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Intergovernmental Transfers and Environmental Pollution

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Abstract

We exploit the dramatic change in intergovernmental transfers after the tax-sharing reform in China to identify the causal effect of intergovernmental transfers on environmental pollution. Applying the two-stage least squares method to China's county-level data, we find that a 1% increase in the annual change in intergovernmental transfers relative to the previous year's GDP will increase the annual growth rate of fine particulate matter (PM2.5) concentration by 4.3145%. The mechanisms include the following: (1) intergovernmental transfers drive county governments to increase expenditures and cut taxes; (2) intergovernmental transfers increase the gross industrial output value above the designated size at the intensive margin; and (3) intergovernmental transfers reduce the proportion of GDP in the secondary industry and increase the proportion in the tertiary industry. In addition, intergovernmental transfers boost GDP growth and prompt the movement of labor from rural to urban areas within a county.

JEL: H77; Q53

1. Introduction

Since 1900, the world has witnessed the deterioration of the ecological environment and the expansion of the public sector. Such scenario brings for this question: what role does the public sector play in the deterioration of the ecological environment? In recent years, research on the effect of vertical intergovernmental relations on the ecological environment has been increasing. Numerous studies have examined the effect of fiscal decentralization on the ecological environment (Xue and Pan, 2012; Li and Liu, 2016; Huang, 2017; Zhang et al., 2017; Kuai et al., 2019; Hao et al., 2020). Meanwhile, some studies have investigated the effect of fiscal pressure on the ecological environment (Bai et al., 2019). However, to the best of our knowledge, no research has estimated the causal effect of the total intergovernmental transfers on the ecological environment. Intergovernmental transfers are large in several countries. For instance, in 2012, the Chinese central government's transfers to local governments accounted for 8.4% of the GDP, 80.8% of the central fiscal revenue, and 42.3% of the local fiscal expenditure (see Appendix for more information). Intergovernmental transfers of this scale are bound to have a crucial impact on economic development, including the ecological environment. Hence, we attempt to identify the causal effect of the total intergovernmental transfers on fine particulate matter (PM2.5), a typical environmental pollutant, to fill the literature gap of the causal effect of the total intergovernmental transfers on environmental pollution.

We use data on China's intergovernmental transfers from 1998 to 2008 because of the rich variation in the country's intergovernmental transfers during this period. In 1994, China initiated the tax-sharing reform. The essence of the reform is the centralization of fiscal revenue. The funds held by the central revenue increased substantially and can be used for intergovernmental transfers. However, as a supporting measure of the reform, tax rebates were introduced to take care of the vested interests. The amount of tax rebates was calculated according to a formula and was positively correlated with the volume of the local economy. Just after the tax-sharing reform, tax rebates accounted for a large

proportion of intergovernmental transfers that consisted of tax rebates, general transfers, and earmarked transfers, thus resulting in a small variation in intergovernmental transfers relative to the local GDP among regions. As time passed, the proportion of tax rebates showed a downward trend. Consequently, the central government could distribute intergovernmental transfers as a policy instrument more flexibly. Moreover, the central government was able to implement its intention of supporting the development of economically underdeveloped areas through central transfers to these areas, which was made clear in the design stage of the plan for the tax-sharing reform. The western area is the least developed among the three regions of the east, center, and west. Thus, when the proportion of tax rebates declines, intergovernmental transfers should be tilted toward the western area. Moreover, in years when the proportion of tax rebates fell more sharply, the central government had more room to implement a regional balance policy. This institutional feature provides an exogenous source of regional variation in intergovernmental transfers. On this basis, we examine the effect of the annual change in intergovernmental transfers relative to the previous year's GDP, $(Tran_t - Tran_{t-1})/GDP_{t-1}$, on the annual growth rate of the PM2.5 concentration, $(PM25_t - PM25_{t-1})/PM25_{t-1}$. Considering that $(Tran_t - Tran_{t-1})/GDP_{t-1}$ may be endogenous, we use the interaction of the annual change in the proportion of national tax rebates and the dummy for the western area, $(TRebR_t - TRebR_{t-1}) \times West_i$, as an instrument variable.

We apply the two-stage least squares (2SLS) method on the basis of this instrumental variable to China's county-level data. The result reveals that a 1% rise in $(Tran_t - Tran_{t-1})/GDP_{t-1}$ will increase $(PM25_t - PM25_{t-1})/PM25_{t-1}$ by 4.3145%. This result is robust to the processing of extreme values, the elimination of potentially problematic observations, the extension of the sample period, and the alternative indicators of intergovernmental transfers. Thus, we attempt to investigate the mechanisms. One mechanism is that intergovernmental transfers affect PM2.5 by affecting local finance. The results reveal that an increase of 1 yuan in intergovernmental transfers will increase the general budget expenditure by 0.7583 yuan and reduce the general budget revenue by 0.1277 yuan. The increase in public goods brought about by the increase in general budget expenditure will boost the growth of all industries, including polluting industries, and, in turn, aggravate environmental pollution. The effect of tax cuts hinges on whether these cuts are inclusive tax cuts or structural tax cuts. A more direct way for intergovernmental transfers to affect PM2.5 is for them to influence the industry that produces the most pollution among the three sectors (the agricultural, industry, and service sectors). The result reveals that an increase of 1 yuan in intergovernmental transfers will increase the gross industrial output value above the designated size by 5.9090 yuan. Given production technology, the increase in the gross industrial output value above the designated size entails an increase in the PM2.5 concentration. To be mentioned, the increase in the gross industrial output value above the designated size comes from the intensive margin. Intergovernmental transfers also affect the industrial structure: they reduce the proportion of the secondary industry's GDP and increase the proportion of the tertiary industry's GDP. This change in the industrial structure helps improve environmental quality. However, its effect is dominated. In addition, we examine the heterogeneous effect of intergovernmental transfers on PM2.5 concentration and find that the pollution effect of intergovernmental transfers is greater in counties with lower population density. Finally, we examine the effect of the change in intergovernmental transfers on GDP growth and

population flow. The results reveal that an increase of 1 yuan in intergovernmental transfers will increase the GDP by 1.1473 yuan; i.e., the intergovernmental transfer multiplier is 1.1473. Although the increase in intergovernmental transfers does not affect the inter-county population flow, it prompts the movement of labor from rural to urban areas within a county. This is a source of growth of GDP and the gross industrial output value above the designated size.

Regarding the effect of intergovernmental transfers on the ecological environment, theoretical studies have not reached a consensus. Some researchers have examined the effect of intergovernmental transfers on local finance. They believe that after an increase in intergovernmental transfers, local government expenditure will increase, while the direction of tax changes will be uncertain (Bradford and Oates, 1971; Gamkharand Shah, 2007). The increase in the local government expenditure will lead to an increase in public goods, boost the growth of all industries including polluting industries, and aggravate environmental pollution. In addition, inclusive tax changes and structural tax changes have different effects. By contrast, other researchers link equalization transfer, regional competition, and the incentives of local governments. They believe that equalization transfer weakens the incentives of local governments to attract mobile capital and leads local governments to strengthen environmental regulation that improves environmental quality (Bucovetsky and Smart 2006; Buettner, 2006).

