \varepsilon_{i,t} \quad (1)$$

where $(EP)_{i,t}$ is the measure of environmental pollution for the ith province in year t; FDC is the degree of fiscal decentralization; u_i and T_t stand for fixed province and time effects respectively. The reason to control for other variables is presented below.

We cannot completely rule out the possibility that the changes in environmental pollution are persistent over time. Therefore, we have controlled for the lagged values of environmental pollution in the regressions. Including the lagged dependent variable will allow us to use system GMM to deal with the potential endogeneity of fiscal decentralization and other independent variables. There is no prior information about whether we should control for the lagged dependent variable in the regressions. Nonetheless, we have checked the results when we do not control for the lagged dependent variable in the regressions, and the results (not reported) indicate that our main findings remain robust.

Following Grossman and Krueger (1991), there is a large body of literature testing the environmental Kuznets curve (EKC) hypothesis (e.g., Chimeli & Braden, 2005; Selden & Song, 1994; Shen, 2006; Song, Zheng, & Tong, 2008; Stern & Common, 2001). The EKC hypothesis indicates that environmental pollution is an inverted-U function of per capita income. Therefore, we control for per capita income and its square. In our analysis, per capita income is measured as per capita real GDP (Gross domestic product), denoted

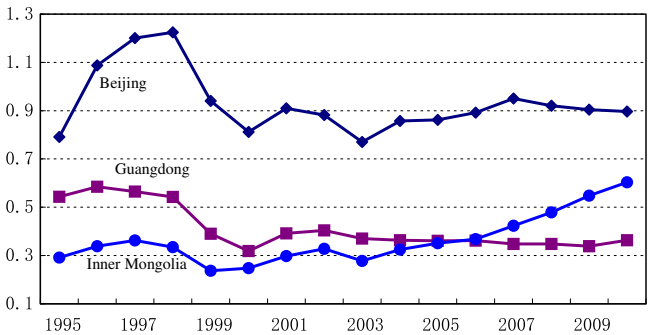

Fig. 3. Degree of fiscal decentralization (*EXPALL*) for three representative Chinese provinces: 1995–2010. Notes: *EXPALL* is calculated as the sum of budgetary and extra-budgetary expenditures of a province divided by the budgetary expenditure of the central government, weighted by the provincial population.
Data sources: *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

RGDPC. Other than the income factors, there is no consensus on what factors are important in determining environmental pollution level. In our other study, we find that physical capital investment rate is driven by fiscal decentralization in the Chinese institutional context mentioned above. Since pollution is a side-product of production and investment, we control for physical capital investment rate, referred to as (*I*/*GDP*).

There are of course many environmental factors such as the stringency of environmental protection and the pollution abatement spending. Nonetheless, we do not control for these environmental factors. The reason is presented in the following section.

2.1.1. The empirical strategy

It is possible that fiscal decentralization impacts environmental pollution by changing the environmental factors such as the stringency of environmental protection and the pollution abatement spending. The usual empirical strategy would be the standard IV approach. That is, we use fiscal decentralization as an instrument variable for the environmental factors. However, as discussed, the standard IV approach suffers from the blunt instrument problem. Therefore, we leave the environmental factors out of our main equation (Eq. (1)). In so doing, we would like to estimate the total effect of fiscal decentralization on environmental pollution. To further identify the possible mechanism for the effect of fiscal decentralization on pollution, we will test the effect of fiscal decentralization on the environmental factors in Subsection 3.5.

One reason why our two-step estimation strategy is more robust is as follows. The standard IV approach assumes the exogeneity of fiscal decentralization, which is essential for the validity of fiscal decentralization as instruments. However, for aggregate level regressions, it is hard to justify that fiscal decentralization is exogenous to the environmental pollution process. Our two-step estimation strategy allows us to take account of the potential endogeneity of fiscal decentralization by estimating the total effect of fiscal decentralization on environmental pollution. Our fiscal decentralization indicators may possibly be endogenous to the environmental pollution process, as elaborated below.

Given the alarming pollution level in China, the central government has begun to use its fiscal system to combat pollution. The central transfers in China include a large number of earmarked transfers, some of which are directly used in environmental protection. Li (2010) illustrates that 9% of China's earmarked transfers in 2009 were directly used towards environmental protection. Moreover, the allocation of the general-purpose grants (another form of central transfers in China) may also depend on the spending on environmental protection. Our data sample covers the period 1995–2010. Moreover, as elaborated in Subsection 1.2, central transfer has caused substantial variations across provinces in our measures of fiscal decentralization. Therefore, there is a feedback effect from environmental pollution to fiscal decentralization. We are not sure how large this feedback effect is, but the existence of reverse causality makes fiscal decentralization endogenous to the environmental pollution process.

Moreover, as in the EKC literature, they may also exist reverse causality between income level and environmental pollution. We use system GMM estimation to deal with the potential endogeneity problem of all of our explanatory variables.

2.2. The data sample

We use the Chinese provincial data for the period 1995–2010. Our data sample begins in 1995 because the new fiscal system was implemented in 1994 in China (see Subsection 1.1). Given the structural break, we only consider the consistent regime after 1994. 2010 is the latest year from which we can collect all data.

Before 1998, among the 31 provincial governments in China, four are municipalities and four are autonomous regions. We delegate the usage 'province' to all. The inclusion of the provinces in our sample adheres to our previous studies (e.g., He, 2012; He, Sun, & Zou, 2013a; He, 2015). Specifically, Chongqing, Sichuan, Hainan and Tibet were excluded.[2] In summary, the data sample comprises panel data from 27 provinces and 16 years (1995–2010), which produces a balanced panel with 432 observations.

