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RESEARCH ARTICLE

Fiscal decentralization and energy intensity: evidence from a quasi-natural experiment of VAT revenue-sharing reform in China

Yumeng Pang[1] and Mengmeng Wang[2]

[1]School of Public Finance and Taxation, Nanjing University of Finance and Economics, Nanjing, China and [2]International Education College, Hebei Finance University, Baoding, China
Corresponding author: Mengmeng Wang; Email: lcwithmm@163.com

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Abstract
The impact of fiscal decentralization on energy intensity has been a long-standing subject of interest and debate. However, to date, there has been a notable absence of studies delving into the effects of fiscal decentralization on energy intensity from the vantage point of tax sharing. This investigation explores the effects of China's value-added tax (VAT) revenue-sharing reform on energy intensity using prefecture-level city data from 2006 to 2020. Results show a correlation between an increased proportion of VAT revenue sharing and higher regional energy intensity. Heightened competition among local governments amplifies this impact, while environmental regulations and technological innovation mitigate it. Our findings contribute to a more scientifically grounded formulation of the revenue-sharing ratio between central and local governments, aiming to reduce local energy intensity.

Keywords: energy intensity; fiscal decentralization; tax revenue sharing; VAT

Introduction
China's economy has experienced rapid development since the initiation of reforms and opening up in 1978. However, this growth has been heavily reliant on industry, which is oriented toward gross domestic product (GDP) and characterized by high energy consumption. China presently stands as the world's foremost energy consumer. As per data from the "Statistical Yearbook of World Energy," in 2022, China's aggregate primary energy consumption reached 159.39 EJ, comprising a substantial 26.4% of the global total. Regrettably, renewable energy sources only contributed a mere 8.3% of this colossal figure. This excessive energy consumption

paradigm is intrinsically unsustainable, thereby precipitating grave ecological and environmental predicaments within the nation (Song et al. 2020).

In recent years, China has embarked upon an array of policies aimed at elevating energy efficiency. Notably, the year 2006 marked the Chinese central government's inauguration of an imperative objective to curtail energy intensity by 20% as delineated in the Eleventh Five-Year Plan for National Economic and Social Development. Further fortifying this commitment, in 2015, the Chinese government formally pledged to attain the zenith of carbon emissions by 2030 within the context of the "U.S.-China Joint Statement on Climate Change." Subsequently, within the 14th Five-Year Plan and the 2035 Long-Term Goals Outline unveiled in 2021, a supplementary reduction of 13.5% in energy intensity was enshrined as an overarching goal encompassing medium and long-term economic and social development. To concretize these policy imperatives, the Chinese government has instigated a spectrum of measures, including the promotion of renewable energy and the bolstering of regulations governing carbon emissions (Lv et al. 2022). Regrettably, the actual impact of these energy policies has yet to manifest with significant prominence (Lin and Zhou 2021). Despite the ongoing trend of diminishing unit GDP energy consumption (viz., energy intensity) within China, this metric continues to tower significantly above the global mean (Bi et al. 2022). Presently, the reduction of energy intensity perseveres as a formidable challenge underpinning China's pursuits of sustainable economic development.

Fiscal decentralization has emerged as a pivotal factor influencing energy intensity and environmental concerns, as underscored by a multitude of scholars (Hao et al. 2020; Khan et al. 2021; Lin and Zhou 2021; Meng et al. 2022). Since the initiation of the tax-sharing reform in 1994, the revenue-sharing system has evolved into a fundamental component of China's fiscal management framework. This system operates as a mechanism for the collaborative allocation of tax revenue between the central government and local governments. It involves the allocation of a portion to the central government and the remainder to local governments. Notably, this framework has, to a certain extent, incentivized local governments to cultivate energy-intensive and highly polluting industries to generate tax revenue, thereby propelling rapid economic growth. This phenomenon substantiates the assertions in the extant literature, suggesting that fiscal decentralization may contribute to environmental degradation (Xu et al. 2023). Consequently, the division of tax revenue sharing between these governmental entities serves as a reflection of the degree of fiscal decentralization in China (Mao et al. 2018). Regrettably, existing scholarly works predominantly employ metrics based on the ratio of local government expenditures or revenues concerning the total central government expenditures or revenues to gauge China's fiscal decentralization (He 2015; Yang et al. 2020; Du and Sun 2021; Lv et al. 2022). There remains an unexplored research gap regarding the examination of fiscal decentralization's impact on China's energy intensity through the lens of tax revenue sharing, which constitutes the central focus of our investigation.

Notably, value-added tax (VAT) stands as the most substantial tax category in China, bearing considerable fiscal implications for local governments. In 2016, China executed a substantial revision to the VAT revenue-sharing ratio between the central and local governments. This revision transitioned the ratio from its previous division of 75:25 to a balanced 50:50 distribution, effectively augmenting the proportion of VAT revenue allocated to local governments. Since the share of VAT revenue concerning fiscal revenue varies among China's diverse regions, the implications of this reform also exhibit regional variations. This unique policy transition provides an opportune window for our examination of the influence of fiscal decentralization on regional energy intensity.

Utilizing data sourced from Chinese prefecture-level cities spanning the period 2006–2020, this study explores the ramifications of VAT revenue-sharing reform on energy intensity. The findings uncover a significant rise in regional energy intensity following the implementation of VAT revenue-sharing reform, particularly pronounced in the eastern and central regions. This suggests that the fiscal incentives arising from the decentralization of fiscal revenue authority do not foster an amelioration of local energy intensity. Furthermore, the results of interaction effects divulge that heightened competition among local governments exacerbates the impact of VAT revenue sharing on energy intensity. Conversely, environmental regulations and technological innovation act as mitigating factors, tempering the influence of VAT on energy intensity.

