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Contributions

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Fiscal Decentralization and Environmental Infrastructure in China

Abstract: This article provides new evidence that fiscal decentralization has supported economic development by incentiving cities to provide more sewage infrastructure. As a result of the 1994 tax reform, Chinese cities retained different shares of their value-added tax (VAT). Exploiting the persistence of this sharing system, we use the VAT share in 1995 as an instrument for the present fiscal incentives. We find that cities with higher fiscal incentives built significantly more sewage treatment capacity between 2002 and 2008. This result suggests that fiscal incentives can play a strong role in the development of city-level infrastructure.

Keywords: China sewage, water pollution, fiscal decentralization, fiscal federalism, tax sharing

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1 Introduction

Decentralization has been a focus of policy experiments over the past two decades among developing and transition economies (Bardhan 2002). Decentralization, as an alternative to centralized authority, offers the tantalizing promise of improved services delivery through local governance. The World Bank placed it as a key initiative entering the twenty-first century. In recent decades, the Bank has committed $31.6 billion in projects related to decentralization, 8% of its total commitments (World Bank 1999, 2008). Fiscal decentralization, the allocation of decision-making over taxes and expenditures to local government authorities, has been a particular area of interest among economists. The welfare consequences of decentralized government were summarized analytically by Gordon (1983), in an elegant optimal tax model of fiscal federalism.

Despite the importance of the topic, empirical examinations of the effects of fiscal decentralization have been relatively sparse. Further obfuscating the issues, evidence has at times been contradictory, even among research looking at the same sample. Zhang and Zou (1998) found that fiscal decentralization is associated with lower economic growth among provinces in China. However, Jin, Qian, and Weingast (2005) and Lin and Liu (2000) also focused on Chinese provinces, both found fiscal decentralization to be associated with higher economic growth.

This article provides new evidence supporting the hypothesis that fiscal decentralization has supported economic development. Our main finding is that fiscal decentralization among cities in China led to increased provision of public infrastructure in the form of sewage treatment. Under China's system of tax sharing, the financial resources available to cities are determined in part by the share of value-added tax (VAT) which they retain. Officials in cities with high VAT sharing rates have greater incentive to expand their tax base than those in cities with low sharing rates. Many government officials believe that providing infrastructure is an important strategy to attract new business. As a result, cities with high VAT shares direct financial resources toward activities that directly boost the industrial tax base, such as sewage treatment capacity.

To study the impact of fiscal incentives on a long-lived, lumpy type of infrastructure such as sewage treatment plants, we use an empirical specification where the observable growth in sewage treatment capacity, which occurred between 2002 and 2008, is regressed on a measure of city-level fiscal incentives. However, there are possible endogeneity problems with using the most direct candidate: a city's share of VAT retained in 2001. While the rule of allocating VAT shares between the central and provincial governments is fixed by law, provinces had the right to change or reassign city tax shares. If a city had a budget surplus, its VAT share might be decreased. If a city had a change of leadership, its new leaders might plausibly negotiate a larger VAT share, or a smaller decrease in share, than would otherwise be expected. While most cities had fixed VAT shares, some had shares that moved up and down over time.

To address this potential endogeneity, we use the share of VAT retained in 1995 as an instrument for a city's fiscal incentives. The history of China's tax system suggests that this instrument is both relevant and valid. The relevance of the instrument can be seen in the evolution of each city's VAT share over time. China's tax reform of 1994 gave provinces the authority to allocate tax shares to cities; each installed its own system of allocating pools of VAT revenue. We find that provincial tax sharing systems installed during this tax reform persisted through the time period of our sewage data.

The instrument is validated by the historical accounts of the methods by which provincial authorities assigned fiscal incentives. We confirm these accounts empirically. We look at which provinces chose to pass through all revenues and which chose to withhold revenues. We study the patterns by which provinces initially deployed fiscal incentives for cities within their domain and find that the most important explanation is "equalization," where poorer cities received higher shares of VAT revenues. We control for the equalization rationale and the routes through which this is likely to affect sewage treatment through the use of covariates.

We have assembled a rich data set for the empirical analysis, which comprises sewage treatment capacity and economic variables for 111 cities between the years 2002 and 2008. Our central result is that cities react to higher VAT sharing ratios by expanding their sewage treatment capacity. A 10% point increase in the 1995 VAT sharing ratio (i.e. from 60% to 70%) resulted in 13.8% more growth in sewage treatment capacity during the 2002–2008 period. Our results are consistent over a wide set of robustness checks. A number of alternative explanations are ruled out through tests demonstrating how these results hold for subgroupings of cities in China, such as provincial capitals and coastal cities. Finally, we show that other forms of public spending, which should have an ambiguous relationship with fiscal incentives, are generally uncorrelated with VAT sharing ratios.

This article benefits from ideas within the "second generation" fiscal federalism literature (Oates 2005). Rather than presenting local officials as benign decision makers focused entirely on social welfare, this strain of literature models them as revenue-maximizing opportunists who channel effort into functions that reap financial reward. Zhuravskaya (2000) argued that local governments with low fiscal incentives have no incentive to increase the tax base or provide public goods. After showing that some cities in Russia must share almost all additional revenues they generate, she connected the absence of fiscal incentives among these cities with inefficient public service provision, in the forms of higher infant mortality and decreased availability of regular schooling.

Our findings offer three contributions to the economics literature on fiscal decentralization and on environmental policy. First, there are very few empirical studies about fiscal federalism at the sub-provincial level (Bardhan 2002). Our work shows how the history of tax reform in China has been connected with the patterns of tax distribution among cities in China and documents the effects of this connection. Second, the prior literature typically linked fiscal federalism with more efficient provision of government services. We demonstrate how higher fiscal incentives can be linked with higher growth of infrastructure, another important policy topic. Third, our empirical setting is sewage treatment in China, a novel setting in the economics literature. Sewage treatment is a cost-effective manner to address water pollution and public health issues in China after decades of rapid economic growth with insufficient pollution control (Ebenstein 2012). Our findings suggest that financial autonomy provides incentive to cities to expand sewage treatment facilities.

The remainder of the article is organized as follows. Section 2 introduces the institutional background, explaining the political economy of VAT sharing and how sewage treatment can affect development. Section 3 describes the data. Section 4 presents the empirical strategy. Section 5 reports empirical results and robustness checks. Section 6 concludes.