Empirically, several researchers have examined the effect of the ecological fiscal transfer, a special type of transfer that emerged in Brazil and spread to several countries, on the ecological environment. Ring and Barton (2015), Droste et al. (2017b), and de Paulo and Camões (2019) believed that the ecological fiscal transfer increases the protected area coverage in Brazil. Droste et al. (2017a) concluded that the ecological fiscal transfer in Portugal contributes to a significant increase in the protected area designations. In another study, Gong (2020) used propensity score matching and difference-in-difference estimation to investigate the effectiveness of payments to national key ecological function zones in China on the reduction of industrial pollution. The researcher found that these payments reduce pollution-intensive activities in national key ecological function zones. After all, the proportion of the ecological fiscal transfer is limited. The direction in which it affects the ecological environment may be inconsistent with the direction in which the total intergovernmental transfers affect the ecological environment. Zhang and Liu (2020) set their sights on the total intergovernmental transfers and study the impact of these transfers on CO2 emissions in China using panel data for China's 30 provinces from 1998 to 2017. However, they do not address the notorious endogeneity problem of intergovernmental transfer research. Therefore, their results reflect the correlation between the two. This work estimates for the first time the causal effect of the total intergovernmental transfers on PM2.5, a typical environmental pollutant. We find that intergovernmental transfers aggravate PM2.5 pollution, which is the opposite of the result that the ecological transfer improves the ecological environment. Thus, extrapolating the effect of EFT to the effect of intergovernmental transfers will reach the wrong conclusion. This study of the relationship between intergovernmental transfers and the ecological environment complements the vertical fiscal system causes of environmental pollution.

The remainder of the paper is organized as follows. Section 2 introduces China's intergovernmental transfers. Next, Section 3 describes the identification strategy and data sources. Then, Section 4 reports and explains the results. The final section concludes the paper.

2. Background: Intergovernmental Transfers In China

2.1 China's intergovernmental transfers after the tax-sharing reform

Before 1994, the central revenue was short of the central expenditure. Under financial pressure, the central government initiated the tax-sharing reform in 1994, which centralized government revenue. The reform divided 75% of the value-added tax and 100% of the consumption tax into the central revenue. Both taxes were originally local revenues. As a result, the reform greatly strengthened the central financial resources and weakened the local financial resources. To protect the vested interests of local governments and promote the reform smoothly, the central government returned part of its 75% share of value-added tax and 100% share of consumption tax to the tax source. This rebate is called the "two-tax rebate." To put it simply, as far as the stock of the two-tax revenues lost by the local governments due to the reform is concerned, the central government returns the full amount to the tax source. Meanwhile, in terms of the increment of the two-tax revenues lost by the local governments due to the reform, the central government returns part of them to the tax source in a decreasing marginal return ratio that is determined by a formula. Both parts of the two-tax rebate are positively correlated with the volume of the local economy. The unreturned part of the increment of the two-tax revenues combined with the central government's original revenue can be used by the central government for government purchases or to increase the general and earmarked transfers to local governments. The central government can freely arrange the general and earmarked transfers to achieve its purpose.

Because of the aforementioned institutional design, when the reform was just implemented, the two-tax revenues lost by local governments was mainly the stock of the two-tax revenues. The increment of the two-tax revenues lost by local governments was still small. As the two-tax revenue stocks had to be returned in full, tax rebates accounted for a large proportion of intergovernmental transfers that consisted of tax rebates, general transfers, and earmarked transfers. As time passed, the two-tax revenue grew rapidly. From 1994 to 2010, the annual growth rate of the national two-tax revenue between was 15.3%. The increment of the two-tax revenues lost by the local governments due to the reform dominated the stock of the two-tax revenues lost by the local governments due to the reform. Because the increment of the two-tax revenues lost by the local governments due to the reform was returned in a decreasing marginal return ratio, the proportion of tax rebates in intergovernmental transfers declined, as shown in Fig. 1, which illustrates the proportion of county-level tax rebates from 1998 to 2007. Also, in 2002 and 2003, the central government implemented the income tax sharing reform to centralize financial power further. From 2003 on, 60% of the income tax was classified as the central revenue. Correspondingly, the central government arranged an income tax rebate of that had a method similar to that of the two-tax

rebate. As a result, the proportion of the income tax rebate showed a downward trend after the income tax sharing reform. Moreover, the decline in the proportion of tax rebates was initially fast and then slowed. The proportion of the rebates of the three taxes decreased by 0.2350 from 1998 to 2001 and decreased by 0.0925 from 2004 to 2007.

2.2 Distribution of intergovernmental transfers among regions

Such an institutional design drives the distribution of intergovernmental transfers among regions to change dynamically after the tax-sharing reform. Just after the reform, tax rebates accounted for a large proportion of intergovernmental transfers. Given that the amount of tax rebates is positively correlated with the volume of the local economy, the regional difference in intergovernmental transfers relative to local GDP will not be very large. Figure 2 illustrates the ratio of transfers from the central government to local governments to local GDP in 1995. As shown in the figure, the difference between the eastern area, the central area, and part of the western area is not large. The median and standard errors of the ratio are 0.0466 and 0.0940, respectively. Overall, the distribution effect of intergovernmental transfers is not very good.

As the proportion of tax rebates declined and the proportion of general and earmarked transfers increased accordingly, intergovernmental transfers as a policy instrument can be distributed more flexibly by the central government. As early as the design stage of the tax-sharing reform, the central government has clearly put forward that one of the guiding principles of the reform is to adjust the distribution of financial resources among regions rationally. For this purpose, the central government should provide sufficient transfers to economically underdeveloped areas to support the development of these areas. Given that the western area is the least developed among the three regions of the east, center, and west, an increase in transfers to the western area is expected. Figure 3 illustrates the change in the ratio of central transfers to local governments to local GDP from 1995 to 2010. As shown in the figure, during the 15-year period, the ratio of six provinces, namely, Beijing, Tianjin, Jiangsu, Shanghai, Zhejiang, and Guangdong declined. The change in the ratio during the period was only slightly greater in the central provinces than in the eastern provinces. However, in seven western provinces, namely, Tibet, Qinghai, Gansu, Guizhou, Xinjiang, Ningxia, and Sichuan, the ratio increased by more than 0.1 during the period. In other words, in more than 10 years after the tax-sharing reform, intergovernmental transfers showed the characteristics of tilting toward the underdeveloped western area. Moreover, to be mentioned, the proportion of tax rebates declined faster before 2002 than after 2002. In years with a larger decline in the proportion of tax rebates, there are more released funds for the central government to dispose according to its own wishes. The central government can increase transfers to the western area to a greater extent to achieve the goal of rationally adjusting the distribution of financial resources among regions. This adjustment provides an exogenous source of variation in intergovernmental transfers that can be used to identify the effect of intergovernmental transfers.