The contributions of this paper are primarily delineated across several dimensions. First, it delves into the impact of fiscal decentralization on energy intensity in China by focusing on the paradigm of tax revenue sharing. This research bears substantial significance as prior inquiries have predominantly fixated on fiscal decentralization at the provincial level, potentially entailing endogeneity issues with the selected fiscal decentralization indicators (Xu et al. 2023). Capitalizing on the quasi-natural experiment of the VAT revenue-sharing reform, this study investigates the ramifications of fiscal decentralization on energy intensity at the prefectural level. This endeavor contributes to a more scientifically grounded evaluation of the repercussions of fiscal decentralization reform on energy-related aspects, and it offers empirical evidence to inform pertinent policy-making decisions. Secondly, we explored the heterogeneity in the effects of the VAT sharing reform on energy intensity. Our findings reveal that the influence of tax revenue sharing on energy intensity exhibits regional variations. This observation underscores the impracticality of adopting a uniform "one-size-fits-all" policy, particularly within the dynamic context of China's fiscal system reform. Finally, we examined the moderating effects of government competition, environmental regulations, and technology innovation. The findings demonstrated that higher levels of government competition enhance the influence of VAT tax sharing on energy intensity, while environmental regulations and technology innovation alleviate this impact. This perspective offers novel insights into energy-efficient improvement strategies.

The subsequent sections of this paper are organized as outlined below. *Literature review and theoretical background* section offers a review of pertinent literature and the theoretical background. *Empirical model and data* section outlines the methodology and data employed. *Empirical results* section delves into the empirical findings. Final section provides the paper's conclusion.

Literature review and theoretical background

Literature review

Global climate change stands as one of the foremost challenges confronting the contemporary world. The extensive utilization of petroleum and fossil fuels has significantly aggravated the predicaments associated with global warming and environmental deterioration. In recent times, scholars have undertaken investigations into the multifaceted determinants of energy efficiency, with fiscal decentralization emerging as a pivotal factor with discernible implications for matters pertaining to energy and the environment.

Currently, two primary perspectives regarding the influence of fiscal decentralization on energy and environmental matters exist. One perspective posits that fiscal decentralization positively impacts energy and environmental concerns. Early theories on fiscal decentralization argued that, in the context of residents "voting with their feet," a decentralized governance system promotes the development of a "benevolent government." This encourages local governments to provide public goods (Tieout 1956), subsequently improving the ecological environment within their jurisdiction. Furthermore, compared to the central government, local governments inherently possess information advantages (Afonso et al. 2005), enabling them to gain a deeper understanding of local environmental and energy conditions and to implement targeted environmental management measures (Oates and Schwab 1988). Additionally, the "environmental federalism" perspective contends that decentralization fosters competition, motivating governments to invest in research and innovation, consequently enhancing regional energy and environmental performance (Hottenrott and Rexhauser 2015; Cheng et al. 2021).

Conversely, another perspective argues that fiscal decentralization can yield adverse effects on local energy and environmental conditions. Influenced by a "GDP worship" mentality, local governments may partake in a "race to the bottom" in their pursuit of economic growth. They do this by lowering environmental regulatory standards to attract energy-intensive and highly polluting enterprises (Oates and Schwab 1988; Cui and Liu 2010; Sjoberg and Xu 2018). Consequently, this leads to increased government rent-seeking behavior and a higher tolerance for corporate pollution (Fredriksson and Millimeter 2002; Lopezópez and Mitra 2000; Boskovic 2016). Consequently, this creates a "pollution paradise" that promotes economic prosperity at the expense of the environment, ultimately diminishing energy efficiency within their jurisdiction.

Numerous empirical studies have explored the effects of fiscal decentralization in China on energy and carbon emissions. However, these studies have yielded varying and at times contradictory conclusions. Some investigations propose that fiscal decentralization has the potential to significantly enhance regional energy efficiency and mitigate carbon emissions (Bi et al. 2022). Conversely, an alternative perspective posits that fiscal decentralization in China can undermine energy efficiency and hinder efforts to reduce carbon emissions and promote sustainable development (Yang et al. 2020; Lin and Zhou 2021). Additionally, a body of research has indicated that the relationship between fiscal decentralization and carbon emissions in China is nonlinear, influenced by the degree of fiscal decentralization (Hao et al. 2020; Lv et al. 2022). Consequently, the influence of fiscal decentralization on energy-related issues in China remains a subject of ongoing and active debate within the scholarly community.

As illustrated in Table 1, a substantial body of recent literature delves into the realm of fiscal decentralization and its interplay with energy-related concerns, rendering valuable insights for our research. It is crucial to acknowledge, however, that this existing corpus of research carries notable constraints. Primarily, many contemporary studies rely on conventional fiscal expenditure or revenue decentralization indicators, typically framed as the ratio of provincial revenues (or expenditure) to central revenues (or expenditure). Regrettably, these metrics primarily reflect the fiscal capacities of local governments, rather than offering a true reflection of the level of decentralization (Lv et al. 2021). Furthermore, the application of these traditional indicators to gauge fiscal decentralization falls short in addressing endogeneity concerns and is susceptible to estimation biases (Xu et al. 2023). Additionally, the predominant focus of existing literature on provincial-level governments has resulted in a relatively limited sample size, consequently introducing substantial estimation biases. Therefore, this study adopts a fresh approach, scrutinizing fiscal decentralization through the lens of tax sharing and treating the VAT revenue-sharing reform as a quasi-natural experiment. Our objective is to evaluate the impact of fiscal decentralization on the energy intensity of prefecture-level cities, thereby addressing certain limitations observed in prior research.

Theoretical background

The tax revenue-sharing system in China pertains to a fiscal framework wherein tax revenues are apportioned between the central government and local governments. Under this system, tax revenue is bifurcated, with one segment directed to the central government and the other portion designated for local governments. This mechanism serves the dual purpose of maintaining fiscal equilibrium between the central government and local governments while stimulating local authorities to actively engage in greater economic endeavors and tax revenue generation, thereby facilitating local economic growth. The specific proportions and regulations governing tax revenue sharing can exhibit variations based on the type of tax, geographical region, and the prevailing period, and these determinations rest with the central government. Consequently, in contrast to conventional metrics employed for gauging fiscal decentralization, the tax revenue-sharing indicator proves more adept at characterizing the fiscal distribution dynamics between government tiers (Mao et al. 2018; Zhou and Wu 2015). This system assumes a pivotal role in the realm of fiscal management in China and exerts a substantial influence on the fiscal strategies and conduct of local governments.