2 Institutional background

2.1 Fiscal incentives

The 1994 Tax Reform represented a watershed change of China's fiscal system. We highlight three changes here to illustrate how completely the tax system was reformed. First, the tax administration system was altered. Rather than relying on local tax authorities to collect taxes and share them with the central government, the 1994 reform gave responsibilities of VAT tax collection to the central government. Second, many important taxes were substantially altered in their base and rate (Ma 1997). The new system applied the VAT to a much broader tax base and set relatively uniform rates. Third, it codified a new system of tax sharing that applied a uniform set of rules to local governments. The VAT was designated a shared tax, with 75% of revenues accruing to the central government and 25% to be shared among lower levels of government.[1]

The 1994 reform, while eliminating many avenues of negotiation between the central government and the provinces, did not specify patterns of tax sharing between provinces and cities. Provinces decided on the allocation of revenues among its subordinate units. Since the central government did not require submission of final accounts for individual local governments (Bahl 1999), provinces had largely unchecked discretion in determining the distribution of revenue between layers of government. The right of local governments to appeal

1 Under the tax system preceding the 1994 reform, provinces had different marginal revenue retention rates. After the 1994 reform, all provinces received the same, fixed share of VAT. Cities still have different VAT revenue shares after the reform.

their tax sharing agreements was limited only to egregious cases (World Bank 2002).

Although the central government took the same, fixed 75% share out of each province's VAT collections, provinces were able to determine themselves how to apportion the remaining 25%. If a province gave a city a lower share of VAT, the province is able to control higher amounts of public funds. Conversely, when provinces gave cities lower shares, the provinces allowed the city to make a wider range of decisions. We observe that a variety of systems proliferated.

An example will facilitate understanding of these systems. Suppose a firm within the city of Zunyi, in the province of Guizhou, pays 100 Renminbi (RMB) of VAT. The central government collects this tax and keeps 75 RMB. It passes 25 RMB to Guizhou, an amount fixed by law. Guizhou has an agreement with Zunyi where Zunyi retains 60% of VAT revenues generated in its domain. Hence, out of the 100 RMB in tax revenue that was initially collected from Zunyi, Zunyi retains 15 RMB, or 15%. On median, cities derived 15.9% of their total taxes collected from their share of VAT. Although the city's share of its VAT could seem small, each city's share of VAT revenues represents an important component of its budget. For many cities, VAT is the biggest single source of tax revenue.

Table 9 illustrates how VAT was actually shared between provinces and cities in 1995 and in 2001.[2] We draw two conclusions from this table. First, it is clear that provinces make decisions on VAT sharing rates: all cities within a province follow the same basic pattern. Sixteen province-level entities, representing 145 of the 285 cities in our public finance dataset, chose to pass through 100% of local VAT revenues to their cities. The other provinces chose to pass through some smaller share of revenues. For most of the cities in this dataset, their sharing rates were fixed with no regard to factors such as their role within the government hierarchy or the ability of city managers to negotiate. Second, each province's system of VAT sharing in 2001 remained basically constant with the system of sharing established in 1995. At the time of the 1994 reform, each province selected a system of VAT sharing for all cities in its domain. Once a

2 For much of our analysis, we use the 1995 VAT sharing rate, although the tax reform in China was initiated in 1994. Wong (1997) writes that the 1994 tax reform was implemented only a few months after it was approved. She documents that neither taxpayers nor local tax officials were "prepared" for the transition. Moreover, through 1994, cities and counties were in doubt as to whether the rules of the contract system (the pre-1994 system) would govern the new tax sharing system.

We conclude from this reading that 1994 VAT sharing rates may be unreliable, since they involved a period of transition and, at best, reflect a system in place for only part of the year.

province decided on a method, it generally retained that method through the relevant period of our analysis.

Nine of the 31 provinces examined here passed less than 100% of VAT revenues and did so in a manner that assigned different VAT sharing rates to different cities. Among these provinces, the VAT share retained by cities often fluctuated between 1995 and 2001. However, the VAT rate was restricted to the domain of possibilities allowed by the province.

Why did different provinces decide on different patterns of VAT sharing? Bahl (1999, 150), writes:

> With so much discretion, it is not surprising that provincial governments have developed many different systems of revenue sharing. Some provinces seem to stress equalization, others seem to promote regions with greater economic development potential, others seem to emphasize incentives for resource mobilization, and in a few instances, the division of revenues seems almost random.

In summary, VAT sharing systems were determined immediately after the 1994 tax reform. Provinces made decisions on the VAT shares of cities in their domain. They made decisions individually, each selecting a different set of reasons. The VAT sharing systems set up in 1994 were strongly related to the shares eventually observed in 2001, the beginning of the period where we can observe cities building up their sewage treatment capacity.

2.2 Sewage treatment in China

Water pollution in China is extensive and serious: 54% of rivers are not fit for consumption (World Bank 2007). Between 300 million and 500 million Chinese lacks access to piped water, and only 28% of rural households have access to improved sanitation (Vennemo et al. 2009). Since China leans so heavily on surface sources of water, water pollution-related damages to health has been rising to an alarming level. For example, the deterioration of water quality in China's rivers raised the rate of digestive cancers significantly (Ebenstein 2012). World Bank (2007) estimates that water pollution alone cost China 9.47 billion RMB in 2003.

To deal with the pollution problem, the Chinese central government established the "three synchronizations policy" (*san tongshi zhengce*) with the enactment of the PRC Environmental Protection Law of 1989. This policy is described in detail in Ma and Ortolano (2000). Under this policy, the design, construction, and operation of a new factory or other industrial facility must be accompanied by the design, construction, and operation of appropriate waste treatment facilities. The official data suggest that this policy was followed: the industrial sewage treatment rate was 92.9% in 2006 (China State Environmental Protection Administration 2002–2009).

Several incentives ensure that local government officials are motivated to comply with policies governing the construction of wastewater treatment facilities. Sewage treatment reduces water pollution and the risk of environmental disasters for which local officials can be blamed. When the media reports widely on an environmental disaster, government officials, such as the head of the local environmental bureau, can be disciplined or fired. A second incentive is to attract industry.[3] Companies considering a choice of location know that, under the three synchronizations policy, they must provide a means of treating their wastewater when they build new industrial facilities. However, instead of constructing their own sewage treatment plants, they can take advantage of city-provided sewage treatment plants, providing the benefit of economies of scale and lower costs.

Sewage treatment plant construction is funded by multiple sources. One source is a set of fees included in the price of water. The level of the water consumption fee varies with each city. One of the fees within the water consumption fee is split between the operation of wastewater treatment facilities and the construction of new plants.[4] Another source is from the central government and provincial governments, both of which can earmark funds for the construction of sewage treatment plants. More generally, the assignment of responsibilities to different levels of government is vague in China (World Bank 2002). Shah (2006) analyzed earmarks and found that they are generally regressive; more earmarks are dedicated to richer and more populated areas.

Land sales have also been an important sourcing of funding infrastructure projects. Cities sell land to developers and can spend the proceeds on infrastructure. In this article, we argue that fiscal incentive, as measured by VAT share, is one of the determinants of sewage treatment capacity, rather than the only determinant. Lacking exogenous variation of these other determinants, we are able to study only the impact of VAT share in this study.