3. Model, Variables, And Data

3.1 Model and variables

The empirical literature on the effect of intergovernmental transfers on the economy (Acconcia et al., 2014; Nakamura & Steinsson, 2014) usually sets the core explanatory variable as the change in intergovernmental transfers relative to GDP and the dependent variable as GDP growth rate, employment growth rate, and so on. Following the literature, we also set the core explanatory variable as the change in intergovernmental transfers relative to GDP. Then, we set the dependent variable as the growth rate of the PM2.5 concentration. The econometric model is

$$\frac{PM25_{i,t} - PM25_{i,t-1}}{PM25_{i,t-1}} = \beta \frac{Tran_{i,t} - Tran_{i,t-1}}{GDP_{i,t-1}} + \gamma X_{i,t} + \alpha_i + \lambda_t + \varepsilon_{i,t}$$

1

In Eq. (1), *i* and *t* denote county and year, respectively. $(PM25_{i,t} - PM25_{i,t-1})/PM25_{i,t-1}$. is denoted as *PM25G*, where *PM25* denotes the PM2.5 concentration. $(Tran_{i,t} - Tran_{i,t-1})/GDP_{i,t-1}$. is denoted as *TranG*, where *Tran* denotes intergovernmental transfers. β represents the scenario in which the annual growth rate of PM2.5 increases by β% when intergovernmental transfers increase by 1% relative to the GDP in the previous year. *X* is a set of control variables. As environmental degradation is a companion to economic development in developing countries, we refer to the literature on economic growth (Mankiw et al., 1992; Davoodi & Zou, 1998; Xie et al., 1999; Zhang, 2006) and incorporate the following control variables: (1) the logarithm of the GDP with a lag of one year (denoted as *L.ln(y)*), which measures the level of economic development; (2) the proportion of the GDP of the primary industry lagging by one year (denotes as *L.Str*), which measures the economic structure; (3) the ratio of the balance of various loans of financial institutions to the balance of saving deposits of urban and rural residents lagging by one year (denoted as *L.FinD*), which is a proxy for the degree of financial deepening; (4) the ratio of the general budget expenditure to the GDP lagging by one year (denoted as *L.ExpR*), which is a measure of the government size; (5) the ratio of the general budget revenue to the general budget expenditure lagging by one year (denoted as *L.RevR*), which indicates the degree of fiscal self-sufficiency; (6) the proportion of value-added tax shared by the county government (denoted as *L.FD*), which is a measure of fiscal decentralization (Mao et al., 2018); (7) the ratio of the fiscal support population to the general budget revenue lagging by one year (denoted as *L.FisB*), which reflects the fiscal burden. We lag each control variable by one year for two reasons. One reason is that the logarithm of the GDP per capita should lag behind according to the theory of economic growth (Mankiw et al., 1992). The other reason is that as the lag value is predetermined, taking the lag value of one year excludes the possibility of intergovernmental transfers affecting the dependent variable through control variables. Thus, the total effect of intergovernmental transfers on the dependent variable is estimated (Angrist & Pischke, 2008). α_i is the individual effect, which represents factors that change with individuals but not with time, such as geography and institutions. λ_t is the year fixed effect, which represents factors that change with time but not with individuals, such as national business cycles and national policies. $\varepsilon_{i,t}$ is the error term.

Eq. (1) uses the ratio of the change in intergovernmental transfers to the GDP of the previous year instead of the ratio of intergovernmental transfers to the GDP. The ratio of intergovernmental transfers to the GDP shows a strong trend. This trend may be correlated with other omitted trends, thus leading to endogeneity problem. This issue can be greatly alleviated by first differentiating intergovernmental transfers and then dividing them by the previous year's GDP. However, some factors can still cause endogeneity problem. For example, the growth of polluting industries will increase the county government revenue and reduce the superior government's transfers to the county government; i.e., a reverse causal relationship exists. As another example, an aging population requires an increase in government expenditure and intergovernmental transfers while also threatening to impact economic growth negatively, including the growth of polluting industries, through reduced labor supply. That is to say, some omitted variables are correlated with intergovernmental transfers.

One way to address endogeneity is to look for exogenous sources of variation of intergovernmental transfers. As stated above, the decrease in the proportion of national tax rebates gives the central government greater freedom in the distribution of fiscal resources among regions, and the central government is able to give additional fiscal resources to the undeveloped western area. Moreover, in years with a larger decline in the proportion of national tax rebates, the central government had more released funds to dispose according to its own wishes, and the central government can increase transfers to the western area to a greater extent. Both the changes in the proportion of national tax rebates and the regional preferences of the central government in the distribution of fiscal resources are independent of the socio-economic situation of an individual county. Together, the two provide an exogenous source of variation in intergovernmental transfers. Hence, we propose to use the following variable as an instrumental variable: $(TRebR_t - TRebR_{t-1}) \times West_i$. $TRebR_t$ denotes the proportion of national tax rebates in year t. $West_i$ is the dummy for the western counties (i.e., it is equal to 1 for a western county and equal to 0 otherwise). First, we run the first-stage regression as follows:

$$\frac{Tran_{i,t} - Tran_{i,t-1}}{GDP_{i,t-1}} = \theta\left(TRebR_t - TRebR_{t-1}\right) \times West_i + \gamma X_{i,t} + \alpha_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$

The coefficient of the instrumental variable in Eq. (2) is expected to be negative. The predicted value of the dependent variable in Eq. (2) is the exogenous part of the variation in intergovernmental transfers disentangled by the instrumental variable. Then, we substitute the predicted value of the dependent variable in Eq. (2) for the core explanatory variable of Eq. (1) and run the following second-stage regression:

$$\frac{PM25_{i,t} - PM25_{i,t-1}}{PM25_{i,t-1}} = \beta \frac{\widehat{Tran_{i,t} - Tran_{i,t-1}}}{GDP_{i,t-1}} + \gamma X_{i,t} + \alpha_i + \lambda_t + \varepsilon_{i,t} \quad (3)$$

The estimator of the coefficient of the predicted value converges on the population parameter by probability.

3.2 Data

3.2.1 Data on intergovernmental transfers

The raw data are from Fiscal Statistics of China's Prefectures and Counties published until 2009. In the raw data, the total intergovernmental transfers had no indicators, and only the indicators of various categories of intergovernmental transfers exist. These indicators vary over time because of the establishment of some new categories of intergovernmental transfers or the adjustment of the statistical scope. Notably, a major adjustment of statistical scope occurred in 2008.

On the basis of these indicators, we calculate the total intergovernmental transfers of each county per year. The correct calculation of the total intergovernmental transfers is a prerequisite for subsequent econometric analysis. To check whether the calculation is correct, we consider the following general budget account income identity:

Balanced income = balance from the previous year + income of the current year + total governmental transfers + income from other budgets + revenues from government bonds + other income.
On the basis of this identity, we construct the variable *Diff*, which is equal to the left side of the equal sign above minus the right side of the equal sign above. *Diff* should be 0. The distribution of non-zero *Diff* across years is shown in Table 1. In 1998–2007, *Diff* is indeed 0 except for a few counties. In 2008 and 2009, several counties had non-zero *Diff*.

Table 1
Distribution of zero *Diff* across years

Year	2001	2002	2004	2005	2006	2007	2008	2009
Frequency	2	5	1	1	5	3	175	68

The results suggest that the calculation of the total intergovernmental transfers suffers from some problems for 2008 and 2009. One possible reason is that intergovernmental transfer statistics are not comprehensive after the adjustment of the statistical scope in 2008. To make the econometric results as credible as possible, we use the data of intergovernmental transfers from 1998 to 2007 for the baseline results. We add the data after 2007 for robustness check as well.