2.3. Measuring environmental pollution

The Environmental Protection Agency (EPA) of the U.S. states: "Hazardous waste is waste that is dangerous or potentially harmful to our health or the environment. Hazardous wastes can be liquids, solids, gases…They can be discarded commercial products, like cleaning fluids or pesticides, or the by-products of manufacturing processes."[3] The EPA has a more sophisticated classification for environmental pollutants. Nonetheless, wastewater, waste gas and solid waste are three main groups of environmental pollutants. The China Environment Yearbook (hereafter CEY) has complete annual provincial data on the three main environmental pollutants (wastewater, waste gas and solid waste) for the industrial sectors. Following previous literature (Selden & Song, 1994), we use the per capita emission of wastewater, waste gas, and solid waste, denoted *WATER*, *GAS*, and *SOLID*, respectively, to measure environmental pollution in China.[4]

[2] There are complete data for Hainan. We follow our previous studies for the data on the other variables. Because these previous studies did not include Hainan, we follow suit. However, we believe that our result would remain robust by adding 16 more observations from Hainan.

[3] http:www.epa.gov/epawaste/hazard/index.htm.

[4] Cole et al. (2008) study determinants of industry level pollution in China.

2.4. Measuring pollution abatement and environmental policy

The CEY also presents complete annual provincial data on efforts to protect the environment. First, the CEY has complete provincial data on the pollution abatement spending. The sources of spending on pollution abatement are budgetary basic construction funds, budgetary technological innovation and upgrading funds, retained profits for comprehensive use, subsidies for environmental protection, loans for environmental protection, and the use of FDI. Since China's provinces vary substantially in terms of size, we use per capita pollution abatement spending, denoted *ABATE*, to establish a comparable measure across provinces. A higher value of per capita pollution abatement spending indicates that the province relatively spends more in abating environmental pollution. All else equal, less pollutants would be emitted into mother nature.

Second, the CEY presents complete provincial data on pollutant discharge fees collected and spent. Pollutant discharge fees refer to those collected from the environmental pollutants emitted including the three main ones that we are interested in. We also use per capita measure to build a comparable measure across provinces. We argue that per capita pollutant discharge fees collected, denoted *FEEIN*, can measure the stringency of environmental protection. All else equal, a higher value of per capita pollutant discharge fees levied indicates that the province has a relatively more stringent environmental policy.

Third, we argue that the per capita pollutant discharge fee spent, denoted *FEEUSE*, is also a measure of pollution abatement spending. According to the CEY, the provinces spend the collected pollutant discharge fees on environmental protection activities and uses. The uses of the collected pollutant discharge fees are divided into abating the sources of pollution, loan exemption, loans for environmental protection, subsidies for comprehensive control, purchasing of equipment and instruments, and others.

Unfortunately, the CEY provides data on pollutant discharge fees collected and pollutant discharge fees spent up to year 2002. Nevertheless, the CEY continues to provide data on pollution abatement spending. Therefore, we have data on per capita pollutant discharge fees collected (*FEEIN*) and per capita pollutant discharge fees spent (*FEEUSE*) during 1995–2002. We have data on per capita pollution abatement spending (*ABATE*) during our whole sample 1995–2010.

2.5. Measuring fiscal decentralization

We use the provincial fiscal data from the FYC to construct our measures of fiscal decentralization. Following Montinola et al. (1995); Zhang and Zou (1998), and Jin, Qian, and Weingast (2005), we consider budgetary and extra-budgetary funds for the provincial governments. As Subsection 1.1 indicates, fiscal decentralization involves both expenditure and revenue dimensions. Moreover, as Subsection 1.1 indicates, the 1994 tax-sharing reform mainly focused on the revenue-sharing rules and only made a few changes in expenditure responsibilities. Therefore, following previous literature (e.g., Fiva, 2006; Jin & Zou, 2002), revenue decentralization and expenditure decentralization are used to measure fiscal decentralization. Specifically, we construct two measures of fiscal decentralization: one revenue decentralization indicator (i.e., *REVALL*) and one expenditure decentralization indicator (i.e., *EXPALL*). The other measures of fiscal decentralization are presented in Subsection 3.4. Specifically, we measure *REVALL* and *EXPALL* as

$$REVALL = (\text{the budgetary revenue of a province} + \text{extra-budgetary revenue of the province}) / (\text{the budgetary revenue of the central government} \times \text{total population of the province}),$$

$$EXPALL = (\text{the budgetary expenditure of a province} + \text{extra-budgetary expenditure of the province}) / (\text{the budgetary expenditure of the central government} \times \text{total population of the province}).$$

Table 2
Descriptive statistics.
Data sources: The first six environmental variables: *China Environmental Yearbook*, 1996–2011 (annual). The fiscal decentralization indicators: *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). The last three variables: *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

	Mean	Standard deviation	Minimum	Maximum
ln(*GAS*)	5.15	0.71	3.71	7.86
ln(*WATER*)	7.32	0.55	5.73	9.39
ln(*SOLID*)	4.45	0.66	2.97	6.53
ln(*ABATE*)	7.40	0.96	4.66	9.79
ln(*FEEIN*)	5.96	0.62	4.25	9.29
ln(*FEEUSE*)	5.88	0.64	4.10	7.10
ln(*REVALL*)	−2.34	0.67	−3.37	−0.34
ln(*EXPALL*)	−1.17	0.50	−2.10	0.36
RGDPC	0.42	0.40	0.06	2.81
$(\text{RGDPC})^2$	0.33	0.83	0.003	7.88
I/GDP	49.58	11.46	30.54	96.71

