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Fiscal decentralisation and green total factor productivity in China: SBM-GML and IV model approaches

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This paper uses the SBM-GML model to measure and evaluate green total factor productivity based on the panel data of 30 provinces and cities in China from 2012 to 2018. It examines the impact of different dimensions of financial decentralisation on green total factor productivity. The research results show that: 1) green total factor productivity in China is improved year by year and better in central and western regions; 2) the decentralisation of fiscal revenue and expenditure significantly weakens the increase of green total factor productivity in provincial level; 3) fiscal decentralisation inhibits green total factor productivity in central and western regions with regional heterogeneity; 4) local government competition affects the relationship between fiscal decentralisation and green total factor productivity, weakens the negative effect of fiscal decentralisation on green total factor productivity. Finally, the study aims to promote green total factor productivity and sustainable development from the perspective of financial decentralisation. This paper expands the literature and evidence of financial decentralisation on green total factor productivity and offers suggestions for governments and policymakers working toward sustainable development.

KEYWORDS

financial decentralization, green total factor productivity, sustainable development, local government competition, SBM-GML model

Introduction

Since the tax sharing reform in 1994, the financial relationship between the central and local governments in China has changed substantially, the core of which is economic and political power centralisation. On the one hand, economic decentralisation has mobilised local governments to develop the economy vigorously (Feltenstein and Iwata, 2005) so that local governments have more substantial economic decision-making power than other countries. It

led to the "Chinese miracle" of sustained rapid growth (Lu et al., 2014; Weingast, 2014; Sun et al., 2017). On the other hand, the central government has greater power in local officials' promotion, and the assessment of economic indicators such as GDP growth triggers the short-sighted local governments to pursue GDP growth blindly and ignore green development (You, 2011; Cheng et al., 2013; Chen et al., 2017), leading to environmental problems such as air pollution. To certain extent, financial decentralisation plays a crucial role in sustainable development (Yuan et al., 2015; Kuai et al., 2019).

Regarding revenue decentralisation, local governments mainly obtain financial revenue from the public budget, tax and non-tax income (Arkin and Slastnikov, 2007; Han and Kung, 2015; He, 2015). In expenditure decentralisation, local governments allocate financial resources through investment in infrastructure construction (Jia et al., 2014; Tang et al., 2019). Thus, expenditure decentralisation restricts green and sustainable development. In recent years, China's central government has established a green total factor productivity-oriented mechanism, requiring local governments to pursue high-quality and sustainable development, and has made remarkable achievements in the green industrial development along the Yangtze River Economic Belt (Chu et al., 2019; Li et al., 2021). However, research on the impact of fiscal decentralisation on green total factor productivity in China is scarce from the perspective of income and expenditure decentralisation (Zhang et al., 2017). So, under the Chinese fiscal decentralisation system, what will be the impact of decentralisation of fiscal revenue and expenditure on the green total factor productivity? Is there regional heterogeneity in its impact? What is the corresponding mechanism of action? This paper examines the "green" consequences and influence mechanism of financial decentralisation in a sample of 30 provinces and cities in China from 2012 to 2018.

The possible contributions in this paper are: 1) to study the "financial decentralisation and green total factor productivity relationship" controversy, this study constructs the SBM-GML model that measures green total factor productivity. Regarding fiscal revenue decentralisation, the fiscal expenditure decentralisation dimension system examines the influence of financial decentralisation on green total factor productivity. This study enriches the financial decentralisation and sustainable development in developing countries literature. 2) To further consider the regional heterogeneity, this study divides the eastern, central and western regions to investigate their role and relationship between fiscal decentralisation and green total factor productivity, deepening the understanding of the regional heterogeneity of the "green" consequences under the fiscal decentralisation. 3) To explore the influence path of fiscal decentralisation on green total factor productivity from the perspective of local government competitions.

Literature review

Fiscal decentralisation refers to the central government empowering local governments in debt arrangement, tax management, and budget implementation (Zhang and Zou, 1998). It reflects labour division and financial power transfer between the central and local governments (Labonne, 2013). As the green movement needs financial support, fiscal decentralisation might impact sustainable development (Kuai et al., 2019). The previous financial decentralisation and sustainable development literature can be sorted into two branches. The first branch of literature is about research on the relationship between fiscal decentralisation and environmental protection, and the second is about the impact of fiscal decentralisation on green total factor productivity.