3.2.2 Data on PM2.5

The raw data come from Socioeconomic Data and Applications Center at Columbia University (van Donkelaar et al., 2016, 2018). This center combines AOD retrievals from multiple satellite instruments and

estimates global annual concentrations (micrograms per cubic meter) of ground-level fine particulate matter (PM2.5) from 1998 to 2016. Gridded data sets at 0.01 degrees are provided. We use the shape file of China's county-level administrative divisions to extract the annual concentrations of ground-level PM2.5 of each county in each year.

3.2.3 Other socio-economic data

Other social and economic data are from Support System for China Statistics Application.

3.2.4 Data processing

We exclude Tibetan counties because of the serious lack of data. In addition, we omit the data on municipal districts because their systems differ greatly from those of counties. We obtain data for 1,934 counties. To exclude the influence of outliers, we winsorize the main variables at the 0.5 and 99.5 quantiles.

In addition, a situation that is often overlooked by the literature is that China's county-level administrative divisions have changed over time. If the area of the administrative division of a county changes in a year, that year's county is no longer the previous year's county. As a result, calculating the annual growth rate of the county's GDP and intergovernmental transfers will be meaningless. Thus, we only retain observations with the annual growth rate of administrative division area between − 0.5% and 0.5%. The reason for setting the cut-off value at 0.5% instead of 0 is that accurately measuring the administrative division area is difficult. Experts measure the administrative division area at intervals and update the estimates. The difference in the estimates of each measurement should be small. We use 0.5% as the cut-off value to tolerate measurement errors.

4. Results

4.1 Baseline results

The baseline results are demonstrated in Table 2. The first two columns of Table 2 are the OLS results. In column (1) of Table 2, only *TranG*, individual fixed effect, and year fixed effect are incorporated. In column (2) of Table 2, the control variables are also included. In both columns, the estimate of the coefficient β is positive but not statistically significant.

Because of potential reverse causality and omitted variable problems, *TranG* may be endogenous, thus resulting in an inconsistent estimator of the coefficient β. To deal with the endogeneity problem, we use *TranG*, which is defined as $(TRebR_t - TRebR_{t-1}) \times West_i$ as an instrument. As mentioned earlier, $TRebR_t$ denotes the proportion of the national tax rebates in year t, and $West_i$ is the dummy for the western counties. The logic that the instrument variable is correlated with *TranG* is as follows: the decrease in the proportion of national tax rebates allows the central government to have greater freedom in the distribution of fiscal resources among regions, and the central government is able to provide more fiscal resources to the undeveloped western area. Moreover, in years with a larger decline in the proportion of

national tax rebates, the central government has more room to maneuver and can increase transfers to the western area to a greater extent. Hence, the instrumental variable should be negatively correlated with *TranG*. Columns (5) and (6) demonstrate the first-stage regression results of the 2SLS method. Regardless of whether we include the control variables, the estimated coefficients for the instrumental variable are significantly negative at the 1% level, which is consistent with our conjecture. The Cragg-Donald Wald F statistics for the two columns are as high as 109.297 and 184.677, respectively, thus indicating that the instrumental variable is not a weak instrumental variable. Moreover, $TRebR_t - TRebR_{t-1}$, one of the two parts of the instrumental variable, reflects the change in the proportion of national tax rebates. $West_i$, the other part of the instrumental variable, reflects the regional preferences of the central government in the distribution of fiscal resources. Both are independent of the specific socio-economic situation of an individual county. Therefore, the assumption that the instrumental variable is uncorrelated with the error term is plausible.

The second-stage regression results of the 2SLS method are listed in columns (3) and (4) of Table 2. In column (3) where the control variables are not incorporated, the estimated β is 2.9943 and statistically significant at the 1% level. In column (4) of Table 2 where the control variables are incorporated, the estimated β is 4.3145 and statistically significant at the 1% level. Both are much larger than the OLS estimate, thus suggesting a severe endogeneity problem that leads to a big bias and a misleading conclusion if not addressed. This outcome is a familiar observation in the literature on the economic impact of intergovernmental transfers. Compared with column (3), column (4) considers more factors by incorporating the control variables. Hence, its result is more reliable. The estimated β in column (4) indicates that a 1% increase in the annual change in intergovernmental transfers relative to the previous year's GDP will increase the annual growth rate of PM2.5 concentration by 4.31%. The standard error of the ratio of the annual change in intergovernmental transfers to the previous year's GDP is 0.0396 in the sample, which implies an increase of 17.09% in the annual growth rate of the PM2.5 concentration. Regarding the control variables, the estimated coefficient of *L.ln(y)* is significantly positive, thus suggesting that the PM2.5 concentration grows faster in counties with higher GDP per capita. The estimated coefficient of *L.ExpR* is significantly positive, thus indicating a positive correlation between the government size and the annual growth rate of the PM2.5 concentration. The estimated coefficient of *L.RevR* is significantly negative, thus suggesting that an increase in fiscal self-sufficiency will reduce the annual growth rate of the PM2.5 concentration. The estimated coefficient of *L.FisB* is significantly positive. One possible reason is that fiscal pressures brought about by fiscal burdens force county governments to sacrifice environmental quality in exchange for an increase in fiscal revenue. *L.Str*, *L.FinD*, and *L.FD* have no significant impact on the annual growth rate of PM2.5.

Table 2
Baseline results

	OLS		2SLS		First Stage	
	OLS		2SLS			
	PM25G	*PM25G*	*PM25G*	*PM25G*	*TranG*	*TranG*
TranG	0.0835	0.1036	2.9943***	4.3145***		
	(0.0730)	(0.0762)	(0.6686)	(0.9418)		
△TRebR×West					-0.1786***	-0.1357***
					(0.0131)	(0.0130)
L.ln(y)		-0.0134		0.1763***		-0.0433***
		(0.0159)		(0.0458)		(0.0018)
L.Str		-0.1484***		-0.0254		-0.0321***
		(0.0493)		(0.0611)		(0.0055)
L.FinD		0.0003		0.0020		-0.0004**
		(0.0020)		(0.0022)		(0.0002)
L.ExpR		-0.0357		0.3532***		-0.0823***
		(0.0502)		(0.1029)		(0.0057)
L.RevR		-0.0044		-0.0882***		0.0185***
		(0.0252)		(0.0336)		(0.0028)
L.FD		-0.0001		-0.0000		-0.0000
		(0.0006)		(0.0006)		(0.0001)
L.FisB		0.0119***		0.0065**		0.0012***
		(0.0023)		(0.0028)		(0.0003)
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of id	1,933	1,933	1,933	1,933	1,934	1,934
Observations	15,615	15,437	15,615	15,437	15,623	15,445

Note: The sample period is 1999–2007. Only observations with the annual growth rate of administrative division area between − 0.5% and 0.5% are retained. Main variables are winsorized on the 0.5 and 99.5 quantiles. The standard error is in parentheses. ***, **, * mean significance at the 1%, 5% and 10% levels, respectively.