3 One saying, "*qitong yiping*," states that, in order to attract investment, local governments must build seven forms of infrastructure: electricity, roads, water, telecommunications, cable, leveled ground, and waste treatment. We note that sewage is just one form of infrastructures that could be interesting to cities. Theoretically, each form of infrastructure should be attractive at the margin. We lack data at the city level to study the behavior of these other forms.

4 However, the price of water is considered a sensitive political subject in China. Cities cannot arbitrarily raise the price of water to fund the construction of new sewage treatment plants; price rises in cities are usually carefully coordinated with the central government and phased in over an extended period.

3 Data

3.1 VAT sharing

The VAT is at the center of our analysis. The VAT is the most important tax in terms of revenue collected, accounting for over 40% of all central government tax revenues. The VAT is levied only on industrial firms during this time and excludes firms in the agricultural and service industries. The VAT share is just one part of a broader revenue-sharing arrangement between provinces and cities. If other parts of these contracts, such as corporate income tax sharing, or transfers, are correlated, they could also drive city incentives to build infrastructure. However, other parts of revenue-sharing agreements between provinces and cities are less likely to serve as incentives to build sewage treatment capacity. These other taxes, such as the corporate income tax or the business sales tax, include in large part nonindustrial sectors that are unlikely to be interested in sewage treatment capacity.

Another possible candidate is the annual rebates which cities receive from higher levels of government. The amount of these rebates is determined through a formula that grows a base amount according to the combined growth rates of the VAT and the consumption tax (Shah 2006). The consumption tax in China is a turnover tax, paid by consumers, and is focused on particular types of goods such as tobacco and alcohol. In the formula determining these rebates, the year-over-year growth rates of VAT and of the consumption tax are mixed.

Hence, this article focuses on the VAT, the tax most directly related to firms in the industrial sector, as the most appropriate subject for our study. The VAT is also attractive, because the data give clean measures that allow direct observation of VAT sharing rates. We believe that the use of VAT share is a significant advance over some prior articles studying decentralization in China. These articles often measure fiscal incentives using the fraction of total government expenditures made by the local government. This form of measure suffers from clear mis-measurement and endogeneity problems in which the measure of VAT share avoids.

City public finance revenues are compiled from the Sub-Provincial Public Finance Statistics (*Quanguo Dishixian Caizheng Tongji Ziliao*), an annual publication of the China's Ministry of Finance. These publications contain detailed statistics of city tax revenues, transfers, and expenditures. The Sub-Provincial Public Finance Statistics reports the amount of VAT retained by the city (*gongshang shuishou – zengzhishui*) and the figure representing 75% of all VAT collected, which is turned over to the central government (*yiban yusuanshouru zongji – zengzhishui* 75%). The VAT share for each city is:

$$\mathrm{FI}_i = \frac{\text{VAT Retained}_i}{\text{Central Government Share}_i} \times 3. \qquad [1]$$

We use eq. [1] to calculate the sharing rate for each city in each year. Cities that retain 25% of VAT generated, the entire local share, will have $\mathrm{FI}_i = 1$; cities that retain none of their VAT will have $\mathrm{FI}_i = 0$. Significant variation among cities exists. Most cities retain between 50% and 100% of local VAT revenues, with a concentration of cities at 100%. A very small number of cities have VAT sharing ratios in individual years above one. We do not understand why cities would be able to retain more than the local share of VAT. It is possible that temporary special deals were negotiated with the government; alternatively, data entry errors are known to be present in China's official yearbooks. Since over 99% of these data show a sharing ratio at or below one, the VAT share data appear to reflect our expectations well.

Fiscal incentives are strongly correlated within a province, with high fiscal incentives apparently concentrated along the eastern and southern coasts, and in the middle of the country (Figure 1). Province-level variation is not a particular driver of our results. We would be concerned if any one province had both low fiscal incentives and low growth in sewage treatment capacity, driving our results by acting as an outlier. However, a variety of provinces have individual cities that have low fiscal sharing rates and low growth in sewage treatment capacity.

Note that there are four directly controlled municipalities (DCMs): Beijing, Shanghai, Tianjin, and Chongqing. These municipalities have been given province-level tax and political authority. We expected DCMs to have fiscal sharing ratios at 1, since they do not share revenues with provinces. However, some DCMs do not (Table 9). We believe that DCMs use a different method to report budgetary statistics to the Sub-Provincial Finance Statistics than other cities. Data from the China City Statistical Yearbook of 2002 match the budgetary information provided in the Sub-Provincial Finance Statistics of 2002 for all cities except DCMs. Our results are largely robust to the inclusion or exclusion of DCMs.

3.2 Sewage treatment and other variables

The sewage treatment data are published by the China Environment Yearbooks (CEYs), a joint publication of the Chinese National Bureau of Statistics and the

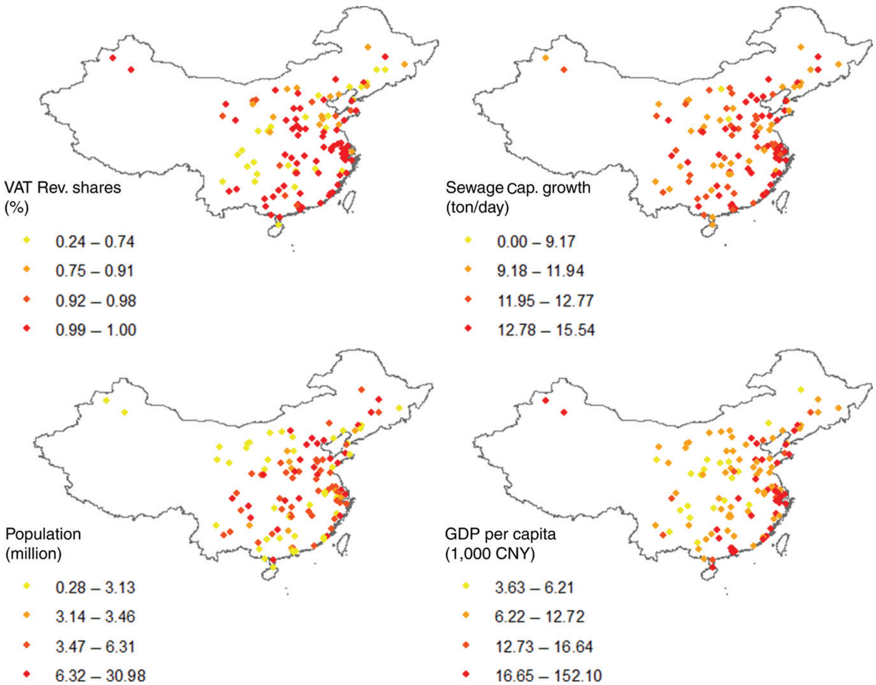

Figure 1: Each dot in these figures represents one city in China for which sewage treatment capacity data are available. The VAT share of each city, as calculated in eq. [1], are graphed on the upper left. The growth in sewage treatment capacity between 2002 and 2008 is graphed on the upper right. The population of each city in 2001 is graphed on the lower left. The GDP per capita of each city in 2001 is plotted on the lower right.