Within the purview of the tax revenue-sharing system, an array of tax categories is encompassed, with the most salient one being the VAT. VAT is the largest tax category in China. According to statistics, in 2021, China's domestic VAT revenue amounted to 63,519 billion yuan, representing a share of 36.8% of the total tax revenue. Since the inception of the tax revenue-sharing reform in 1994, the ratio governing the sharing of VAT revenue between the central government and local governments has consistently stood at 75:25 and has endured over an extended

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Table 1. Selection of indicators and key findings in previous literature

Authors	Sample/periods	Methods	Fiscal decentralization indicators	Environment indicators	Results
Zhang et al. (2017)	29 provinces of China; 1995–2012	GMM	Fiscal revenue decentralization (the ratio of provincial revenues to central revenues)	CO2	Chinese-style fiscal decentralization makes the environmental policy significantly promote carbon emissions
Hao et al. (2020)	29 provinces of China; 1995–2015	Two equations; GMM	Fiscal expenditure decentralization (the ratio of per capita provincial fiscal expenditure to per capita national fiscal expenditure)	Per capita CO2 emissions	The total effects of fiscal decentralization on both carbon and sulfur dioxide emissions are found to be dependent on the levels of fiscal decentralization and GDP
Yang et al. (2020)	30 provinces of China; 2005–2016	Spatial Durbin model	Fiscal expenditure decentralization (the ratio of per capita provincial fiscal expenditure to per capita national fiscal expenditure)	Total CO2 emissions	The increasing fiscal decentralization in the region will increase carbon emissions in surrounding areas and on the whole
Lin and Zhou (2021)	30 provinces of China; 2000–2017	Two-way fixed effects model	Vertical fiscal imbalance (calculated by fiscal revenue decentralization and fiscal expenditure decentralization)	Energy and environmental performance	The divergence between revenue decentralization and expenditure decentralization leads to vertical fiscal imbalance, which significantly reduces energy and environmental performance

(*Continued*)

Table 1. (*Continued*)

Authors	Sample/periods	Methods	Fiscal decentralization indicators	Environment indicators	Results
Bi et al. (2022)	30 provinces of China; 1995–2015	Spatial econometric model; panel threshold model	Fiscal Decentralization Index (calculated by fiscal revenue decentralization and fiscal expenditure decentralization)	Energy intensity	Chinese fiscal decentralization can significantly improve the regional energy intensity, and the fiscal decentralization of a region can significantly reduce the energy intensity in nearby regions
Lv et al. (2022)	30 provinces of China; 1997–2017	Spatial Durbin model	Fiscal expenditure decentralization (the ratio of per capita provincial fiscal expenditure to per capita national fiscal expenditure)	Per capita CO2 emissions and CO2 intensity	Fiscal decentralization has an inverted N-shaped relationship with carbon emissions and carbon intensity, and the impacts are mainly revealed through direct effects

timeframe. In 2016, China effectively transitioned from business tax to VAT, concomitantly revising the distribution ratio for VAT revenue between the central government and local governments to an equitable 50:50 apportionment. This reform instigated heightened financial incentives for local governments, thereby enhancing their impetus to bolster tax collection efforts and propel economic development. However, it may also be concomitant with an escalation in regional energy intensity.

The impact of VAT revenue-sharing reform on energy intensity manifests through two primary avenues. First, the elevation of revenue-sharing ratios serves to augment financial incentives for local governments, catalyzing their active promotion of business development to bolster tax revenues. Local governments often extend financial subsidies, tax incentives, and increased credit access to bolster business growth (Xu et al. 2023). In response to these incentives, businesses invest in expansion, leading to a corresponding uptick in energy consumption. The acquisition of new production equipment, facility expansions, and daily production operations necessitates a greater energy input, thereby amplifying energy intensity. Second, the escalation of revenue-sharing ratios can compel local governments to relax environmental regulatory standards as a means to attract investments from high-energy-consuming enterprises in their pursuit of tax revenue (Lin and Zhou 2021). China's decentralized environmental management system grants local governments' decision-making and enforcement authority over local environmental matters. Consequently, they possess the autonomy to adjust environmental control measures for businesses independently (Ran et al. 2020). The relaxation of environmental regulations often results in the proliferation of high-energy-consuming enterprises, thereby elevating regional energy intensity.

Furthermore, the impact of VAT revenue-sharing reform exhibits variation among different prefecture-level cities due to disparities in the proportion of VAT revenue in their government income. Regions with a higher share of VAT revenue experience more pronounced effects, while those with a lower share encounter comparatively modest repercussions. This divergence presents an opportune avenue for discerning the influence of VAT revenue sharing on energy intensity.

Empirical model and data

Model specification

This article employs a standard double difference model to analyze how fiscal decentralization incentives, marked by the VAT revenue-sharing reform, affect urban energy intensity. The model is constructed as follows:

$$EI_{i,t} = \theta_{\mathrm{i}} + \eta_t + \lambda \times \mathrm{Treated}_i \times post_t + \rho \times Control_{i,t} + \varepsilon_{\mathrm{i},t} \tag{1}$$

In this context, $EI_{i,t}$ represents the energy intensity of city i in year t. $Treated_i$ is a binary variable used to categorize cities into treatment and control groups, with 0 for the control group and 1 for the treatment group. $Post_t$ represents dummy variables for the pre and post-reform years, taking the value of 1 in and after 2016, and 0 otherwise. The interaction term, $Treated_i \times Post_t$, is the policy treatment effect variable, capturing the impact of the VAT revenue-sharing reform on urban energy intensity. The parameter, λ, is the estimated policy effect parameter of interest in this study. $Control_{i,t}$ serves as control variables, θ_i represents city-specific fixed effects, and η_i represents time-specific fixed effects.