4.2 Robustness tests

Table 3 lists the results of various robustness tests. The first two columns of Table 3 adopt two approaches to handle outliers. Column (1) of Table 3 truncates the main variables at the 0.5% and 99.5% quantiles. The estimated β is lower than that of the baseline but still reaches 3.8713 and statistically significant at the 1% level. Column (2) of Table 3 winsorizes the main variables at the 1% and 99% quantiles. The estimated β changes slightly. Column (3) of Table 3 only uses observations where the general budget account income identity holds. The estimated β changes slightly. Column (4) of Table 3 adopts stricter criteria to exclude observations that face administrative division adjustments: we only keep observations with the annual growth rate of administrative division area between − 0.1% and 0.1%. The estimated β increases and reaches 4.7053. So far, we have used the intergovernmental transfer data from 1998 to 2007. The 2008 data suffer from the problem that the general budget account income identity does not hold for several counties; thus, the accuracy of the intergovernmental transfer data is questionable for these areas. Nevertheless, we include the 2008 data in column (5). The estimated β does not change much. In addition, some researchers exclude tax rebates when calculating intergovernmental transfers. Column (6) replaces the ratio of the annual change in intergovernmental transfers to the previous year's GDP, which is *TranG*, with the ratio of the annual change in intergovernmental transfers excluding tax rebates to the previous year's GDP, which is denoted as *Tran2G*. The estimate of the effect of intergovernmental transfers excluding tax rebates on PM2.5 concentration is close to the baseline estimate.

Table 3
Robustness tests

	(1)	(2)	(3)	(4)	(5)	(6)
PM25G	Truncation	Winsorization (1, 99)	Identity holds	Area change ≤ 0.1%	2008 data added	Excluding tax rebates
TranG	3.8713***	4.3638***	4.3483***	4.7053***	4.4943***	
	(0.8642)	(0.9285)	(0.9463)	(0.9599)	(1.2248)	
Tran2G						4.4625***
						(0.9783)
L.ln(y)	0.1302***	0.1710***	0.1778***	0.2042***	0.1465***	0.1688***
	(0.0364)	(0.0426)	(0.0460)	(0.0474)	(0.0516)	(0.0445)
L.Str	-0.0492	-0.0233	-0.0287	0.0065	0.0471	-0.0342
	(0.0548)	(0.0582)	(0.0612)	(0.0631)	(0.0614)	(0.0605)
L.FinD	0.0017	0.0020	0.0020	0.0033	0.0032	0.0020
	(0.0020)	(0.0021)	(0.0022)	(0.0025)	(0.0022)	(0.0022)
L.ExpR	0.1028	0.2956***	0.3566***	0.3884***	0.0826	0.3553***
	(0.0688)	(0.0873)	(0.1033)	(0.1039)	(0.0586)	(0.1037)
L.RevR	-0.0820***	-0.0839***	-0.0886***	-0.1011***	-0.0353	-0.0836**
	(0.0282)	(0.0307)	(0.0336)	(0.0347)	(0.0298)	(0.0332)
L.FD	-0.0001	-0.0000	-0.0000	-0.0000	-0.0001	-0.0000
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
L.FisB	0.0080***	0.0071***	0.0064**	0.0062**	0.0092***	0.0058**
	(0.0025)	(0.0026)	(0.0028)	(0.0028)	(0.0024)	(0.0029)
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of id	1,933	1,933	1,933	1,933	1,933	1,933
Observations	15,156	15,420	15,420	14,873	17,048	15,437

Note: The standard error is in parentheses. ***, **, * mean significance at the 1%, 5% and 10% levels, respectively.

4.3 Mechanism analysis

We attempt to analyze the mechanisms through which intergovernmental transfers affect PM2.5 concentration. Intergovernmental transfers may affect PM2.5 concentration by influencing local finance. The first two columns of Table 4 examine the impact of intergovernmental transfers on expenditures and taxes of county governments where the dependent variables are $(Exp - L.Exp)/L.GDP$ (denoted as *ExpG*) in column (1) and $(Rev - L.Rev)/L.GDP$ (*denoted as RevG*) in column (2). In column (1) of Table 4, the estimated β is 0.7583 and significant at the 1% level, thus indicating that an increase of 1 yuan in intergovernmental transfers will increase the general budget expenditure of the county government by 0.7583 yuan. The result confirms the existence of the flypaper effect, that is, a large proportion of intergovernmental transfers will be converted into local expenditure (Gamkharand Shah, 2007). The increase in county government expenditures will lead to the increase in public goods, promote the productivity of private capital, and boost the growth of all industries, including polluting industries. Given production technology, this will aggravate environmental pollution. In column (2) of Table 4, the estimated β is − 0.1277 and significant at the 1% level, thus indicating that an increase of 1 yuan in intergovernmental transfers will lead the county government to cut taxes by 0.1277 yuan. The effect of tax cuts hinges on whether the tax cuts are inclusive tax cuts or structural tax cuts. Inclusive tax cuts will boost the growth of all industries and lead to environmental degradation. Structural tax cuts disproportionately benefiting polluting industries will lead to the development of polluting industries and environmental degradation, while structural tax cuts disproportionately benefiting non-polluting industries can promote economic growth without leading to environmental degradation.

We are particularly concerned about the performance of industries that are closely related to environmental pollution. Among the three sectors, namely, the agricultural, industry, and service sectors, the industry sector produces the most pollution. Thus, we continue to examine the effect of intergovernmental transfers on the gross industrial output value above the designated size (denoted as *IndV*). In column (3) of Table 4, the dependent variable is $(IndV - L.IndV)/L.GDP$. The estimated β is 5.9090 and statistically significant at the 1% level. This result indicates that an increase of 1 yuan in intergovernmental transfers will increase the gross industrial output value above the designated size by 5.9090 yuan. Given production technology, the increase in the gross industrial output value above the designated size will convert into an increase in the PM2.5 concentration. A possible source of the increase in the gross industrial output value above the designated size is that increased intergovernmental transfers expand the budget set of county governments. This enables county governments to provide better infrastructure and more tax incentives to attract mobile capital. In column (4) of Table 4, we use the annual growth rate of the number of industrial enterprises above the designated size as the dependent variable. We add the logarithm of the number of industrial enterprises above the designated size lagging by one year as an additional control variable. The reason for doing so is to take into account the limited number of industrial enterprises above the designated size for many counties. For these counties, even an increase of 1 in the number will have a large impact on the annual growth rate of the number. Controlling the number of existing industrial enterprises above the designated size

can eliminate the influence of this purely mathematical calculation. The result reveals that the estimated β is insignificant, thus suggesting that the increase in intergovernmental transfers does not lead to an inflow of industrial enterprises above the designated size. Therefore, the increase in the gross industrial output value above the designated size can only be attributed to the active production of the existing industrial enterprises above the designated size.

In addition, intergovernmental transfers may also have an impact on environmental pollution by affecting industrial structure. If the increase in intergovernmental transfers mainly boosts the development of the secondary industry, it will aggravate environmental pollution. If the increase mainly boosts the development of the tertiary industry, it will alleviate environmental pollution. The effect of intergovernmental transfers on the industrial structure is examined in columns (5) and (6), where the dependent variables are the annual change in the proportion of the secondary industry's GDP and the annual change in the proportion of the tertiary industry's GDP, respectively. The results indicate that intergovernmental transfers significantly reduce the proportion of the secondary industry's GDP but significantly increase the proportion of the tertiary industry's GDP. This change in the industrial structure helps improve environmental quality and mitigate the increase in the PM2.5 concentration brought about by the increase in the gross industrial output value above the designated size. However, its effect is dominated.