Observations: 432 (the panel data for 27 provinces during 1995–2010). For *ln*(*FEEIN*) and *ln*(*FEEUSE*) the number of observation is 216 (1995–2002). *ln*(*GAS*), *ln*(*WATER*), and *ln*(*SOLID*) are the logarithms of per capita emission of waste gas, waste-water, and solid waste, respectively; the units are 0.1 billion cubic meters per 100 people, tons per 100 people, and tons per 100 people, respectively. ln(*ABATE*), *ln*(*FEEIN*), and *ln*(*FEEUSE*) are the logarithms of per capita pollution abatement expenditure, pollutant discharge fees collected, and pollutant discharge fees spent, respectively; the units of *ABATE*, *FEEIN* and *FEEUSE* are all yuan (the Chinese currency) per 100 people. *ln*(*REVALL*) and *ln*(*EXPALL*) are the revenue decentralization and expenditure decentralization indicators, respectively. *REVALL* (*EXPALL*) is calculated as the sum of budgetary and extra-budgetary revenues (expenditures) of a province divided by the budgetary revenue (expenditure) of the central government, weighted by the provincial population. RGDPC is per capita real GDP, which is in 10,000 yuan. *I/GDP* is the ratio of nominal investment to nominal GDP (in percentage term).

Take Guangdong for example. In 1995, its values of *REVALL* and *EXPALL* would be.

REVALL = (budgetary revenue (380.7) + extra-budgetary revenue (191.7)) / (budgetary revenue of the central government (32) × Population of Guangdong (69)) = 0.26,

EXPALL = (budgetary expenditure (576.2) + extra-budgetary expenditure (186.8)) / (budgetary revenue of the central government (20.5) × Population of Guangdong (69)) = 0.54.

2.6. Measuring other variables

The China Statistical Yearbook (CSY) provides nominal GDP and GDP indexes for each province. With 1978 as our base year, we multiply the nominal GDP in 1978 by the GDP index in that year and divide the result by 100 to get real GDP. Then with the population data from CSY, we get real GDP per capita (RGDPC) and its square ($RGDPC^2$).

The provincial investment data are available from the CSY. Following our previous studies, we use the nominal investment rate, which is the ratio of nominal physical capital investment to nominal GDP, for (*I/GDP*). Table 2 presents the summary statistics of our final complete data.

3. Empirical results

3.1. LSDV estimation results

We first use LSDV estimation (i.e., OLS (Ordinary least squares) estimation that includes 27 province dummies and 16 time dummies) and present the results in Table 3.

Table 3
LSDV regressions between environmental pollution and fiscal decentralization.
Annual provincial data 1995–2010.
Data sources: *China Environmental Yearbook*. Beijing: China Environmental Statistical Press 1996–2011 (annual). *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

	Regression number					
	3.1	3.2	3.3	3.4	3.5	3.6
	Dependent variable as					
Indep. Vari.	*ln*(*GAS*)		*ln*(*WATER*)		*ln*(*SOLID*)	
ln(*REVALL*)	0.14**		0.06		0.14**	
	(0.06)		(0.09)		(0.06)	
ln(*EXPALL*)		0.07		−0.0005		0.10*
		(0.06)		(0.09)		(0.06)
$ln(GAS)_{t-1}$	0.72***	0.73***				
	(0.04)	(0.04)				
$ln(WATER)_{t-1}$			0.71***	0.71***		
			(0.04)	(0.04)		
$ln(SOLID)_{t-1}$					0.76***	0.77***
					(0.03)	(0.03)
RGDPC	−0.21	−0.10	0.003	0.06	−0.03	0.10
	(0.14)	(0.13)	(0.20)	(0.19)	(0.13)	(0.12)
$(RGDPC)^2$	−0.004	−0.02	−0.07	−0.08	−0.03	−0.05
	(0.04)	(0.04)	(0.06)	(0.05)	(0.03)	(0.03)
I/GDP	0.002**	0.002**	0.002	0.002	0.002**	0.002**
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Time FE	Yes	Yes	Yes	Yes		Yes
Province FE	Yes	Yes	Yes	Yes		Yes
R^2	0.97	0.97	0.89	0.89	0.97	0.97
Observations	405	405	405	405	405	405

Note: *ln*(*GAS*), *ln*(*WATER*), and *ln*(*SOLID*) are the logarithms of per capita emission of waste gas, waste-water, and solid waste, respectively; the units are 0.1 billion cubic meters per 100 people, tons per 100 people, and tons per 100 people, respectively. *ln*(*REVALL*) and *ln*(*EXPALL*) are the revenue decentralization and expenditure decentralization indicators, respectively. *REVALL* (*EXPALL*) is calculated as the sum of budgetary and extra-budgetary revenues (expenditures) of a province divided by the budgetary revenue (expenditure) of the central government, weighted by the provincial population. RGDPC is per capita real GDP, which is in 10,000 yuan. *I/GDP* is the ratio of nominal investment to nominal GDP (in percentage term).
(Standard error in parentheses.)
*** Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.10 level.

According to regression 3.1 in Table 3, when the logarithm of waste gas pollution (i.e., *ln*(*GAS*)) is the dependent variable, the estimated coefficient on the revenue decentralization indicator (*ln*(*REVALL*)) is positive, which is significant at the 5% level. That is, a higher degree of revenue decentralization is significantly and positively associated with waste gas pollution in China during 1995–2010. The estimated coefficient on the lagged dependent variable is positive and significant at the 1% level, as expected. The estimated coefficients on per capital real GDP and its square term are both negative and insignificant at the 10% level. This result demonstrates that there is no EKC with respect to waste gas pollution. The estimated coefficient on physical capital investment rate is positive and significant at the 5% level. The R-squared is 0.97, meaning our empirical specification fits the Chinese waste gas pollution data quite well. According to regression 3.2 in Table 3, when *ln*(*GAS*) is the dependent variable, the estimated coefficient on the expenditure decentralization indicator (*ln*(*EXPALL*)) is positive, which is insignificant at the 10% level. That is, a higher degree of revenue decentralization is insignificantly associated with waste gas pollution in China during 1995–2010. The results on other explanatory variables remain similar to those in regression 3.1.