An essential prerequisite for the effectiveness of the difference-in-differences (DID) model is the requirement of parallel trends. In the context of this article, this implies that before the VAT revenue-sharing reform, the treatment group and the control group should exhibit similar time trends in energy intensity. We construct the following model to examine this:

$$\mathrm{EI}_{i,t} = \theta_i + \eta_t + \sum_{t=2007}^{2020} \alpha_t \times Treated_i \times D_t + \rho \times Control_{i,t} + \varepsilon_{i,t} \tag{2}$$

We use the first year of the sample period (i.e., 2006) as the base year, D_t represents time-point dummy variables (with a value of 1 for the respective year and 0 otherwise). $Treated_i \times D_t$ represents the interaction term between the policy variable and the time-point dummy variable. α_t denotes the estimated coefficients for the years 2007–2020, while other variables follow Equation (1). The parameter of primary interest in this section is α_t, which signifies whether there is a significant difference in energy intensity between the treatment and control groups in year t. If α_t is not significant before the policy implementation but becomes significant after the policy, it suggests that the difference in energy intensity between the treatment and control groups is primarily due to the reform.

Data source

This paper selects data from 282 Chinese cities for the years 2006–2020. The data primarily come from various editions of the "China City Statistical Yearbook," "China Energy Statistical Yearbook," and "China Taxation Yearbook," as well as individual city statistical yearbooks and city development statistical bulletins.

The indicators used from the "China City Statistical Yearbook (2007–2021)" include (1) regional GDP, (2) total regional population, (3) total import and export trade volume, (4) the number of regular undergraduate and postgraduate students, (5) the number of nonagricultural population, (6) the value added in the secondary sector, (7) year-end financial institution deposit balance and year-end financial institution loan balance, (8) fiscal scientific expenditure, and (9) annual electricity consumption. From the "China Energy Statistical Yearbook (2007–2021)," the following indicators are used: (1) total natural gas supply and (2) total supply of liquefied petroleum gas. Indicators from the "China Taxation Yearbook (2007–2021)" include (1) government tax revenue and (2) government VAT revenue. The city statistical yearbooks and city development statistical bulletins are primarily utilized to gather information on road mileage between various cities.

Variable description

Independent variables

In a double difference model, it is necessary to divide the sample into treatment and control groups based on whether they are affected by the policy shock. However, in the VAT sharing reform, all cities were affected by the policy, making it impossible to establish distinct treatment and control groups. In reference to Chen (2017), this paper categorizes the treatment and control groups based on the intensity of reform impact in the regions. We utilize the proportion of VAT revenue to the total regional tax revenue for each city in the fiscal year prior to policy enactment (i.e., 2015) as an empirical proxy indicating the local government's level of dependency on VAT. The extent to which local tax revenues depend on the VAT is directly proportional to the impact experienced from the VAT sharing reform. Hence, this paper employs the median value of this indicator as a critical threshold for categorizing cities into two distinct groups: those significantly impacted by the reform are designated as the "treatment group," while those less affected by the reform constitute the "control group."

Dependent variable

The dependent variable in this study is energy intensity, defined as the ratio of energy consumption to GDP. In consideration of data availability, we opted to analyze three primary energy sources: natural gas, liquefied petroleum gas (LPG), and electricity. Data on the consumption of these energy sources were extracted from the China City Statistical Yearbook. Subsequently, we calculated the energy consumption in terms of standard coal using the IPCC 2006 conversion factors. The conversion factor for natural gas was determined to be 1.33 kilograms per cubic meter, while LPG exhibited a conversion factor of 1.7143 kilograms per kilogram, and electricity was standardized at 0.1229 kilograms per 10,000 kilowatt-hours. Finally, we computed the total energy consumption for each city by summing the standardized energy consumption values for natural gas, LPG, and electricity.

Figure 1 presents the average energy intensity across different Chinese cities spanning the period from 2006 to 2020. The graphical representation highlights notable disparities in energy intensity observed among these cities. Regions characterized by higher energy intensity levels include the northern cities, where heavy industry is prevalent, certain cities within the coal and mineral-rich central region, and urban centers within the densely populated and highly urbanized Yangtze River Delta and Pearl River Delta areas. In summary, a substantial degree of variation in energy intensity is evident across cities throughout China.

Control variables

Referring to Chen et al. (2019), Guang et al. (2019), and Ma et al. (2022), the following variables are chosen to act as the control variables:

(1) Per capita GDP (PGDP): Per capita GDP refers to the logarithmic representation of the percentage of GDP to the total population of residents.
(2) Technology expenditure (TECH): Technology expenditure is measured by the proportion of technology spending to the regional GDP.
(3) Urbanization (URBAN): The level of urbanization is evaluated by the proportion of urban residents to the country's overall population.