Table 4
Mechanisms for intergovernmental transfers to affect PM2.5 concentration

	(1)	(2)	(3)	(4)	(5)	(6)
	ExpG	*RevG*	*IndVG*	*IndNG*	*SIR*	*TIR*
TranG	0.7583***	-0.1277***	5.9090***	0.0428	-0.5176***	0.2348*
	(0.0595)	(0.0317)	(1.1096)	(0.6512)	(0.1438)	(0.1251)
L.ln(y)	-0.0048*	-0.0047***	0.2087***	-0.0093	-0.0300***	0.0454***
	(0.0029)	(0.0015)	(0.0541)	(0.0458)	(0.0070)	(0.0061)
L.Str	-0.0010	-0.0103***	0.1730**	-0.0623	0.1732***	0.2065***
	(0.0039)	(0.0021)	(0.0715)	(0.0657)	(0.0093)	(0.0081)
L.FinD	-0.0004***	-0.0000	0.0095***	-0.0009	0.0002	-0.0005*
	(0.0001)	(0.0001)	(0.0026)	(0.0027)	(0.0003)	(0.0003)
L.ExpR	-0.0036	-0.0024	0.0809	-0.1949	-0.0341**	-0.0060
	(0.0065)	(0.0035)	(0.1249)	(0.1571)	(0.0157)	(0.0137)
L.RevR	0.0122***	-0.0011	-0.0523	0.0027	0.0279***	0.0031
	(0.0021)	(0.0011)	(0.0394)	(0.0456)	(0.0051)	(0.0045)
L.FD	-0.0000	-0.0000	0.0002	0.0005	0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0007)	(0.0006)	(0.0001)	(0.0001)
L.FisB	0.0004**	0.0005***	-0.0048	-0.0029	-0.0006	-0.0012***
	(0.0002)	(0.0001)	(0.0034)	(0.0039)	(0.0004)	(0.0004)
L.ln(lnDN)				-0.3323***		
				(0.0087)		
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of id	1,934	1,934	1,934	1,933	1,934	1,934
Observations	15,445	15,445	15,410	12,363	15,444	15,440

Note: The standard error is in parentheses. ***, **, * mean significance at the 1%, 5% and 10% levels, respectively.

4.4 Heterogeneity effect analysis

The baseline results reflect the average effect of intergovernmental transfers. We continue to examine the possible heterogenous effects of intergovernmental transfers. Intergovernmental transfers are closely related to local fiscal structure, so we investigate whether local fiscal structure will affect the effect of intergovernmental transfers on the PM2.5 concentration. We also investigate the role of population density, a factor associated with the PM2.5 concentration. Population density is influenced by topography, which will influence the diffusion of PM2.5. In column (1) of Table 5, we add the interaction of *TranG* and the ratio of the general budget expenditure to the GDP in 1998 (denoted as $ExpR_{1998}$). In column (2) of Table 5, we add the interaction of *TranG* and the ratio of the general budget revenue to the general budget expenditure in 1998 (denoted as $RevR_{1998}$). In column (3) of Table 5, we add the interaction of *TranG* and the logarithm of population density in 2000 (denoted as $\ln(PopD_{2000})$). The results reveal that the coefficients of $TranG \times ExpR_{1998}$ and $TranG \times RevR_{1998}$ are not statistically significant. The coefficients of $TranG \times ln(PopD_{2000})$ is significantly negative. One possible explanation is that places with low population density tend to be places with a high proportion of mountainous area, where PM2.5 is not easy to diffuse.

Table 5
Heterogeneous effects of intergovernmental transfers on PM2.5 concentration

	(1)	(2)	(3)
	PM25G	*PM25G*	*PM25G*
TranG	3.3168	6.2889***	7.4195***
	(2.3036)	(1.8063)	(1.1555)
$TranG \times ExpR_{1998}$	4.5276		
	(6.8683)		
$TranG \times RevR_{1998}$		-6.0134	
		(7.3934)	
$TranG \times ln(PopD_{2000})$			-0.8698*
			(0.4487)
L.ln(y)	0.1660***	0.1583**	0.1517***
	(0.0565)	(0.0627)	(0.0561)
L.Str	-0.0321	-0.0142	-0.0565
	(0.0656)	(0.0588)	(0.0692)
L.FinD	0.0023	0.0026	0.0017
	(0.0022)	(0.0022)	(0.0023)
L.ExpR	0.3805***	0.3560***	0.3195***
	(0.0775)	(0.1019)	(0.1171)
L.RevR	-0.0933***	-0.1279***	-0.1007***
	(0.0315)	(0.0439)	(0.0327)
L.FD	-0.0000	-0.0000	-0.0000
	(0.0006)	(0.0006)	(0.0006)
L.FisB	0.0075**	0.0079**	0.0060**
	(0.0037)	(0.0039)	(0.0028)
County FE	Yes	Yes	Yes

Note: The standard error is in parentheses. ***, **, * mean significance at the 1%, 5% and 10% levels, respectively.

	(1)	(2)	(3)
Year FE	Yes	Yes	Yes
Number of id	1,921	1,921	1,927
Observations	15,374	15,374	15,412
Note: The standard error is in parentheses. ***, **, * mean significance at the 1%, 5% and 10% levels, respectively.			

4.5 Additional results

In addition to the above results, we continue to examine the effect of intergovernmental transfers on GDP. This examination contributes to a comprehensive presentation of the role of intergovernmental transfers in local development, both its advantages and disadvantages. To this end, we set the dependent variable to the annual growth rate of GDP in column (1) of Table 6 (denoted as *GDPG*). The estimated β is 1.1473 and significant at the 1% level, thus indicating an increase of 1 yuan in intergovernmental transfers will increase GDP by 1.1473 yuan; i.e., the intergovernmental transfer multiplier is 1.1473.

Finally, we investigate the effect of the change in intergovernmental transfers on population flow. Labor is an important input to GDP and the gross industrial output value above the designated size, and the change in labor partly explain the changes in GDP and the gross industrial output value above the designated size. Column (2) of Table 6 focuses on the relationship between the change in intergovernmental transfers and inter-county population flow. The dependent variable is the annual growth rate of total population at the end of the year (denoted as *PopG*). β is not significant, thus suggesting that intergovernmental transfers do not cause population inflows or reduce population outflows. Although intergovernmental transfers do not have an impact on inter-county population flow, they may affect the movement of labor from rural to urban areas within a county, a scenario that improves resource allocation and is a feature of China's reform and opening up process. Column (3) of Table 6 focuses on the relationship between intergovernmental transfers and population flow between rural to urban areas. The dependent variable is the annual growth rate of rural employment. The estimated β is − 1.0019 and significant at the 1% level, thus indicating an 1% increase in the annual change in intergovernmental transfers relative the previous year's GDP will reduce the annual growth rate of rural employment by 1.0019%. As the total population at the end of the year does not change, this result suggests an increase in the urban employment. That is, intergovernmental transfers prompt the movement of labor from rural to urban areas within a county, which is a source of growth of GDP and the gross industrial output value above the designated size.