According to regression 3.3 in Table 3, when the logarithm of wastewater pollution (i.e., *ln*(*WATER*)) is the dependent variable, the estimated coefficient on the revenue decentralization indicator (*ln*(*REVALL*)) is positive, which is insignificant at the 10% level. That is, a higher degree of revenue decentralization is insignificantly associated with wastewater pollution in China during 1995–2010. The estimated coefficient on the lagged dependent variable is positive and significant at the 1% level. The estimated coefficients on per capital real GDP is positive and insignificant. The estimated coefficients on the square term of per capital real GDP is negative and insignificant. This result demonstrates that there is no EKC with respect to wastewater pollution. It is worth noting that, when we do not control for the lagged dependent variable in the regression, there is strong evidence of an EKC with respect to wastewater pollution in China. Nonetheless, our main finding concerning the causal relationship between fiscal decentralization and environmental pollution remains robust. The estimated coefficient on physical capital investment rate is positive and insignificant. According to regression 3.4 in Table 3 when *ln*(*WATER*) is the dependent variable, the estimated coefficient on the expenditure decentralization indicator (*ln*(*EXPALL*)) is negative and insignificant. That is, a higher degree of revenue decentralization is insignificantly and negatively associated with wastewater pollution in China during 1995–2010. The results on other explanatory variables remain similar to those in regression 3.3.

According to regression 3.5 in Table 3 when the logarithm of solid waste pollution (i.e., *ln*(*SOLID*)) is the dependent variable, the estimated coefficient on revenue decentralization (*ln*(*REVALL*)) is positive, which is significant at the 5% level. That is, a higher degree of revenue decentralization is significantly and positively associated with solid waste pollution in China during 1995–2010. The results on other explanatory variables remain similar to those in regression 3.1. According to regression 3.5 in Table 3 when *ln*(*SOLID*) is the dependent variable, the estimated coefficient on expenditure decentralization (*ln*(*EXPALL*)) is positive, which is significant at the 10% level. The results on other explanatory variables remain similar to those in regressions 3.1 and 3.5.

In summary, a higher degree of revenue decentralization (*ln*(*REVALL*)) is positively and significantly associated with waste gas pollution and solid waste pollution in China during 1995–2010, while it is insignificantly associated with wastewater pollution in China during the same period. A higher degree of expenditure decentralization (*ln*(*EXPALL*)) is insignificantly (at the 5% level) associated with the three main types of environmental pollutions (waste gas pollution, solid waste pollution, and wastewater pollution) in China during 1995–2010. The association between fiscal decentralization and environmental pollution cannot be taken as causal. In the following two subsections, we try to establish a causal relationship between fiscal decentralization and environmental pollution in China.

3.2. System GMM estimation

As discussed, fiscal decentralization may be endogenous, thus blurring the relationship between fiscal decentralization and pollution. We use the most efficient system GMM estimator to establish a causal relationship between environmental pollution and fiscal decentralization. Because we use the macro-level data, it is possible that the other explanatory variables may also be endogenous due to reverse causality. Since we use yearly data, we have enough observations to deal with the potential endogeneity problem of all the important explanatory variables. In using the system GMM estimation, we treat lagged variables as predetermined and the other variables as endogenous. Moreover, following Roodman (2006, p. 31), the fixed province dummies are excluded, while the time dummies are used as exogenous instruments.

Moreover, because the two-step GMM is asymptotically more efficient than the corresponding one-step GMM, we use the two-step system GMM estimation. However, the two-step GMM presents estimates of the standard errors that tend to be severely downward biased. To solve this problem, Windmeijer (2005) proposes a small-sample correction for the two-step standard errors that would facilitate two-step robust estimations to be more efficient than corresponding one-step estimations, especially for system GMM. We take the Windmeijer correction into account in using two-step system GMM estimations.

We are aware of the instrument proliferation problem in system GMM estimation highlighted in Roodman (2009). We follow Jia et al. to deal with this problem (we use the second lag of the levels as instruments for the difference equation and the first lag of the differences as instruments for levels). Moreover, following Roodman (2006), we have collapsed the instruments. Now the number of instruments is reduced to 27 (by comparison, without the command "collapse", we would have 168 instruments). The two-step system GMM estimation results are presented in Table 4. According to Table 4, the p-values of the Hansen tests for over-identifying restrictions and the Difference-in-Hansen tests of exogeneity of instrument subsets are much smaller than one. Nevertheless, the p-values are still above 0.1, confirming that the instrument set can be considered valid. The F-test shows that the overall regression is significant. The Arellano–Bond AR(2) test accepts the hypothesis of no autocorrelation of the second order. These results support the validity of system GMM estimation.