State Environmental Protection Agency. The data comprise 111 cities for the period 2002–2008.[5] Publication of these yearbooks began in 2002. No data are available before this period. In general, CEYs report only large cities and "important" cities such as provincial capitals. Hence, the results of this study apply only to major cities, all those for which sewage data are reported. Lacking data, we are unable to generalize our hypothesis to smaller cities, and do not claim that it holds for these cities.

Sewage treatment capacity is the key dependent variable of interest. There are clear differences in both the sizes and treatment levels of the different types of cities. Municipalities are the clearest outliers: Shanghai, Beijing, and

5 We found some occasional errors in the data of sewage treatment. This issue is discussed in "Sewage treatment data" in the Appendix in detail.

Chongqing have far higher populations than other cities. Shenzhen and Xiamen have very high sewage treatment capacity per capita, although their actual treatment capacity is not out of line with other cities. Spatially, the growth of sewage treatment capacity appears to be more concentrated in the east and along the major Yellow River and Yangtze River systems.

Some Chinese statistics have been criticized for being mis-measured or fabricated. However, we believe that sewage treatment plants are relatively free from mis-reporting. Sewage plants are easily visible; it is difficult to pretend that a sewage plant has been constructed if no plant exists.

Another concern might be the utilization of sewage infrastructure, since the desire to increase economic growth might lead some localities to build overly large amounts of infrastructure. However, we observe that sewage treatment facilities operated at near capacity in most cities during the entire period of our sample, 2002–2008. This period represented a building-out stage for sewage treatment facilities; all plants, once built, had demonstrated demand in place. As a result, wasted infrastructure construction did not seem to be a problem.

Other city-level characteristics include population, GDP per capita, city expenditures, industrial output and structure, and water consumption. These variables will be used as controls in identifying the relationship between fiscal incentive and sewage treatment capacity. The data are obtained from the China City Statistical Yearbooks, another official publication of the Chinese government. Summary statistics of key variables are presented in Table 1.

Table 1: Summary statistics of the variables used in regression.

Variables	Mean	Std	Min	Max
Treatment capacity (10^4 tons/day)	41.59	61.77	0.03	648.84
Fiscal incentive (1995)	0.91	0.17	0.37	1.00
Fiscal incentive (2001)	0.86	0.21	0.07	1.00
Population (10^4)	494.14	368.46	28.43	3,257.05
GDP/capita (10^4 yuan/person)	2.31	1.75	0.36	15.21
City expenditures (10^8 yuan)	108.63	211.17	1.75	2,593.92
Industrial output (10^8 yuan)	1,803.55	2,687.35	8.89	25,121.20
Secondary share	50.59	10.80	20.44	90.97
Tertiary share	38.52	9.25	8.58	73.25
Water consumption/capita (tons)	59.52	34.90	1.78	282.56
City expenditure/GDP	0.08	0.04	0.01	0.42

Notes: The data cover 111 cities from 2002 to 2008. Sewage data from China Environmental Yearbooks. Other data from China City Statistical Yearbooks.

4 Methodology

4.1 A model of revenue sharing and infrastructure

We use a stylized model to illustrate the relationship between revenue sharing and construction of infrastructure. The model is in the same spirit as that of Zhuravskaya (2000). Consider a city manager deciding where to spend public funds. Spending on public infrastructure, S, increases city welfare by αS, where α, representing the welfare returns to infrastructure, is an exogenous constant. The manager can also choose to spend public funds through other means, such as transfers. Transferring an amount E provides non-financial benefits to the city at the same amount.

Infrastructure expands tax revenue $g(S)$ of the city. The revenue function is assumed to be strictly increasing and concave.[6] The city retains only an exogenous share β of tax revenue: the city's fiscal incentive. Its total budget is $\beta g(S)$. The cost function of purchasing and operating the public infrastructure, $I(S)$, is strictly increasing and convex.[7] The cost of transfers is E. Under these assumptions, the manager's problem is maximizing the welfare of the city subject to the budget constraint:

$$\begin{aligned}&\max_{S} \quad \alpha S + E\\&\text{subject to} : I(S) + E \leq \beta g(S).\end{aligned} \qquad [2]$$

If we define the optimal choice of spending on public infrastructure as S^*, we prove in "Solution of model (2) in Section 4.1" in the Appendix that $dS^*/d\beta > 0$. We see from this simple model that increasing the share of revenue retained by a city should increase its spending in areas which will increase its future revenue. This motivates our primary hypothesis, hypothesis 1:

> *Hypothesis 1*: Cities with higher fiscal incentives construct greater sewage treatment capacity.

6 More infrastructure spending always increases the size of the tax base, since the city becomes more attractive to both businesses and consumers. Early spending can generate high returns, since important facilities such as clean water and electricity are essential to development. Later spending generates comparatively diminished marginal returns, since the highest return opportunities have already been selected.

7 More infrastructure always costs more to purchase and maintain. The initial units of infrastructure are comparatively cheap, while later ones are comparatively expensive.

Among forms of spending that do not directly expand the tax base, such as transfers, there is an ambiguous predicted relationship. A higher sharing rate β mechanically increases the financial resources of the city $\beta g(S)$, allowing more to be spent on transfers. However, higher sharing rates also increase substitution toward S away from E.

4.2 Empirical specification

We have laid out a brief model of the choice of public spending under a system of revenue sharing. The intuition behind this model is that cities with higher shares of revenue retained have higher marginal benefit from directing funds toward activities generating more taxes. As a result, they expand infrastructure more relative to cities with low fiscal incentives. Applying this model to sewage treatment capacity yields our baseline specification:

$$\log(y_{i,2008} - y_{i,2002}) = \beta_1 \mathrm{FI}_i + \beta_2 x_{i,2001} + \varepsilon_i. \qquad [3]$$

In this form, $y_{i,t}$ is the sewage treatment capacity for city i at year t. The difference $y_{i,2008} - y_{i,2002}$ is the growth in sewage treatment capacity over our sample period for city i.[8] We designate FI_i as city i's share of VAT revenue retained and use $x_{i,2001}$ to represent a vector of control variables for city i in the year 2001. We also designate ε_i as an unobservable error term. Parameter β_1 is expected to be positive under Hypothesis 1.

We use the difference between the years 2008 and 2002 as the entire period where sewage treatment data are available.[9] Over this period, total sewage treatment capacity increased more than 200%.