In the first branch of literature, many documents have analysed and examined the influence of financial decentralisation on environmental protection, which is mainly reflected in the concept of service promotion and weakening. On the one hand, the empirical evidence of He (2015), Khan (2020), and Ran et al. (2020) supported the notion that fiscal decentralisation positively impacts environmental protection. He (2015) took the per-capita discharge of "three wastes" (water, gas, and solid) as the environmental pollution measurement index and examined the impact of China's financial decentralisation on environmental pollution at the provincial level. They found that financial decentralisation played a positive role in promoting environmental governance. Khan (2020), based on the Organization for Economic Co-operation and Development (OECD) country data from 1990 to 2018, examined the impact of fiscal decentralisation on sustainable development and found that financial decentralisation and ecological innovation have promoted renewable energy consumption and reduced the use of non-renewable energy. Ran et al. (2020) used the panel data of 30 provinces and cities in China from 2005 to 2016 to study the relationship between environmental decentralisation and carbon emissions and found that environmental decentralisation has a significant governance effect on carbon emissions.

On the other hand, fiscal decentralisation reduces fiscal and environmental protection financial resources, relaxes the supervision of highly polluting enterprises, and negatively impacts environmental quality. West and Wong (1995) showed that financial decentralisation crowded out investment in public services and adversely impacted social welfare. Yang (2016) found that fiscal decentralisation was not always beneficial and affected the green development of the secondary industry. Pan et al. (2020) found that financial decentralisation negatively affected environmental protection in central and western China, despite a weak impact.

In the second branch of literature, scholars focused on the relationship between fiscal decentralisation and green production and efficiency, but they also had contradictory findings. First, fiscal decentralisation may not be conducive to green production and development. Xie et al. (1999) studied the impact of fiscal decentralisation on the United States public expenditure and concluded that financial decentralisation was not conducive to

the significant growth of public expenditure and implied a negative impact on green ecological projects. Li et al. (2022) integrated the ecological environment into green total factor productivity and empirically found that green total factor productivity was driven by technical efficiency, and financial decentralisation weakened the improvement of green production efficiency. On the other hand, Song et al. (2018) examined the impact of fiscal decentralisation on green total factor productivity in 11 provinces and cities in the Yangtze River Economic Belt between 2000 and 2015. They concluded that fiscal decentralisation increased green total factor productivity at the provincial level. Third, there were different phrases in financial decentralisation's impact on green behaviour. Elheddad et al. (2020) found a non-linear relationship between fiscal decentralisation and green behaviours such as energy consumption. Finally, to further understand the relationship between fiscal decentralisation and green total factor productivity, Konisky (2010), Hong et al. (2019), and Yang et al. (2020) proposed to analyse the "competition to the end" of local governments.

As an essential aspect of sustainable development, comprehensive discussion about the relationship between fiscal decentralisation and green total factor productivity, the relationship between the two is still controversial, and the research on the influence mechanism is relatively scarce. Based on the previous literature, this study utilised the SBM-GML model to construct a green total factor productivity index and systematically examined the influence of Chinese fiscal decentralisation on green total factor productivity under fiscal revenue and expenditure decentralisation. It also analysed the mechanism of a local government competition to study the relationship between fiscal decentralisation and green total factor productivity.

Measurement models and data

SBM-GML model

Model setting

This study estimates green efficiency (GTFP) by using Data envelopment analysis (DEA). It is a non-parametric technical efficiency analysis method to compare multiple input-output systems (Sueyoshi et al., 2016). DEA method can quantify the results of index data to evaluate the results of production efficiency more objectively (Tyteca, 1996). The output of green total factor productivity mainly includes environmental emissions such as water, gas, and solid, which constitutes unexpected output. On this basis, the SBM model is used to study the relationship between input, production, and pollution problems and better solve the problem of insufficient efficiency evaluation (Tone and Tsutsui, 2010). The Formula 1 shows the SBM model:

$$\begin{aligned} \min \rho &= \frac{1-\frac{1}{m}\sum_{i=1}^{m} S_i^- / x_{ik}}{1+\frac{1}{q1+q2}\left(\sum_{r=1}^{q2} S_r^+ / y_{rk} + \sum_{t=1}^{q2} S_t^b / b_{rk}\right)} \\ X\lambda + S^- &= x_k \\ Y\lambda + S^+ &= y_k \\ B\lambda + S^b &= b_k \\ \lambda, S^-, S^+ &\geq 0 \end{aligned} \tag{1}$$

In Formula 1, m represents the number of DMU input elements, q_1 represents the number of classes corresponding to expected output, and q_2 represents the number of types corresponding to an unexpected result. x_{ik} represents the input element of green total factor productivity, y_{rk} represents the expected output element of green total factor productivity, and b_{rk} represents the unexpected output element of green total factor productivity. In contrast, Si^-, Sr^+, and $S_t{}^b$ represent the slack variables corresponding to information, desired outcome, and surprising result. λ is a constant vector. The greater the efficiency value of the objective function, the higher the efficiency of the DMU.