Table 4
GMM regressions between environmental pollution and fiscal decentralization.
Two-step system GMM. Annual provincial data 1995–2010.
Data sources: *China Environmental Yearbook*. Beijing: China Environmental Statistical Press 1996–2011 (annual). *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

	Regression number					
	4.1	4.2	4.3	4.4	4.5	4.6
	Dependent variable as					
Independent variable	*ln*(*GAS*)		*ln*(*WATER*)		*ln*(*SOLID*)	
ln(*REVALL*)	0.12		−0.01		−0.05	
	(0.14)		(0.07)		(0.10)	
ln(*EXPALL*)		0.08		−0.01		−0.03
		(0.16)		(0.09)		(0.11)
$ln(GAS)_{t-1}$	0.85***	0.85***				
	(0.10)	(0.09)				
$ln(WATER)_{t-1}$			1.05***	1.04***		
			(0.15)	(0.17)		
$ln(SOLID)_{t-1}$					0.95***	0.90***
					(0.17)	(0.18)
RGDPC	−0.21	−0.003	−0.08	−0.10	0.07	−0.004
	(0.32)	(0.19)	(0.40)	(0.40)	(0.29)	(0.21)
$(RGDPC)^2$	0.04	−0.01	−0.02	−0.02	−0.02	−0.01
	(0.08)	(0.07)	(0.13)	(0.13)	(0.07)	(0.05)
I/*GDP*	0.005	0.006	−0.001	0.000	0.002	0.002
	(0.004)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Hansen OverID test (p-val)	0.31	0.43	0.62	0.60	0.38	0.32
Difference-in-Hansen[a] (p-val)	0.68	0.32	0.38	0.44	0.28	0.52
Difference-in-Hansen[b] (p-val)	0.23	0.42	0.60	0.56	0.39	0.26
Number of instruments	27	27	27	27	27	27
Arellano–Bond test for AR(1)	Pr > z = 0.00	Pr > z = 0.00	Pr > z = 0.23	Pr > z = 0.23	Pr > z = 0.00	Pr > z = 0.001
Arellano–Bond test for AR(2)	Pr > z = 0.95	Pr > z = 0.99	Pr > z = 0.31	Pr > z = 0.31	Pr > z = 0.42	Pr > z = 0.41
F-test	348,923***	25,587***	21,569***	32,715***	43,776***	22,621***
Observations	405	405	405	405	405	405

Note: 1. *ln*(*GAS*), *ln*(*WATER*), and *ln*(*SOLID*) are the logarithms of per capita emission of waste gas, waste-water, and solid waste, respectively; the units are 0.1 billion cubic meters per 100 people, tons per 100 people, and tons per 100 people, respectively. *ln*(*REVALL*) and *ln*(*EXPALL*) are the revenue decentralization and expenditure decentralization indicators, respectively. *REVALL* (*EXPALL*) is calculated as the sum of budgetary and extra-budgetary revenues (expenditures) of a province divided by the budgetary revenue (expenditure) of the central government, weighted by the provincial population. RGDPC is per capita real GDP, which is in 10,000 yuan. *I*/*GDP* is the ratio of nominal investment to nominal GDP (in percentage term).
2. Lagged dependent variables are treated as predetermined. All other variables except the time dummies are treated as endogenous. Time dummies are used as instruments.
(Corrected standard error in parentheses.)
[a] Difference-in-Hansen tests of exogeneity of instrument subsets for levels.
[b] Difference-in-Hansen tests of exogeneity of instrument subsets for difference.
*** Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.10 level.

According to the two-step system GMM estimation results presented in Table 4, the estimated coefficients on both revenue decentralization (*ln*(*REVALL*)) and expenditure decentralization (*ln*(*EXPALL*)) become insignificant at the 10% level, regardless of whether environmental pollution is measured as waste gas pollution (*ln*(*GAS*)), wastewater pollution (*ln*(*WATER*)), or solid waste pollution (*ln*(*SOLID*)).

3.3. Robustness checks

Because of the institutional features on the expenditure and revenue decentralization in China (see e.g., Jia et al., 2014, for details), we follow Jia et al. to put both the expenditure and revenue decentralization indicators in the same regression to check the robustness of our results. We have followed the same method to reduce the number of instruments. The results in Table 5 now show that the p-values of Hansen tests and Difference-in-Hansen tests are much smaller than one (but they are still above 0.10), confirming the validity of the instruments. The results in Table 5 indicate that the estimated coefficients on both revenue and expenditure decentralization indicators remain insignificant at the 10% level.

Moreover, we have used the level of GDP per capita and its squared value to capture the Kuznets curve. We believe that their coefficients have a clearer interpretation. Nevertheless, because the existing literature uses the logarithm of GDP per capita, we follow suit to check the robustness of our results. The results are also presented in Table 5. One can observe that our results remain robust. That is, the estimated coefficients on both revenue and expenditure decentralization indicators remain insignificant at the 10% level.

Table 5
Including both revenue and expenditure decentralization in one regression.
Two-step system GMM. Annual provincial data 1995–2010.
Data sources: *China Environmental Yearbook*. Beijing: China Environmental Statistical Press 1996–2011 (annual). *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

	Regression number					
	5.1	5.2	5.3	5.4	5.5	5.6
	Dependent variable as					
Independent variable	*ln*(*GAS*)	*ln*(*WATER*)	*ln*(*SOLID*)	*ln*(*GAS*)	*ln*(*WATER*)	*ln*(*SOLID*)
ln(*REVALL*)	0.07	0.02	0.08	−0.13	−0.04	0.13
	(0.29)	(0.39)	(0.18)	(0.29)	(0.22)	(0.16)
ln(*EXPALL*)	0.08	−0.30	−0.08	0.13	−0.14	−0.03
	(0.32)	(0.38)	(0.17)	(0.28)	(0.47)	(0.19)
$ln(GAS)_{t-1}$	0.84***			0.83***		
	(0.09)			(0.09)		
$ln(WATER)_{t-1}$		0.78***			0.83***	
		(0.21)			(0.37)	
$ln(SOLID)_{t-1}$			0.90***			0.88***
			(0.16)			(0.20)
RGDPC	−0.33	1.01	−0.09			
	(0.29)	(1.15)	(0.53)			
$(RGDPC)^2$	0.09	−0.32	0.01			
	(0.07)	(0.34)	(0.16)			
I/*GDP*	0.004	0.008	0.004	0.003	0.003	0.003
	(0.003)	(0.008)	(0.003)	(0.004)	(0.006)	(0.004)
ln(RGDPC)				0.09	−0.06	−0.13
				(0.17)	(0.23)	(0.15)
$(ln(RGDPC))^2$				−0.01	−0.09	−0.002
				(0.04)	(0.11)	(0.03)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Hansen OverID test (p-val)	0.53	0.53	0.49	0.90	0.72	0.37
Difference-in-Hansen[a] (p-val)	0.87	0.52	0.27	0.21	0.32	0.38
Difference-in-Hansen[b] (p-val)	0.42	0.46	0.52	0.96	0.73	0.34
Number of instruments	29	29	29	29	29	29
Arellano–Bond test for AR(1)	Pr > z = 0.00	Pr > z = 0.20	Pr > z = 0.001	Pr > z = 0.00	Pr > z = 0.15	Pr > z = 0.002
Arellano–Bond test for AR(2)	Pr > z = 0.91	Pr > z = 0.26	Pr > z = 0.38	Pr > z = 0.87	Pr > z = 0.24	Pr > z = 0.35
F-test	380,944***	7771***	17,728***	143,055***	7426***	21,236***
Observations	405	405	405	405	405	405