For this empirical context, we employ a cross-sectional specification involving the growth in sewage treatment capacity. We also considered using a panel dataset with city-level fixed effects and found this to be inappropriate for several reasons. First, investment in sewage treatment is lumpy. In some cities, constructing even one plant can double or triple a city's treatment capacity. Cities

8 We note that the dependent variable, change in sewage treatment capacity, is a stock variable, while the primary independent variable, a city's VAT share, is a flow variable. Conceptually, the city's VAT share should also affect a flow, which is the investment in sewage treatment during each year. Hence, we are answering the question of how fiscal incentives affect the aggregate set of investments in sewage treatment infrastructure.

9 Prior to 2002, China's Environmental Yearbooks were not published, and the sewage treatment capacity of its cities was not known.

could construct a plant by financing it, which would appear in the data as a burst of growth poorly tied to some change in fiscal sharing rate. Hence, measuring the change in facilities over a period of time is appropriate. In addition, for 60% of cities, their fiscal incentives are virtually constant. Using a panel dataset rather than a cross-section would eliminate the use of these cities.

We also considered using total sewage treatment capacity, $y_{i,2008}$, as the dependent variable. We rejected this specification, because sewage treatment facilities are long-lived; sewage plants may have been built for other reasons outside the years that our data cover. We have data that provide detailed information on a subset of sewage plants. Some of these plants were built before the 1994 fiscal reform; these could not be affected by VAT sharing rates. We do control for a city's initial level of sewage treatment capacity.

We considered employing growth variables rather than baseline levels $x_{i,2001}$ as controls. We rejected these specifications, because growth in variables such as GDP or population is surely interwoven with growth in sewage treatment capacity. As a result, cities that build more sewage treatment capacity should be rewarded with higher growth, leaving this specification unable to test the hypothesis in question.

We include in our control variables that are likely to influence the amount of sewage treatment capacity constructed, such as population, city wealth, and the amount of industrial output in a city. We control for the possibility that different fee levels influenced sewage plant construction by including per household consumption of water. The price of water includes a fee specifically designated for wastewater treatment; it is collected by government billing agencies and distributed to wastewater treatment plant operators.

4.3 Identification

The empirical specification from eq. [3] leaves our analysis open to the possibility that unobserved, city-level variation could affect both fiscal incentives and the construction of sewage treatment plants. Many unobservable differences between cities may be correlated with both fiscal share and infrastructure development. For example, a more competent city manager might be able to negotiate a higher fiscal share; this competence might also lead to the ability to construct more sewage treatment capacity. In this case, the ordinary least-squares (OLS) estimation of eq. [3] yields inconsistent results.

We employ an instrumental variable approach to limit the possible pathways of this endogeneity to those that are related to the assignment of fiscal incentives. Specifically, we use a city's 1995 VAT share as an instrument for its 2001 VAT share. A city's VAT share in 1995 is relevant, because provincial systems assigned in 1995 are strongly related to those in place in 2001. Provinces adopted a variety of systems, with some provinces designating a complete pass-through and others deciding to keep much of the revenues generated. While a city's share of VAT retained may have changed between 1995 and 2001, the data suggest that the systems of assigning incentives remained essentially constant (see Table 9).

The validity of our instrument relies on the history and political economy of China's system of prefecture-level fiscal incentives. As recounted in section 2.1.3, Bahl (1999) states that provinces did not give out fiscal incentives randomly, but instead had underlying motives. Some provinces stressed equalization (giving higher control of revenues to poorer cities), while others stressed the mobilization of economic development potential (giving higher control of revenues to richer cities).

As a robustness check, we empirically verify this account, with the specific goal of determining which methods of fiscal incentive assignment are likely to be related to the construction of infrastructure. We make sure to account for these methods in our instrumental variables regressions. We first examine whether the provinces that allowed complete pass-through of VAT revenues differed systematically from those that retained city revenues. We then empirically examine the assignment of fiscal incentives and assess whether these assignments are endogenous in some way to sewage treatment infrastructure.

5 Results and discussion

5.1 Baseline results

The instrumental variables regression results are presented in Tables 2 and 3. First-stage regression results of fiscal incentives in 2001 and fiscal incentives in 1995 are displayed in Table 2. The Cragg-Donald F-statistics for excluded instruments exceed 10 in our primary specifications. This strongly rejects the null hypothesis of weak instruments (Stock, Wright, and Yogo 2002). Results from our instrumental variables regressions of eq. [3] are presented in Table 3. Our preferred specification is presented in column 6. In this specification, we use the extended set of covariates as discussed in Section 4.2 and exclude province-level municipalities, which have different properties than other cities.

Table 2: First-stage IV regression results: dependent variable – VAT share in 1995.

	(1)	(2)	(3)	(4)	(5)	(6)
VAT share (1995)	0.449***	0.538***	0.537***	0.452***	0.539***	0.543***
	(0.118)	(0.113)	(0.119)	(0.118)	(0.113)	(0.119)
log(Population)	−0.069	−0.178***	−0.200**	−0.058	−0.167***	−0.162*
	(0.054)	(0.057)	(0.092)	(0.054)	(0.058)	(0.094)
log(GDP/Capita)	−0.069	−0.118	−0.158	−0.075	−0.123	−0.153
	(0.078)	(0.075)	(0.105)	(0.079)	(0.075)	(0.105)
log(Ind. Output)	0.074	0.167***	0.180***	0.082	0.178***	0.197***
	(0.053)	(0.055)	(0.058)	(0.054)	(0.055)	(0.059)
VAT revenues/GDP		−0.044***	−0.043***		−0.044***	−0.044***
		(0.011)	(0.011)		(0.011)	(0.011)
log(Capacity 2002)		−0.025	−0.023		−0.028	−0.029
		(0.020)	(0.021)		(0.020)	(0.021)
Water Consump./ Capita			0.470			0.413
			(0.616)			(0.619)
City Expend./GDP			−0.325			0.753
			(1.804)			(1.984)
log(City Expenses)			0.012			−0.010
			(0.085)			(0.087)
Constant	0.901	1.606***	1.828***	0.918	1.636***	1.859***
	(0.616)	(0.605)	(0.680)	(0.618)	(0.605)	(0.677)
R^2	0.16	0.28	0.29	0.17	0.30	0.30
N	106	106	105	103	103	102

Notes: Each independent variable is the level of that variable in 2001. Columns 1–3 include the full sample. Column 4–6 exclude DCMs. Robust standard errors, clustered by province, in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Our central estimate suggests that a 10% point increase in a city's share of VAT retained (e.g. from 0.6 to 0.7) resulted in an increase in sewage treatment capacity of 13.8% over the sample period. We tested for endogeneity using the Durban-Wu-Hausman test. Neither VAT sharing ratios in 1995 nor those in 2001 show endogeneity under this test. In our instrumental variables approach, we used a city's VAT share in 1995 as the instrument. We also tested VAT shares in 1996 and 1997 to confirm that our finding remains consistent.