Table 6
Change of intergovernmental transfers, GDP growth and population flow

	(1)	(2)	(3)
	GDPG	*PopG*	*RurEG*
TranG	1.1473***	0.0079	-1.0019***
	(0.3819)	(0.0375)	(0.2156)
L.ln(y)	-0.1554***	0.0058***	-0.0464***
	(0.0186)	(0.0018)	(0.0105)
L.Str	-0.2121***	-0.0028	-0.0146
	(0.0248)	(0.0024)	(0.0140)
L.FinD	0.0037***	0.0000	-0.0002
	(0.0009)	(0.0001)	(0.0005)
L.ExpR	0.3363***	0.0162***	-0.0995***
	(0.0417)	(0.0041)	(0.0245)
L.RevR	0.0566***	-0.0056***	0.0297***
	(0.0136)	(0.0013)	(0.0084)
L.FD	-0.0000	-0.0000	-0.0001
	(0.0003)	(0.0000)	(0.0001)
L.FisB	-0.0014	-0.0002	0.0012*
	(0.0011)	(0.0001)	(0.0007)
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Number of id	1,934	1,934	1,931
Observations	15,445	15,445	14,999

Note: The standard error is in parentheses. ***, **, * mean significance at the 1%, 5% and 10% levels, respectively.

5. Conclusion And Policy Implications

This work estimates for the first time the causal effect of the total intergovernmental transfers on environmental pollution. Applying the 2SLS method to China's county-level data from 1998 to 2008, we find that intergovernmental transfers aggravate PM2.5 pollution. Specifically, a 1% rise in $(Tran_t - Tran_{t-1})/GDP_{t-1}$ will increase $(PM25_t - PM25_{t-1})/PM25_{t-1}$ by 4.3145%. This outcome is the opposite of the result that the ecological transfer improves the ecological environment. Intergovernmental transfers affect PM2.5 pollution through county government expenditures and taxes, the gross industrial output value above the designated size, and industrial structure. Meanwhile, the increase in intergovernmental transfers promotes GDP growth. Specifically, the intergovernmental transfer multiplier is 1.1473.

Intergovernmental transfers lead to environmental degradation on the one hand and increase the GDP on the other. That is, intergovernmental transfers manifest both negative and positive effects. The government should weigh economic growth and environmental protection and make an optimal choice. If the government wants to strengthen environmental protection, it can start by regulating industrial enterprises above the designated size. These enterprises are relatively large in scale and small in number. Strengthening environmental regulation of them can do more with less.

Declarations

Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

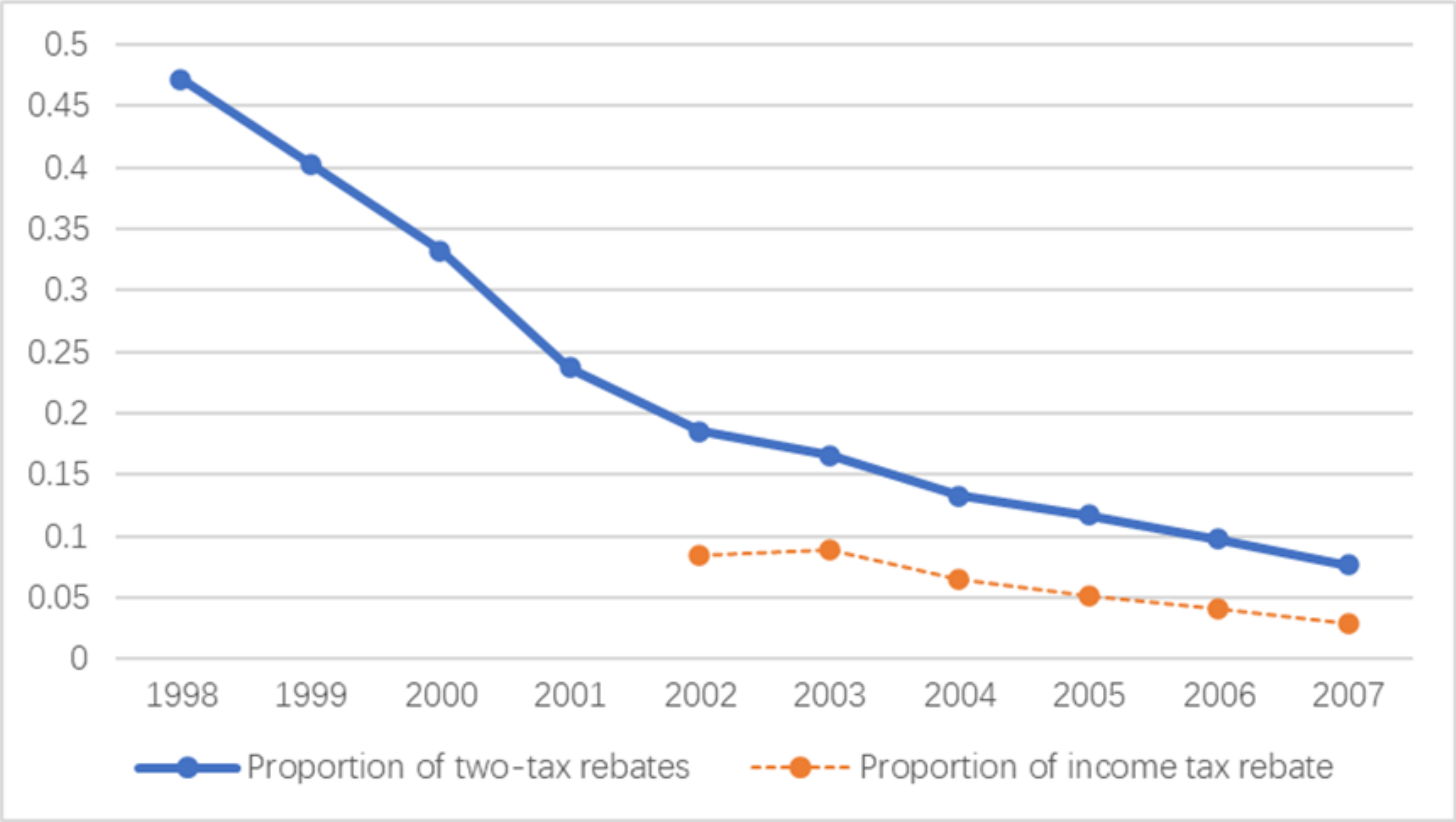


Figure 1

Proportion of tax rebates at the county level from 1998 to 2007

Note: We aggregate the county data to calculate total tax rebates and intergovernmental transfers. Then we the proportion of tax rebates in intergovernmental transfers.