Note: 1. *ln*(*GAS*), *ln*(*WATER*), and *ln*(*SOLID*) are the logarithms of per capita emission of waste gas, waste-water, and solid waste, respectively; the units are 0.1 billion cubic meters per 100 people, tons per 100 people, and tons per 100 people, respectively. *ln*(*REVALL*) and *ln*(*EXPALL*) are the revenue decentralization and expenditure decentralization indicators, respectively. *REVALL* (*EXPALL*) is calculated as the sum of budgetary and extra-budgetary revenues (expenditures) of a province divided by the budgetary revenue (expenditure) of the central government, weighted by the provincial population. RGDPC is per capita real GDP, which is in 10,000 yuan. *I*/*GDP* is the ratio of nominal investment to nominal GDP (in percentage term).
2. Lagged dependent variables are treated as predetermined. All other variables except the time dummies are treated as endogenous. Time dummies are used as instruments.
(Corrected standard error in parentheses.)
[a] Difference-in-Hansen tests of exogeneity of instrument subsets for levels.
[b] Difference-in-Hansen tests of exogeneity of instrument subsets for difference.
*** Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.10 level.

3.3.1. Considering only environmental Kuznets curve

Observing the results in Tables 3–5, one can see that only the estimated coefficient of the lagged dependent variable is significant, while the coefficients of the other variables are insignificant, casting doubts on the results. To address this issue, we drop the investment rate from the regressions. We include the investment rate in the regressions because one of our working papers found that fiscal decentralization has a significant effect on investment rate (please see He, Sun, & Zou, 2013b, for an early version of the paper). Including the investment rate in the regressions may cause the multi-collinearity problem that would cause all the estimated coefficients on the income level and the investment rate to be insignificant. However, there is no prior information on which specification is the correct one. Therefore, to focus exclusively on the environmental Kuznets curve that has support from existing literature (please see the references cited above), we drop the investment rate from the regressions. As discussed, because the existing literature uses the logarithm of GDP per capita, we follow suit. The new regression results are presented in Table 6.

According to the results in Table 6, the estimated coefficients on the fiscal decentralization indicators remain insignificant. In regression 6.1 of Table 6, when the logarithm of waste gas pollution (i.e., *ln*(*GAS*)) is the dependent variable, the estimated coefficient on the logarithm of per capital real GDP is negative and insignificant, while that on its square is negative and significant at the 5% level. Therefore, there is evidence of environmental Kuznets effect concerning air pollution in China. In regression 6.2 of Table 6, the

Table 6
Robustness checks.
Two-step system GMM. Annual provincial data 1995–2010.
Data sources: *China Environmental Yearbook*. Beijing: China Environmental Statistical Press 1996–2011 (annual). *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

	Regression number					
	6.1	6.2	6.3	6.4	6.5	6.6
	Dependent variable as					
Independent variable	*ln*(*GAS*)		*ln*(*WATER*)		*ln*(*SOLID*)	
ln(*REVALL*)	0.03		−0.16		0.14	
	(0.14)		(0.19)		(0.17)	
ln(*EXPALL*)		0.08		−0.17		0.13
		(0.11)		(0.19)		(0.13)
$ln(GAS)_{t-1}$	0.86***	0.86***				
	(0.08)	(0.09)				
$ln(WATER)_{t-1}$			0.98***	0.97***		
			(0.16)	(0.18)		
$ln(SOLID)_{t-1}$					0.82***	0.78***
					(0.19)	(0.19)
ln(RGDPC)	−0.08	−0.07	0.03	−0.06	−0.25	−0.18
	(0.16)	(0.07)	(0.26)	(0.18)	(0.19)	(0.11)
$(\ln(RGDPC))^2$	−0.05**	−0.041*	−0.05	−0.071*	−0.05	−0.05
	(0.02)	(0.021)	(0.03)	(0.035)	(0.04)	(0.03)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Hansen OverID test (p-val)	0.81	0.82	0.72	0.67	0.37	0.37
Difference-in-Hansen[a] (p-val)	0.12	0.42	0.10	0.22	0.59	0.12
Difference-in-Hansen[b] (p-val)	0.99	0.81	0.97	0.77	0.29	0.54
Number of instruments	25	25	25	25	25	25
Arellano–Bond test for AR(1)	Pr > z = 0.00	Pr > z = 0.00	Pr > z = 0.23	Pr > z = 0.22	Pr > z = 0.00	Pr > z = 0.01
Arellano–Bond test for AR(2)	Pr > z = 0.84	Pr > z = 0.83	Pr > z = 0.30	Pr > z = 0.30	Pr > z = 0.41	Pr > z = 0.41
F-test	125,780***	38,214***	540,869***	121,445***	29,002***	19,937***
Observations	405	405	405	405	405	405