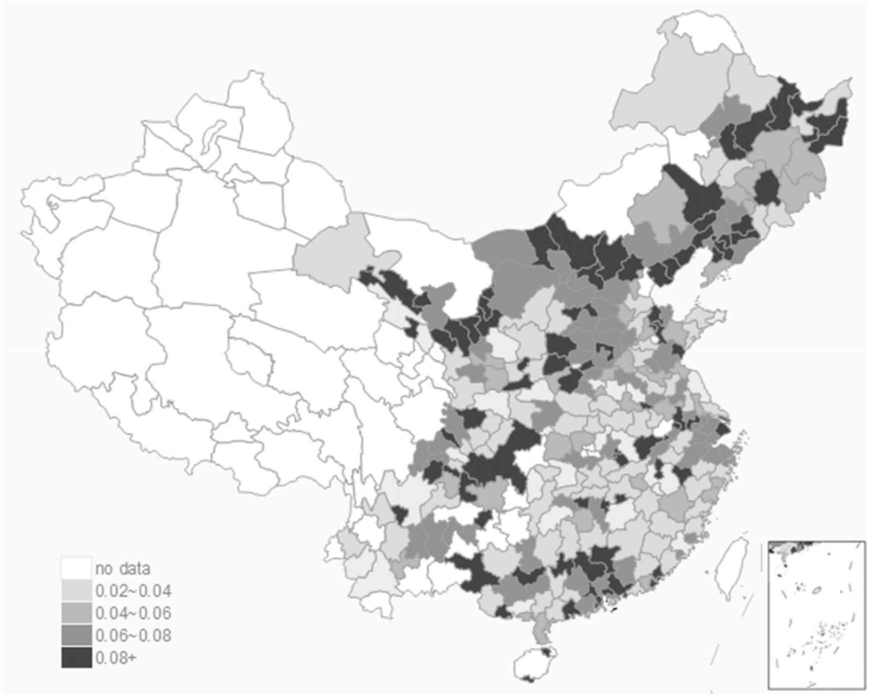

Figure 1. Average energy intensity by cities (2006–2020).

(4) Human capital (HC): HC is represented in this article by the ratio of the total number of regular undergraduate and graduate students to the total population at the end of the year.
(5) Openness (OPEN): Openness is measured by the ratio of the sum of imports and exports to total GDP, the amount of imports and exports multiplied by the RMB/US dollar exchange rate for that year.
(6) Transport infrastructure (TRANS): Measured by the logarithm of the road mileage.
(7) Financial development (FINANCE): Financial development is measured by the proportion of the year-end balance of financial institutions' loans and deposits to the regional GDP.
(8) Industrial structure (INDUS): We measure the industrial structure of a region with the value-added of secondary industry to GDP.

Table 2 provides a comprehensive overview of the summary statistics for the pivotal variables employed in the regression analysis, encompassing the mean values and disparities within the "treatment group" and "control group" subsamples. Additionally, we assess the legitimacy of the incorporated control variables. Significantly divergent results emerge from mean difference tests conducted on an array of indicators between the treatment and control groups, thus substantiating the rationale for incorporating these variables into the econometric model.

Table 2. Descriptive analysis

	Whole sample					Subsample "treatment" or "control"				
VarName	Obs	Mean	SD	Min	Max	Obs[c]	Mean[c]	Obs[T]	Mean[T]	Difference
EI	4230	0.101	0.137	0.006	4.176	–	–	–	–	–
PGDP	4230	10.452	0.723	4.595	13.056	2085	10.30	2145	10.60	−0.299***
OPEN	4230	0.301	0.730	0.000	24.877	2085	0.204	2145	0.396	−0.191***
HC	4230	1.973	2.493	0.013	13.394	2085	1.668	2145	2.270	−0.601***
TRANS	4230	9.226	0.698	6.291	12.105	2085	9.300	2145	9.154	0.146***
URBAN	4230	0.393	0.233	0.075	1.926	2085	0.349	2145	0.435	−0.086***
INDUS	4230	47.222	11.092	11.700	90.970	2085	44.41	2145	49.95	−5.539***
FINANCE	4230	2.285	1.161	0.560	21.301	2085	2.092	2145	2.473	−0.382***
TECH	4230	0.015	0.015	0.000	0.207	2085	0.0110	2145	0.0180	−0.007***

Note: ***, **, and *indicate significance at the 1%, 5%, and 10% levels, respectively. The entire sample includes the total sample size, average values, standard deviations, maximum values, and minimum values for each variable. Subsamples present sample sizes, mean values, and mean differences for the treatment group and the control group, respectively.

Table 3. Baseline results

Variables	(1)	(2)
Treated×Post	0.028***	0.019***
	(0.007)	(0.007)
PGDP		−0.003
		(0.007)
OPEN		−0.008***
		(0.003)
HC		0.001
		(0.001)
TRANS		−0.046***
		(0.004)
URBAN		0.085***
		(0.013)
INDUS		0.002***
		(0.000)
FINANCE		0.014***
		(0.003)
TECH		−1.077***
		(0.169)
Constant	0.096***	0.427***
	(0.002)	(0.074)
Observations	4,230	4,230
R-squared	0.196	0.298
Year FE	YES	YES
City FE	YES	YES

Note: ***, **, and *indicate significance at the 1%, 5%, and 10% levels, respectively.

Empirical results

Baseline results

The outcomes of the baseline regression analysis are presented in Table 3. In the initial column (1), the coefficient associated with the interaction term (Treated×Post) is 0.028, demonstrating statistical significance at the 1% level. In the subsequent column (2), accounting for additional variables, the coefficient

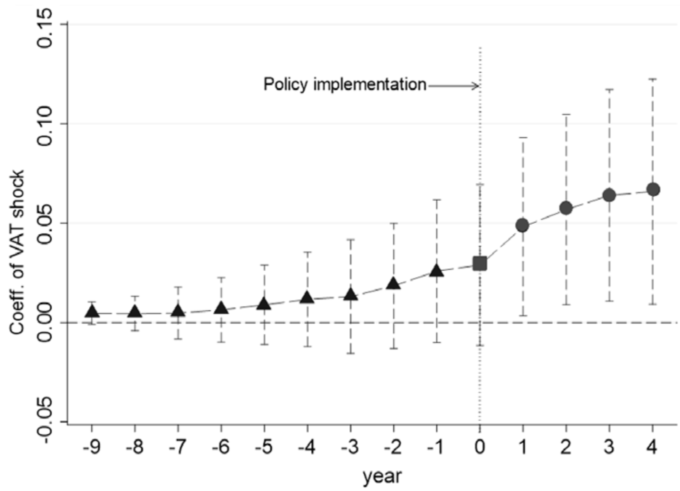

Figure 2. Parallel trends test.

pertaining to the interaction term registers at 0.019, retaining statistical significance at the 1% level. This observation suggests a favorable influence on urban energy intensity resulting from the fiscal decentralization incentive introduced by the VAT sharing reform.