In these baseline results, we control for factors that might influence both our instrument and the dependent variable. These include VAT dependence, which we find in Section 5.2 influenced the initial assignment of fiscal incentives. To control for the equalization motive of provinces, we include the initial level of sewage treatment capacity, a city's ability to spend as defined by total expenditures divided by GDP, and each city's absolute level of expenses. To address the possibility that sewage treatment fees are tied to both fiscal incentives and

Table 3: IV regression results: dependent variable – log growth of sewage treatment capacity 2002–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VAT share (2001)	1.732**	1.487**	1.372*	1.701**	1.476**	1.378*
	(0.856)	(0.705)	(0.750)	(0.826)	(0.686)	(0.723)
log(Population)	0.748***	0.838***	0.864**	0.700***	0.791***	0.804**
	(0.201)	(0.263)	(0.393)	(0.195)	(0.247)	(0.360)
log(GDP/Capita)	0.609***	0.686***	0.542	0.646***	0.716***	0.559*
	(0.227)	(0.232)	(0.345)	(0.213)	(0.216)	(0.327)
log(Ind. Output)	0.140	0.177	0.215	0.086	0.120	0.195
	(0.170)	(0.235)	(0.248)	(0.161)	(0.224)	(0.250)
VAT revenues/GDP		0.034	0.029		0.032	0.026
		(0.054)	(0.049)		(0.052)	(0.049)
log(Capacity 2002)		−0.131**	−0.171***		−0.120**	−0.158***
		(0.055)	(0.056)		(0.054)	(0.060)
Water Consump./ Capita			−0.583			−0.647
			(1.959)			(2.046)
City Expend./GDP			6.047			4.981
			(4.969)			(4.630)
log(City Expenses)			0.060			0.064
			(0.261)			(0.238)
Constant	3.832*	4.421**	5.454**	3.739**	4.263**	5.320**
	(1.970)	(2.197)	(2.651)	(1.857)	(2.058)	(2.562)
R^2	0.59	0.63	0.67	0.56	0.60	0.63
N	106	106	105	103	103	102

Notes: Independent variable in 2001 level. VAT share 2001 is instrumented by VAT share 1995. Columns 1–3 include the full sample. Columns 4–6 exclude DCMs. Robust standard errors, clustered by province, in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

sewage treatment capacity, we include each city's water consumption per capita.[10]

All control variables in Table 3 are the level of those variables in 2001. As expected, cities that were larger in population and richer also grew their sewage treatment capacity more. These cities may have higher needs for wastewater treatment and greater ability to build infrastructure. In addition, the initial level of sewage treatment capacity provided in 2002 appeared to be negatively related to growth over the period examined. As noted before, sewage treatment

10 Sewage treatment fees are collected as a portion of the water consumption fee. These fees fund the construction and operation of treatment plants. Sewage treatment fees are widely regarded as inadequate to pay for the operating costs of sewage treatment. They fall far short of paying for the construction of sewage treatment plants (Lee 2010).

Table 4: Ordinary least-squares regressions: dependent variable – log growth of sewage treatment capacity 2002–2008.

	(1)	(2)	(3)	(4)	(5)	(6)
VAT share (2001)	0.712**	0.667*	0.675	0.879**	0.837**	0.751*
	(0.339)	(0.390)	(0.407)	(0.345)	(0.397)	(0.439)
log(Population)	0.633***	0.666**	0.663*	0.601***	0.637**	0.717*
	(0.175)	(0.254)	(0.350)	(0.177)	(0.247)	(0.353)
log(GDP/Capita)	0.549***	0.603**	0.418	0.592***	0.643***	0.505
	(0.195)	(0.224)	(0.322)	(0.190)	(0.214)	(0.329)
log(Ind. Output)	0.216	0.286	0.319	0.146	0.211	0.304
	(0.155)	(0.222)	(0.247)	(0.153)	(0.219)	(0.258)
VAT revenues/GDP		0.007	0.003		0.008	0.001
		(0.050)	(0.042)		(0.050)	(0.044)
log(Capacity 2002)		−0.131**	−0.183***		−0.124**	−0.172***
		(0.054)	(0.054)		(0.053)	(0.058)
Water Consump./ Capita			−0.623			−0.745
			(2.157)			(2.218)
City Expend./GDP			5.608			7.277
			(4.367)			(5.566)
log(City Expenses)			0.100			0.018
			(0.250)			(0.254)
Constant	5.152***	5.882***	7.108***	4.863***	5.554***	6.623**
	(1.552)	(1.939)	(2.428)	(1.506)	(1.868)	(2.479)
R^2	0.62	0.63	0.68	0.57	0.59	0.63
N	109	109	108	105	105	104

Notes: Robust standard errors, clustered by province, in parentheses. Each independent variable is the level of that variable in 2001. Columns 1–3 include the full sample. Columns 3–6 exclude DCMs. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

investment is lumpy, with some cities constructing only one or two plants. Having high capacity at the beginning of the sample may indicate that a greater fraction of sewage is presently being treated, with relatively less need required in the future.

Ordinary least-squares regressions of the impact of fiscal incentives in 2001 on sewage treatment capacity are presented in Table 4. Relative to the instrumental variables results, the ordinary least-squares results have significantly smaller coefficients. We believe the most likely explanation is tied to the rationale behind provincial adjustment of city sharing rates. Some cities may have run fiscal surpluses, or smaller fiscal deficits, after the 1994 tax reform shuffled their revenues. These cities would have been more likely to construct sewage treatment facilities and may have had their tax sharing rates adjusted downward in years following the tax reform.

5.2 Robustness checks

This first robustness check is to test the methods by which provinces chose their method of assignment. Since the VAT share is driven strongly by province-level choices, do needier provinces keep higher shares of VAT revenues for themselves? These poorer and needier provinces would then be unable or unwilling to supply sewage treatment infrastructure. To address this concern, we looked closely at which provinces allowed their cities high levels of fiscal incentives and which provinces kept high shares for themselves.

Table 5: Key covariates of provinces that passed through VAT shares against provinces that retained shares.

Variables	Provinces with 100% VAT sharing	Provinces with < 100% VAT sharing	*P*-value of difference
Number of provinces	15	12	
Population (thousands)	45,629	39,882	0.696
GDP/Capita (RMB)	3,689	3,227	0.797
Total city income (10^6 RMB)	20,505	15,818	0.779
Total city expenditures (10^6 RMB)	19,658	15,214	0.785
Secondary share	42.8%	43.3%	0.444
Tertiary share	32.5%	31.8%	0.703
VAT dependence	4.84%	5.39%	0.176
Sewage treatment Cap. (tons/day)	759,006	640,065	0.648

Notes: Unweighted means are reported for each category. VAT dependence = VAT generated/GDP. Sewage treatment capacity is based on the 2001 data.