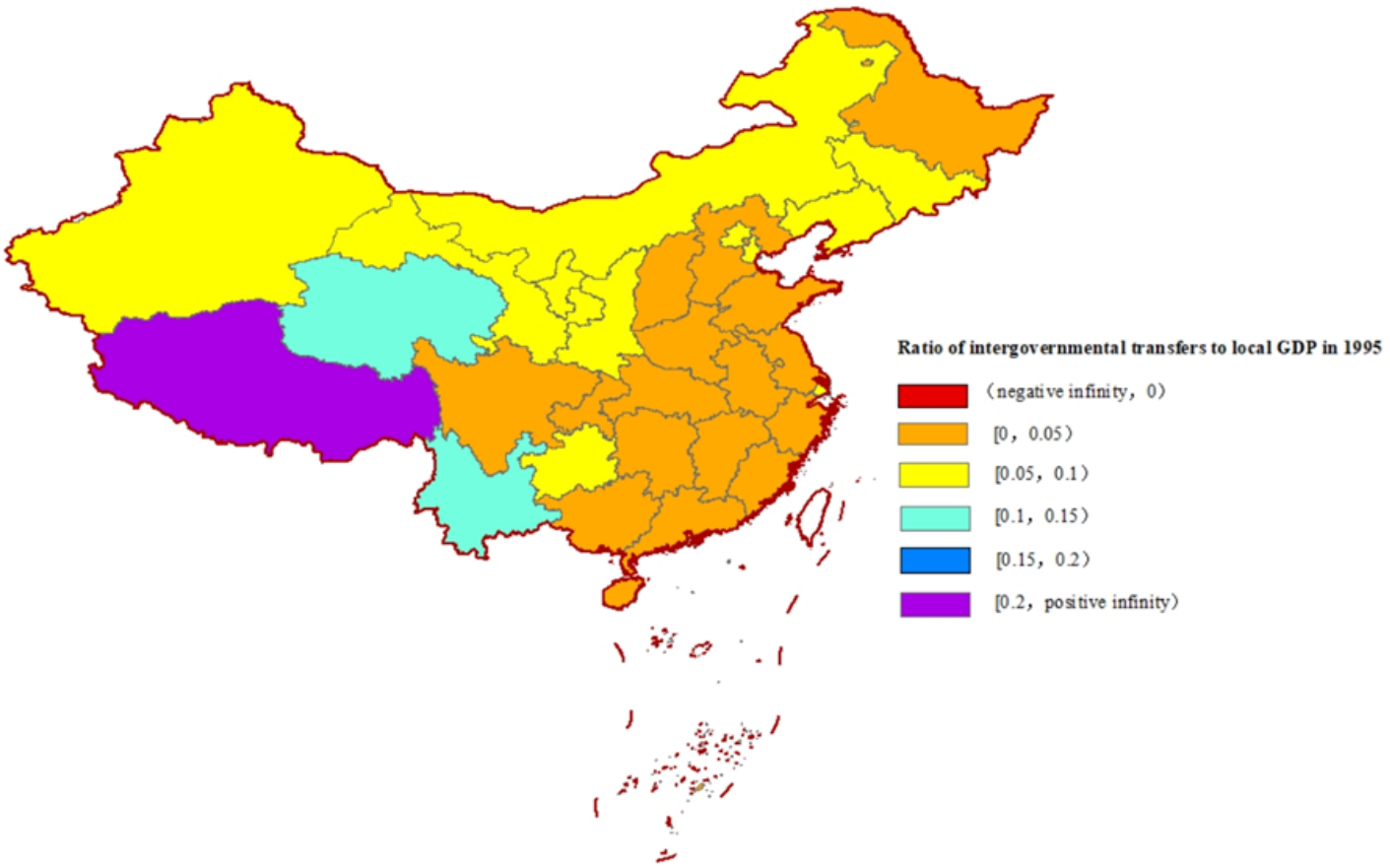


Figure 2

Ratio of intergovernmental transfers to local GDP in 1995

Note: In 1995, Chongqing has not become a provincial level unit. Its data are missing. We use its data in 1997 instead.

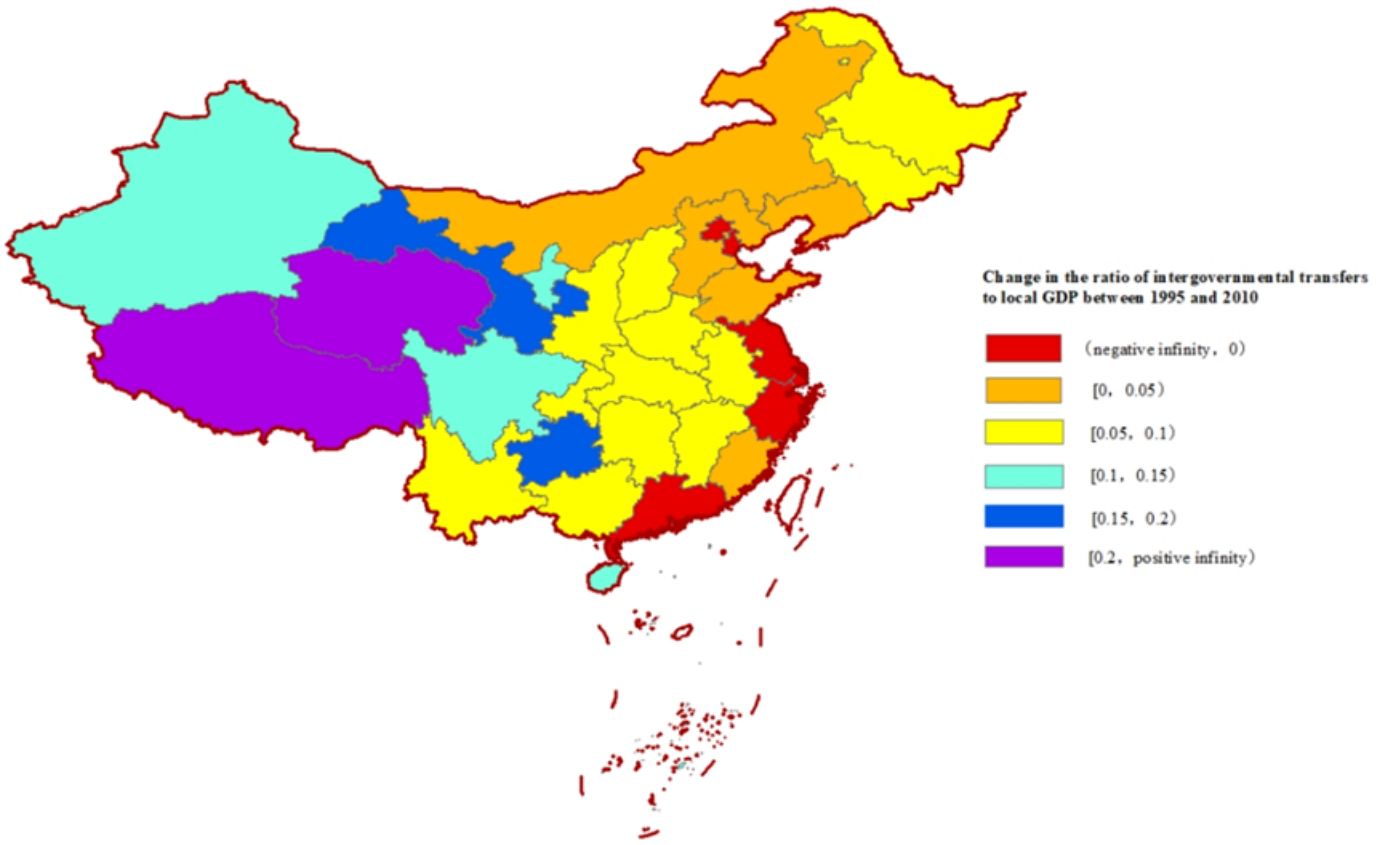


Figure 3

Change in the ratio of intergovernmental transfers to local GDP between 1995 and 2010

Note: In 1995, Chongqing has not become a provincial level unit. Its data are missing. We use its data in 1997 instead.

Supplementary Files

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- Appendix.docx