Parallel trends test

The investigation entails estimating coefficients and 95% confidence intervals for the interaction term, as per Formula (2), and presenting them graphically (refer to Figure 2). The outcomes reveal an absence of a substantial disparity in energy intensity changes between the treatment and control groups preceding the initiation of the VAT sharing reform. This observation implies the absence of a noteworthy pre-existing trend divergence in energy intensity between the treatment and control group cities prior to the reform, thereby supporting the validity of the parallel trends test. Furthermore, the interaction term coefficient lacks significance in the year of reform implementation but attains significance in the subsequent year. This suggests a distinct and enduring positive impact of the VAT sharing reform on energy intensity.

Robustness checks

Placebo test

This study employs a placebo test methodology by manipulating the timing of events. In order to prevent ascribing changes in energy intensity between the treatment and control groups to temporal variations, the investigation conducts additional regressions, advancing the policy shock points to 2011 and 2013. The policy dummy variables are denoted as post2011 and post2013, respectively. The results presented in Table 4 indicate that the estimated coefficients of the interaction term (Treated×Post2011 and Treated×Post2013) do not achieve significance in the

Table 4. Time placebo test: Altering the timing of reform implementation

Variables	(1)	(2)
Treated × Post2011	0.000	
	(0.002)	
Treated × Post2013		0.002
		(0.002)
Control variables	YES	YES
Observations	2,820	2,820
R-squared	0.278	0.279
Year FE	YES	YES
City FE	YES	YES

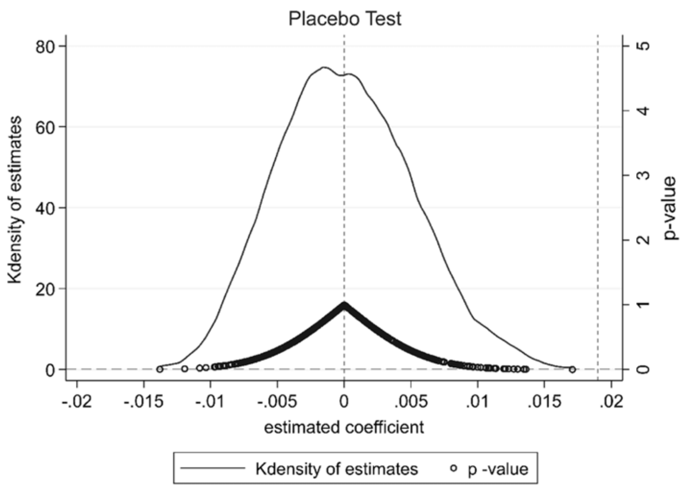

Figure 3. Distribution of estimated coefficients from randomly generated treatment groups.

10% level. This implies that the positive effect of the VAT sharing reform on energy intensity was not observable before the reform's implementation.

Additionally, in order to mitigate the possibility of policy impact effects arising from random occurrences, this study adopts a methodology inspired by Moon (2022). It involves the random generation of a treatment group to derive coefficient estimates for the reform's impact on "pseudo-treated" urban energy intensity. This process is iterated 500 times, resulting in 500 estimated coefficients and their corresponding p-values. As illustrated in Figure 3, the distribution of estimated coefficients from these random simulations converges around 0, while the baseline regression coefficient (0.019) lies completely outside this distribution. This underscores that the empirical findings of this study are not contingent on randomness or incidental factors.

Adjusting the setting standards for the treatment and control groups

In the baseline regression, this study categorizes cities based on their local governments' reliance on VAT in the year preceding the VAT sharing reform, designating the top and bottom halves as the treatment and control groups, respectively. To enhance result robustness, we redefine the treatment and control groups to include cities in the top and bottom thirds of local government reliance on VAT. Given that the newly defined treatment and control groups display a more substantial disparity in local government reliance on VAT prior to the reform, the coefficient of the interaction term in the DID model is expected to be larger (Campello and Larrain 2016). As illustrated in the initial column of Table 5, the estimated coefficient of the VAT sharing reform variable (Treated×Post) is 0.028, surpassing the baseline regression's 0.019 and significantly positive at the 1% level. This suggests that the VAT sharing reform has a significant impact on increasing urban energy intensity (see Column [1] of Table 5).

Substitution of the dependent variable

Considering the various methods available for measuring energy intensity, this study draws inspiration from Mohamed et al. (2020) and employs the ratio of total city electricity consumption to GDP from 2006 to 2020 as an alternative metric for assessing energy intensity. The results affirm the stability of the findings in this study, as evidenced by the consistently positive significance of the interaction term coefficient (see Column [2] of Table 5).

Excluding the provincial capitals

Considering the unique characteristics of provincial capital cities (including planned cities), this article further excludes them in robustness testing. In China, provincial capital cities hold a relatively high administrative level, and both central and provincial governments tend to allocate more financial resources to support their development. Therefore, provincial capital cities may exhibit lower sensitivity to tax-sharing reforms. Consequently, we excluded samples from provincial capital cities to enhance the accuracy of regression results. The findings indicate a positive correlation between tax-sharing reforms and urban energy intensity, with an increase in the coefficient, affirming the robustness of the findings in this study (see Column [3] of Table 5).

Controlling for provincial fixed effects

To eliminate the impact of provincial economic development on energy intensity, this study further incorporates provincial fixed effects into the model. The results indicate that the VAT sharing reform continues to significantly increase urban energy intensity, reaffirming the robustness of the baseline regression (see Column [4] of Table 5).