Our test results rejected the hypothesis that poorer provinces kept higher shares of VAT for themselves and did not fund sewage treatment infrastructure. Table 5 divides the provinces by whether they allowed a 100% pass-through of VAT revenues and illustrates their key characteristics.[11] Provinces that allowed high fiscal incentives are moderately more populous, richer, and have higher spending overall. However, these means mask the high level of variation within each category. Within each set of provinces, some provinces are relatively rich and populous, and others are poorer and smaller. Overall, the two groups cannot be distinguished with any significant level of statistical confidence, as reflected by the *p*-values in the last column. Regressions support these general findings, as shown in Table 6.

11 This table excludes direct-controlled municipalities.

Table 6: The determinants of province-level fiscal incentives.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log(Population)	0.064	0.010	0.028	0.040	0.185	0.044	−0.087
	(0.049)	(0.043)	(0.041)	(0.038)	(0.150)	(0.052)	(0.184)
GDP/Capita	0.307	0.099	0.171	0.193	0.660	0.172	−0.298
	(0.258)	(0.276)	(0.394)	(0.242)	(0.465)	(0.281)	(0.692)
Expenditures/GDP	1.249					1.192	3.156*
	(1.042)					(1.035)	(1.554)
City deficit/GDP		6.910				6.599	−1.669
		(5.701)				(5.666)	(6.622)
Is coastal			0.026				0.020
			(0.116)				(0.110)
VAT revenues/GDP				−4.320*			−7.591**
				(2.273)			(3.351)
log(Ind. Output)					−0.092		0.134
					(0.085)		(0.125)
Constant	−0.496	0.659	0.329	0.336	−1.050	−0.113	0.263
	(0.947)	(0.740)	(0.714)	(0.648)	(1.419)	(0.995)	(1.525)
R^2	0.12	0.13	0.07	0.20	0.11	0.18	0.36
F	1.04	1.05	0.54	1.82	0.94	1.13	1.46
N	26	26	26	26	26	26	26

Notes: All regressions are OLS. Standard errors in parentheses. All variables are aggregated to the province level. The regression excludes DCMs. The dependent variable is our measure of fiscal incentives from eq. [1]. Provincial level VAT shares are calculated using all VAT revenues retained by cities in a province, and all revenues retained by that province. All variables are measured in the year 1995. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

The second robustness check is to investigate the methods by which each province assigns fiscal incentives to its cities. We studied within-province variation in the assignment of VAT shares to cities by using a city-level regression that includes province-level fixed effects. These regressions are presented in Table 7. These regressions support the hypothesis that "equalization" rather than "economic mobilization" (Bahl 1999) seemed to play a role in within-province assignment of VAT shares; poorer cities receive higher shares of VAT. Empirically, provinces appear to allow less-developed cities with greater shares of VAT revenue, potentially to facilitate their development.

This robustness check rejects the notion that factors such as favoritism and negotiation are associated with the provincial assignment of fiscal incentives in 1994. For the large number of cities located in provinces that assigned constant fiscal incentives to all cities in their domain, negotiation and favoritism cannot possibly have played a role. For the cities that offered heterogeneous fiscal

Table 7: The determinants of city-level fiscal incentives.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log(Population)	0.006	0.008	0.007	0.008	0.003	0.008	−0.024
	(0.012)	(0.012)	(0.012)	(0.012)	(0.018)	(0.012)	(0.018)
GDP/capita	−0.030	−0.031*	−0.032*	−0.039**	−0.038	−0.031	−0.044*
	(0.019)	(0.018)	(0.019)	(0.019)	(0.024)	(0.019)	(0.024)
Expenditures/GDP	0.027					0.005	0.451***
	(0.045)					(0.048)	(0.122)
City deficit/GDP		−0.335				−0.325	0.477
		(0.237)				(0.254)	(0.327)
Is coastal			−0.008				−0.022
			(0.025)				(0.024)
VAT revenues/GDP				−0.200			−1.473***
				(0.149)			(0.374)
log(Ind. Output)					0.004		0.025*
					(0.013)		(0.013)
Constant	0.379*	0.358*	0.372*	0.385*	0.378*	0.360*	0.598***
	(0.207)	(0.207)	(0.207)	(0.207)	(0.208)	(0.207)	(0.210)
R^2	0.63	0.64	0.63	0.64	0.63	0.64	0.65
F	13.70	13.86	13.67	13.84	13.67	13.32	13.30
N	251	251	251	251	251	251	251

Notes: All regressions are OLS. Standard errors in parentheses. The dependent variable is our measure of fiscal incentives from eq. [1]. All variables are measured in the year 1995. Regressions include province-level fixed effects. There are more cities in this regression than in prior regressions, because the sample includes all cities for which we have public finance statistics, not just those for which we have sewage treatment data. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

incentives, cities that were poorer tended to receive higher fiscal incentives, rather than cities that were richer. This finding suggests that VAT shares were assigned as part of a provincial plan to provide more financial resources to less-well-off cities and not given as a result of well-off cities being able to negotiate good deals for themselves.

Our third robustness check is to re-run the regressions by sample groups. The ideal natural experiment would be to have two identical bins of cities separated only by their exogenously imparted fiscal incentives. By placing cities within subgroups and then controlling for important differentiating factors like population and wealth, we attempt to econometrically construct these bins. Cities within the same bin are likely to experience similar degrees of favoritism, isolating the impact of fiscal incentives. To create these groups, we utilized China's unique pattern of development, which emphasized the development of some areas, such as coastal cities, over inland cities. These types of cities, which are more similar, are likely being benefited or harmed in the same way by equalization or mobilization. We examine whether the impacts of fiscal incentives can be seen within these subgroups of cities.

We tested eq. [3] on three subgroups of cities: provincial capitals (25 cities), coastal cities (17 cities), and sub-provincial cities (15 cities). While these samples are too small to obtain reliable estimates, we found that a positive and quantitatively significant relationship exists for each of these smaller groupings. The magnitude of the coefficient is actually bigger for each of these subgroups than for our main result reported in Table 3, suggesting that, as the group of cities being compared becomes more similar, the impact of fiscal incentives is more important.

5.3 Additional results

Our empirical model from Section 4.1 finds an ambiguous relationship between fiscal incentives and other forms of spending which do not directly promote the tax base. Since spending on transfers does not build the tax base, we expected a null result. Transfer payments can also be used as a form of placebo test, ensuring that our methods do not produce a positive result when tested against forms of spending that should be unrelated to fiscal incentives.

Our testing, displayed in Table 8, shows a moderately positive but smaller relationship between fiscal incentives and spending on education. Since spending on education has positive returns, this finding is consistent with our model. Also consistent with our model, there are statistically insignificant relationships for spending on pensions and social security. Most functional forms actually have a moderately negative result for these forms of spending.