Note: 1. *ln*(*GAS*), *ln*(*WATER*), and *ln*(*SOLID*) are the logarithms of per capita emission of waste gas, waste-water, and solid waste, respectively; the units are 0.1 billion cubic meters per 100 people, tons per 100 people, and tons per 100 people, respectively. *ln*(*REVALL*) and *ln*(*EXPALL*) are the revenue decentralization and expenditure decentralization indicators, respectively. *REVALL* (*EXPALL*) is calculated as the sum of budgetary and extra-budgetary revenues (expenditures) of a province divided by the budgetary revenue (expenditure) of the central government, weighted by the provincial population. RGDPC is per capita real GDP, which is in 10,000 yuan.
2. Lagged dependent variables are treated as predetermined. All other variables except the time dummies are treated as endogenous. Time dummies are used as instruments.
(Corrected standard error in parentheses.)
[a] Difference-in-Hansen tests of exogeneity of instrument subsets for levels.
[b] Difference-in-Hansen tests of exogeneity of instrument subsets for difference.
*** Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.10 level.

estimated coefficient on the square term of the logarithm of per capital real GDP remains negative and significant at the 10% level. The results on the environmental Kuznets effect are weaker when water pollution or solid waste pollution is the dependent variable.

3.4. Using other measures of fiscal decentralization

In this subsection, we check the robustness of our results with other measures of fiscal decentralization. The first new measure of fiscal decentralization, denoted *REVALL1*, further considers the extra-budgetary funds of the central government. Besides considering the extra-budgetary funds of the central government, the second new measure of fiscal decentralization, denoted *REVALL2*, further considers per capita central funds instead of total central funds. Specifically, we measure *REVALL1* and *REVALL2* as.

REVALL1 = (the budgetary revenue of a province + extra-budgetary revenue of the province) / (the budgetary and extra-budgetary revenue of the central government × provincial population),

REVALL2 = (the budgetary revenue of a province + extra-budgetary revenue of the province / provincial population) / (the budgetary and extra-budgetary revenue of the central government / country population).

The corresponding expenditure decentralization indicators are constructed similarly.

The system GMM estimation results indicate that our main results remain robust when we include revenue and expenditure decentralization indicators independently or together in one regression (the results are not reported, but available upon request). The results are expected. Considering the revenue decentralization indicator *ln*(*REVALL1*) that further considers the extra-budgetary

revenue of the central government, the reason is double-fold. First, the extra-budgetary revenue of the central government is relatively small when compared to the sum of the extra-budgetary revenue of the provinces. According to the FYC (2011), the ratio of the central extra-budgetary revenue to the sum of the extra-budgetary revenue of the provinces was below 8% for most years during 1995–2010. Second, the central extra-budgetary revenue appears in the denominator in calculating *REVALL1*, which means that it will not cause any provincial variations. Instead, it just causes small variations across time for all provinces. The arguments apply to the indicator *ln*(*REVALL2*) that further divides the central budget by the country population.

3.5. Possible mechanism

China's institutional details reveal the reward structure of local officials. The central government evaluates, punishes and promotes its local officials based on growth performance (see Blanchard & Shleifer, 2001; Li & Zhou, 2005, among others) or revenue collection as highlighted in Shih et al. (2012). Regardless of the promotion criterion, spending effort in pushing up the growth rate or revenue collection, rather than in protecting the environment seems to be the rational choice of local officials. It seems that fiscal decentralization in China would increase environmental pollution. However, we find that fiscal decentralization in China is not the culprit for the alarming environmental pollution in China. In the following, we provide some evidence to illustrate that the local government would still make efforts to protect the environment, despite the fact that the promotion of local officials during the 1995–2010 period does not depend on the environmental performances of the provinces. The mechanism may help us to understand the main findings above.

We conjecture that direct environmental factors such as the stringency of environmental protection and the pollution abatement spending would be the intermediate channels for fiscal decentralization to affect environment pollution. Therefore, to uncover the mechanism to check the validity of the results found above, we test the following.

$$\ln(EF)_{i,t} = \alpha_0 + \alpha_1 \ln(FDC)_{i,t} + \alpha_2 RGDPC_{i,t} + \alpha_3 (RGDPC)_{i,t}^{\ 2} + u_i + T_t + \varepsilon_{i,t} \quad (2)$$

where $(EF)_{i,t}$ stands for the environmental factor that may affect environmental pollution. We drop the investment rate because there is no prior information to believe that physical capital investment rate would affect the stringency of environmental protection and the pollution abatement spending. In contrast, per capita income obviously would affect the stringency of environmental protection and pollution abatement spending.

Subsection 2.4 has constructed the measures of the pollution abatement spending (*ABATE* and *FEEIN*) and that of the stringency of environmental protection (*FEEUSE*). The regression results of estimating Eq. (2) are presented in Table 7.

According to regressions 7.1 and 7.2 of Table 7, when the per capita pollution abatement spending (*ABATE*) is the dependent variable, the estimated coefficients on both revenue decentralization (*ln*(*REVALL*)) and expenditure decentralization (*ln*(*EXPALL*)) are

Table 7
Immediate channels.
Data sources: *China Environmental Yearbook*. Beijing: China Environmental Statistical Press 1996–2011 (annual). *Finance Yearbook of China*, Beijing: China Finance Press 1996–2011 (annual). *China Statistical Yearbook*. Beijing: China Statistical Press 1996–2011 (annual).