Heterogeneous effects

Heterogeneity of geographical location

China's extensive territory showcases substantial disparities across its regions concerning resource endowment, levels of technological development, and managerial proficiency. In the realm of energy consumption, a noteworthy

Table 5. Robustness checks

Variables	(1)	(2)	(3)	(4)
Treated×Post	0.028***	0.005***	0.013**	0.020**
	(0.010)	(0.005)	(0.007)	(0.007)
PGDP	−0.006*	−0.032***	−0.026**	0.004
	(0.003)	(0.007)	(0.011)	(0.007)
OPEN	0.004**	0.006**	−0.005*	−0.010***
	(0.002)	(0.003)	(0.003)	(0.003)
HC	−0.054***	−0.004***	0.005	0.001
	(0.005)	(0.001)	(0.006)	(0.001)
TRANS	0.056***	−0.032***	−0.050***	−0.045***
	(0.018)	(0.004)	(0.015)	(0.004)
URBAN	0.001**	0.055***	0.002	0.084***
	(0.000)	(0.013)	(0.026)	(0.013)
INDUS	0.011***	0.003***	−0.001*	0.002***
	(0.004)	(0.000)	(0.000)	(0.000)
FINANCE	−1.227***	0.013***	0.015***	0.011***
	(0.232)	(0.003)	(0.003)	(0.003)
TECH	−0.000	−0.372**	−0.605***	−1.109***
	(0.010)	(0.170)	(0.207)	(0.181)
Constant	0.517***	0.586***	0.297*	0.349***
	(0.111)	(0.074)	(0.159)	(0.075)
Observations	2,715	4,230	3,705	4,155
R-squared	0.287	0.732	0.543	0.372
Year FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Province FE	NO	NO	NO	YES

Note: ***, **, and *indicate significance at the 1%, 5%, and 10% levels, respectively.

divergence is evident among the eastern, central, and western regions concerning energy acquisition costs, methods of energy utilization, and various other factors. This dissimilarity gives rise to distinct levels of energy intensity within the eastern, central, and western regions. The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the central region includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, and Guangxi; and the western region includes Sichuan, Guizhou, Yunnan, Xizang, Shaanxi, Gansu, Ningxia, Qinghai and Xinjiang. Consequently, this study stratifies the entire sample based on geographical location, specifically into eastern, central, and western regions, and conducts a comprehensive analysis of the regional heterogeneity characteristics associated with the impact of VAT reform on energy intensity.

The findings, as presented in the first three columns of Table 6, reveal that the coefficient of the interaction term (Treated×Post) is not statistically significant in the eastern region, whereas in the central and western regions, this coefficient is significant. This implies that the influence of the VAT reform is more prominent in the central and western regions. The observed discrepancy can be attributed to the advanced economic development in the eastern region, characterized by a preference for cleaner industrial growth, along with substantial local fiscal resources. As a result, the impact of the VAT apportionment reform on energy intensity remains inconspicuous in the eastern region. In contrast, the central and

Table 6. The results of heterogeneous effects

Variables	(1) East	(2) Middle	(3) West	(4) Low-energy-consuming	(5) High-energy-consuming
Treated × Post	0.015	0.126***	0.054*	0.018*	0.022***
	(0.018)	(0.017)	(0.029)	(0.010)	(0.008)
PGDP	0.049	0.192***	0.015	0.018*	−0.015*
	(0.031)	(0.036)	(0.036)	(0.011)	(0.009)
OPEN	0.000	−0.061***	0.013*	−0.005	−0.005
	(0.013)	(0.016)	(0.007)	(0.004)	(0.004)
HC	−0.012	0.024**	0.015	0.003	0.003**
	(0.010)	(0.011)	(0.018)	(0.004)	(0.001)
TRANS	0.074*	0.126***	0.054	−0.051***	−0.044***
	(0.042)	(0.027)	(0.052)	(0.006)	(0.005)
URBAN	0.366***	−0.156**	−0.896***	0.091***	0.055***
	(0.050)	(0.076)	(0.169)	(0.021)	(0.018)
INDUS	0.000	0.010***	0.001	0.001*	0.003***
	(0.001)	(0.001)	(0.002)	(0.000)	(0.000)
FINANCE	0.049***	0.024***	0.007	0.022***	0.013***
	(0.010)	(0.007)	(0.015)	(0.006)	(0.003)
TECH	−0.790*	−1.038**	−0.691	−0.450	−1.172***
	(0.448)	(0.519)	(0.974)	(0.331)	(0.197)
Constant	13.048***	10.050***	13.106***	0.278**	0.492***
	(0.502)	(0.441)	(0.600)	(0.122)	(0.099)
Observations	1,515	1,815	900	2,115	2,115
R-squared	0.974	0.960	0.960	0.384	0.343
Year FE	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES

Note: ***, **, and *indicate significance at the 1%, 5%, and 10% levels, respectively.

western regions, marked by less developed economies and heightened fiscal pressures compared to the eastern region, exhibit a substantial effect on energy intensity. This is driven by government efforts, incentivized by tax reforms, to boost tax revenue through the introduction of a significant number of energy-intensive industries.

Heterogeneity of energy dependence

Due to differences in industrial structure, economic development levels, and other factors, cities vary in their degree of energy dependence. Some cities have developed by relying on energy-intensive industries, such as heavy industry and chemical manufacturing, while others have a more diversified industrial structure that includes a greater share of services and high-tech industries. To examine whether the impact of the VAT sharing reform varies across cities with different levels of energy dependence, this paper divides the sample into two groups: high-energy-consuming cities and low-energy-consuming cities, based on the differences in energy consumption per unit of GDP before the VAT sharing reform. The median of the average energy consumption per unit of GDP for the sample cities from 2006 to 2015 is used as the dividing point. Cities with values above this median are classified as the high-energy-consuming cities group, while those with values below are classified as the low-energy-consuming cities group. As shown in the last two columns of Table 6, the impact of the VAT sharing reform on energy intensity is

Table 7. Moderating effects

Variables	(1)	(2)	(3)
Treated × Post	0.055***	0.015*	0.174***
	(0.012)	(0.012)	(0.066)
Treated × Post × GC	0.010***		
	(0.003)		
Treated × Post × ER		−0.051**	
		(0.023)	
Treated × Post × TEC			−0.019***
			(0.007)
Control variables	YES	YES	YES
Observations	4,230	4,230	4,230
R-squared	0.960	0.540	0.544
Year FE	YES	YES	YES
City FE	YES	YES	YES

Note: ***, **, and *indicate significance at the 1%, 5%, and 10% levels, respectively.

more pronounced in the high-energy-consuming cities group, with the coefficient of the interaction term (Treated × Post) being higher in these cities compared to the low-energy-consuming group. This may be because, compared to high-energy-dependent cities, the low-energy-consuming cities tend to have a more diversified industrial structure and higher energy efficiency, resulting in a relatively smaller impact of the VAT reform on their energy intensity.