These results suggest that the relationships between spending and fiscal incentives that we have found are not purely income effects driven by increased levels of spending. Cities appear to substitute among different types of spending as their incentives go up. They increase types of spending that may be attractive to expanding their tax base, like infrastructure and education, and decrease types of spending that have no impact on tax base, like transfers.

6 Conclusions

Fiscal decentralization is an important topic and has played an important role in the development work of the World Bank. This article has provided evidence that fiscal decentralization has boosted the development of infrastructure in China. Under China's tax reform of 1994, cities were assigned shares of VAT.

Table 8: The relationship between fiscal incentives and other forms of public spending.

	(1)	(2)	(3)	(4)
	Education	**Science**	**Pension**	**Soc. Sec.**
VAT share (2001)	0.644*	0.784	−0.348	−2.274**
	(0.386)	(0.534)	(0.360)	(0.906)
log(Population)	0.814***	0.328	0.495	−0.103
	(0.260)	(0.285)	(0.324)	(0.334)
log(GDP/Capita)	0.478*	0.256	−0.243	−0.947**
	(0.261)	(0.256)	(0.341)	(0.436)
log(Ind. Output)	0.019	0.386*	0.162	0.351
	(0.134)	(0.200)	(0.104)	(0.252)
VAT revenues/GDP	0.050*	0.053	−0.003	−0.050
	(0.027)	(0.046)	(0.033)	(0.075)
log(Capacity 2002)	0.071**	0.042	0.071**	0.032
	(0.034)	(0.041)	(0.032)	(0.101)
Water Consump./Capita	0.559	1.401	0.808	−0.262
	(1.041)	(0.879)	(0.964)	(2.916)
City expend./GDP	2.688	0.291	1.274	−3.192
	(3.714)	(4.237)	(5.222)	(6.389)
log(City Expenses)	−0.035	0.375**	0.301	0.920***
	(0.168)	(0.182)	(0.225)	(0.238)
Constant	6.455***	2.105	9.457***	14.470***
	(1.861)	(2.084)	(1.890)	(4.078)
R^2	0.86	0.87	0.81	0.33
F	52.39	119.30	110.20	20.01
N	103	103	103	103

Notes: These regressions are all instrumental variables regressions using the same method as column 6 of Table 3. The dependent variable is the sum of expenditures, between the years 2002 and 2008, on that type of expense. Robust standard errors, clustered by province, are in parentheses. Regressions exclude DCMs. Each independent variable is the level of that variable in 2001. $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Cities in China responded to higher VAT shares by increasing the growth of sewage treatment capacity.

This finding also has important environmental policy implications: it suggests that financial incentives might be part of the solution to pressing water pollution issues. While city-level fiscal incentives are too broad a weapon to level at these problems, targeted financial incentives might be provided to cities in key geographic areas, such as those upstream from large populations, or to cities sharing a common-pool water resource.

More broadly, China has seen an increasing devolution of expenditures to local authorities, coupled with an increasing centralization of revenues to the central government. If fiscal incentives are an important driver of local government behavior, decreasing the local share of revenues may have significant unintended consequences. Since, on the margin, local governments will participate less in the gains of their investments, they may choose to invest less of their scarce resources in important infrastructure projects.

Appendix

Table 9: Patterns of fiscal incentives by province.

Province	Number of cities	VAT share retained by city	
		In 1995	In 2001
Beijing	1	Not reported	61%
Tianjin	1	100%	100%
Hebei	11	61–94%	53–93%
Shanxi	11	All 100%	All 100%
Neimenggu	8	100% (Huhehaote: 80%)	100% (Huhehaote: 79%)
Liaoning	14	23–100%	17–100%
Jilin	8	All 40%	41–100%
Heilongjiang	12	82–100%	83–100%
Shanghai	1	87%	75%
Jiangsu	13	All 100%	All 100%
Zhejiang	11	All 100%	All 100%
Anhui	17	All 100%	All 100%
Fujian	9	All 100%	All 100%
Jiangxi	11	73–100%	42–100%
Shandong	17	12–100%	14–100%
Henan	17	All 100%	All 100%
Hubei	12	All 100%	All 100%
Hunan	13	54–91	44–100%
Guangdong	21	90–100%	95–100%
Guangxi	14	All 100%	All 100%
Hainan	2	Both 100%	One 24%, one 70%
Chongqing	1	100%	62%
Sichuan	18	All 100%	All 65%
Guizhou	4	All 60%	All 60%
Yunnan	8	All 100%	All 100%
Tibet	1	100%	100%
Shanxi	10	46–100%	36–100%
Gansu	12	37–100%	42–100%
Qinghai	1	45%	93%
Ningxia	5	Not reported	78–100%
Xinjiang	2	Both 100%	Both 100%

Solution of model (2) in Section 4.1

Here, we replicate model (2) in Section 4.1. A city manager's problem is to maximize the welfare of the city subject to the budget constraint:

$$\max_{S} \quad \alpha S + E$$
$$\text{subject to} : I(S) + E \le \beta g(S).$$

The first-order condition of the above model with respect to S yields:

$$a + \beta g'(S) = I'(S).$$

Differentiating this equation with respect to β, we find:

$$g'(S) + \beta g''(S)\frac{dS}{d\beta} = I''(S)\frac{dS}{d\beta}.$$

Solving for $dS/d\beta$:

$$\frac{dS}{d\beta} = \frac{g'(S)}{-\beta g''(S) + I''(S)}.$$

We have assumed that the tax revenue function $g(S)$ is strictly increasing and concave, which implies that $g'(S) > 0$ and $g''(S) < 0$. The cost function $I(S)$ is assumed to be strictly increasing and convex, which implies that $I(S) > 0$, $I'(S) > 0$, and $I''(S) > 0$. Under these assumptions, $dS/d\beta > 0$. That is, a greater revenue share incentivizes infrastructure expansion. □

Sewage treatment data

We have corrected some errors in the data. The sewage treatment capacity in Shanghai reported in CEY 2008 is 539,100 tons/day, an inexplicable drop from CEY 2007's figure of 4,704,105. In CEY 2009, Shanghai reports 6,488,400. The most reasonable explanation is that a "'0" has been omitted from the 2008 figure. The empirical results are largely robust to either a correction of the CEY 2008 figure to "5,391,000" or dropping the observation altogether. Some cities shrank sewage treatment capacity or did not change over the 2002–2008 sample time frames. To incorporate these cities into our analysis, we took the biggest drop in sewage treatment capacity within a city and added this figure to the sewage capacity increase in each city. With this correction, all cities receive positive sewage treatment investment, except the city with the largest drop in sewage treatment capacity, which is excluded from the results presented. Our results are robust to this correction or to simply dropping cities that did not increase sewage treatment capacity.

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