	Regression number			
	7.1	7.2	7.3	7.4
	Dependent variable as			
Indep. Vari.	ln(*ABATE*)		*ln*(*FEEIN*)	*ln*(*FEEUSE*)
ln(*REVALL*)	1.21***			
	(0.19)			
ln(*EXPALL*)		1.08***	0.57***	0.48***
		(0.20)	(0.20)	(0.18)
RGDPC	−1.17***	0.01	2.21**	−0.05*
	(0.43)	(0.41)	(1.01)	(0.93)
$(RGDPC)^2$	0.07	−0.14	−1.17***	−0.03
	(0.12)	(0.12)	(0.44)	(0.40)
Time FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
R^2	0.82	0.81	0.89	0.91
Observations	432	432	216	216

Note: 1. ln(*ABATE*), *ln*(*FEEIN*), and *ln*(*FEEUSE*) are the logarithms of per capita pollution abatement expenditure, pollutant discharge fees collected, pollutant discharge fees spent, respectively. The units of *ABATE*, *FEEIN* and *FEEUSE* are all yuan per 100 people. *ln*(*REVALL*) and *ln*(*EXPALL*) are the revenue decentralization and expenditure decentralization indicators, respectively. *REVALL* (*EXPALL*) is calculated as the sum of budgetary and extra-budgetary revenues (expenditures) of a province divided by the budgetary revenue (expenditure) of the central government, weighted by the provincial population. RGDPC is per capita real GDP, which is in 10,000 yuan.
2. The CEY (China Environmental Yearbook) stopped collecting data on pollutant discharge fees collected and pollutant discharge fees spent after 2003. Therefore, we only have *ln*(*FEEIN*) and *ln*(*FEEUSE*) during 1995–2002.
(Standard error in parentheses.)
*** Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.10 level.

significant at the 1% level. According to regression 7.3 of Table 7, when the pollutant discharge fees collected (i.e., *ln*(*FEEIN*)) serve as the dependent variable, the estimated coefficient on expenditure decentralization (*ln*(*EXPALL*)) is positive and significant at the 1% level. According to regression 7.4 of Table 7, when pollutant discharge fees spent (i.e., *ln*(*FEEUSE*)) serve as the dependent variable, the estimated coefficient on expenditure decentralization (*ln*(*EXPALL*)) is positive and significant at the 1% level. These results indicate that fiscal decentralization leads to more pollution abatement spending and more stringent environmental policy.

3.6. Possible explanation

As discussed, the reward structure for Chinese local officials implies that spending effort in pushing up the growth rate or revenue collection, rather than in protecting the environment would be the rational choice for local officials. However, we find that fiscal decentralization in China is not the significant culprit for its environmental pollution. The above results on the intermediate channels indicate that the local government would still make efforts to protect the environment. The results are not totally unexpected, as elaborated below.

Although the reward structure for Chinese local officials may prevent the local government from acting as a benevolent one, local officials are not totally driven by promotion considerations. Every Chinese citizen including the government officials is sympathetic to the old Chinese saying in the more than two thousand years of history of Chinese civilization: "If a government official cannot do good deeds for his people, it is better for him to step down and go home selling sweet potatoes." Therefore, promoting the welfare of the local people (specifically, protecting local environment) would also be a consideration for local officials, even in a non-democratic country such as China. The government officials in China, although some of them may be corrupt, may choose the career of being government officials because they care about the welfare of the people and love to work to enhance the welfare of the people. Their ambition, their self-consciousness, and the cultural norm all drive them to act as benevolent government officials. This explanation together with the results on the intermediate channels helps to explain why fiscal decentralization in China is not the significant culprit for its environmental pollution.

4. Conclusions

China's environmental pollution casts a darkening shadow over its economic success brought by decentralization. Fiscal decentralization, underscoring China's economic success, seems to be the culprit for its environmental pollution. Using the provincial panel data during the period 1995–2010, we find that fiscal decentralization has no significant effect on environmental pollution as measured per capita emission of wastewater, waste gas or solid waste, in system GMM estimation. We further find that fiscal decentralization has a significant, positive effect on pollution abatement spending and pollutant discharge fees levied and spent, which indicates possible mechanisms for fiscal decentralization to help protect the environment.

Our results are striking in the sense that China's fiscal decentralization has its own Chinese style (Montinola et al., 1995). In the Chinese institutional context, and from an economic standpoint, decision-making has been decentralized to local governments. However, from the political perspective, China has maintained political centralization (Blanchard & Shleifer, 2001; Maskin et al., 2000; Qian & Xu, 1993). Local officials are not elected by local constituents. Rather, they are appointed by upper-level officials. The political centralization allows the central government to discipline the local officials. The central government is argued to use the growth rate of the local economy (Blanchard & Shleifer, 2001; Li & Zhou, 2005) or revenue collection (Shih et al., 2012) to evaluate and promote the local officials. Given the reward structure in a politically centralized and economically decentralized economy, it seems to be rational for the local officials to spend all investments to raise growth or fiscal revenue, rather than spend them to control pollution. In so doing, their chance of promotion would be maximized. Nonetheless, we find that the preference of China's local officials may still reflect local needs in terms of protecting the environment.

Our results can be rationalized by the sentiment towards being a benevolent official in the Chinese culture. Loosely speaking, the sentiment is a common virtue of all human beings as illustrated in Adam Smith's (1759) seminal work of "The Theory of Moral Sentiments". Chinese officials of course, care about promotion, but they also want to contribute to society. That is, they are also driven by self-selection into government jobs, ambition, self-consciousness, and the Chinese cultural norm to be somewhat benevolent (i.e., to care about growth as well as clean environment like a representative local constituent). In-depth research in this area is important, and we leave it to future research.

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