Moderating effects

Government competition

In the face of both fiscal constraints and promotion incentives, local government competition serves as an enduring driver for rapid economic growth within the region. The persistent introduction of high-energy-consuming industries, spurred by governmental competition, further amplifies urban energy intensity. Consequently, the augmentation of VAT sharing intensifies the endeavors of local governments in business attraction due to heightened governmental competition. This posits that governmental competition may magnify the impact of VAT sharing reforms on energy intensity.

To empirically examine this proposition, the study assesses the moderating effect of governmental competition on the correlation between VAT sharing reforms and energy intensity. The degree of governmental competition is gauged by the logarithm of per capita actual utilization of foreign capital in each city. The regression analysis includes the interaction term (Treated × Post × GC), symbolizing the reform's interaction with governmental competition. The results, presented in the initial column of Table 7, reveal a regression coefficient of 0.010 for the interaction term, signifying statistical significance at the 1% level. This implies that, in regions characterized by heightened local governmental competition, the implementation of VAT sharing reforms corresponds to a more substantial increase in energy intensity.

Environmental regulation

Environmental regulations can concurrently diminish energy consumption and foster economic growth, facilitating a sustainable, green transformation of economic development (Murshed et al. 2021). In locales characterized by more stringent environmental regulations, diverse policies may have been enacted to curtail energy intensity. Consequently, when juxtaposed with regions featuring less stringent regulations, areas that enforce more rigorous environmental control measures experience a mitigated incentive effect regarding tax sharing linked to energy intensity.

To empirically assess this hypothesis, this study introduces a variable representing the intensity of environmental regulation (ER) at the prefecture-level city government, derived from the frequency of "environmental protection"-related terms in government work reports. There are 15 environmentally related terms: low-carbon, environmental protection, air, green, PM2.5, chemical oxygen demand, carbon dioxide, PM10, ecological, pollution discharge, emission reduction, pollution, environmental protection, sulfur dioxide, and energy consumption. The calculation involves determining the proportion of environmental vocabulary relative to the total vocabulary in the report. Regression results, presented in column (2) of Table 7, demonstrate a significantly negative coefficient associated with the interaction term between environmental regulations and the reform of VAT revenue sharing (Treated×Post×ER) at the 5% significance level. This suggests that, in regions with more rigorous environmental regulations, the influence of VAT sharing on energy intensity is attenuated.

Technological innovation

Existing literature suggests that innovation has the potential to decrease energy intensity, phase out obsolete production capacity, and facilitate industrial transformation and upgrading (Cheng et al. 2021; Lin and Zhou 2021). Consequently, in regions characterized by robust innovation capabilities, the anticipated effect of VAT revenue-sharing reform on energy intensity is expected to be mitigated.

To empirically scrutinize this hypothesis, this study quantifies the degree of technological innovation in each city by taking the logarithm of the number of patent applications and subsequently incorporating this measure into the regression analysis model. The regression outcomes presented in column (3) of Table 7 reveal that the coefficient associated with the interaction term (Treated×Post×TEC) is significantly negative at the 1% significance level. This suggests that with an escalation in the level of technological innovation within cities, the influence of VAT revenue-sharing reform on energy consumption intensity diminishes.

Conclusion and policy implications

This paper investigates the impact of the VAT revenue-sharing reform on energy intensity using Chinese urban data spanning from 2006 to 2020. The research reveals a significant increase in local energy intensity due to the VAT revenue-sharing reform. Furthermore, the study explores the moderating effects of government competition, environmental regulations, and technological innovation, finding that government competition amplifies the impact of VAT revenue sharing on energy intensity, while environmental regulations and technological innovation mitigate this effect.

The research findings contribute significantly to academic knowledge. First, we offer a reference for the exogeneity of fiscal decentralization measurement. While the economic impact of fiscal decentralization in China has long been a focal point for scholars, traditional metrics relying on the proportion of fiscal expenditure (revenue) to total expenditure (revenue) are prone to endogenous biases, potentially distorting empirical results. By treating the VAT revenue-sharing reform as a natural experiment, we sidestep the endogeneity issues present in existing research indicators, which provides a reference for future research in the field of fiscal decentralization. Additionally, we delve into the moderating effects of government competition, environmental regulations, and technological innovation on the impact of tax sharing on energy intensity, presenting innovative findings not explored in the existing literature. These findings offer valuable policy recommendations for addressing the impact of tax revenue sharing on energy and even environmental pollution.

First, it is imperative to give careful consideration to the alignment of jurisdictional and expenditure responsibilities across government tiers when formulating the revenue-sharing system between central and local governments. Simultaneously, the potential impact of incentive effects on local administrative behavior should be taken into account. Second, refining the green assessment mechanism for officials' promotions is crucial. The root cause of China's energy issues lies in the asymmetrical priorities between central and local governance, with economic considerations taking precedence in the evaluation of official advancements by the central government. To address this, environmental safeguarding should be established as a primary obligation of local authorities, thereby increasing the significance of ecological civilization construction metrics within the local government evaluation process. This approach will create positive incentives for local officials to engage in environmentally protective behavior. Finally, the study suggests that environmental regulations and technological innovation can help mitigate the impact of tax revenue sharing on energy intensity. Therefore, in the future, devolving the authority of environmental management and supervision to higher-level government and implementing more stringent environmental regulations would be beneficial. Additionally, social planners should actively encourage more fiscal resources to flow into the technological innovation field to improve energy efficiency.

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