SBM model is the basis for us to calculate green efficiency. Compared with other models, the SBM model has transitive and global characteristics, which avoids the problem that linear programming has no feasible solution when calculating efficiency (Oh, 2020). Next, this research constructed the Global Malmquist Luenberger (GML) index model. The index of green efficiency is constructed through the GML model, as shown in the formula (2):

$$GML_t^{t+1} = \frac{1+\overline{D_0^G}\left(x^t, y^t, b^t; y^t, -b^t\right)}{1+\overline{D_0^G}\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)} \tag{2}$$

In Formula 2, $\overline{D_0^G}$ represents the global directional distance function, x represents the input element of green total factor productivity, y represents the expected output element of green total factor productivity, and b represents the unexpected output element of green total factor productivity. t is a time variable, t represents the current period, and $t+1$ represents the next period. In addition, the specific input and output factors of green total factor productivity are shown in Table 1.

Variables

Many methods help measure the green total factor productivity of sustainable development: the parameter method (Yao and Li, 2010), DEA-Malmquist (Fare et al., 1997), Shephard-Malmquist (Wang Q. et al., 2019). We used the SBM-GM index to measure the level of green production at China's provincial level. Based on the SBM-GM model, input factor variables and output factor variables are selected, respectively.

TABLE 1 Input and output variables based on the SBM-GML model.

Input factor variables	Output factor variables
Annual number of employees in the region	Real GDP (expected)
Average annual balance of net fixed assets in the region	Wastewater discharge (unexpected)
Total regional energy consumption	Exhaust emissions (unexpected)
	Solid waste emissions (unexpected)

(Source: China Statistical Yearbook and China Environmental Statistical Yearbook).

Li and Lin (2016) suggested that the production input factors of Chinese provinces include labour, capital and energy. Thus, this study chose the annual number of employees in the region, the annual average balance of net fixed assets, and the region's total energy consumption. Concerning output factor variables, in addition to GDP, China's production brought wastewater, gas and solid waste. Adopt the practice of (Wang Y. et al., 2019), the expected output is the actual regional GDP, while the non-expected output is wastewater, gas, and solid waste discharge. Table 1 introduces the input and output variables under the SBM-GML model.

Instrumental variable model (IV model)

Model setting

The IV model, which lags the first explanatory variable, is used to examine the impact of fiscal decentralisation on green sustainable development at the provincial level in China. The IV model needs to select a variable as the instrumental variable of the explanatory variable in the model and estimate the corresponding parameters together with other variables in the model. The model overcomes the errors of missing variables and measurement errors, and the choice of lagging explanatory variables as instrumental variables has specific applicability (Bellemare and Carnes, 2015). Accordingly, Formula 3 constructed the instrumental variable model:

$$GTFP_{i,t} = \beta_0 + \beta_1 Fisde_{i,t-1} + \beta_2 Controllers_{i,t} + Year + Province + \varepsilon_{i,t} \quad (3)$$

Among them, GTFP represents green efficiency, FID represents fiscal decentralisation, Controller represent other control variables affecting green total factor productivity, the year is the annual effect, and the province is the regional effect of 30 provinces and cities in China. ε is a random disturbance term, i represents 30 individual provinces and cities, and t represents time.

Variables

The dependent variable of this study is green efficiency (GTFP): Under the condition of sustainable development, energy, like labour, capital, and other factors, also has the characteristics of scarcity, compensation, and direct participation in production activities, so green total factor productivity considering the input of production factors and the consumption of energy resources can measure the effect of sustainable development. Based on the variable measurement method of Fang et al. (2020), this study adopts the SBM-GML model to evaluate green total factor productivity.

The academic community of financial decentralisation is mainly based on fiscal revenue decentralisation (Lin and Zhou, 2021) and fiscal expenditure decentralisation (Cheng et al., 2019). To avoid the estimation bias caused by a single index measure, this study integrates the financial decentralisation practices, which focuses on the calculation method of Kassouri (2022), and measures the fiscal revenue decentralisation (FIRD) and fiscal expenditure decentralisation (FIED) separately. Following Wang et al. (2020), Qiu et al. (2021), and Zhuo et al. (2022), control variables include economic development level (EDEL), industrial structure (INDS), foreign direct investment (FDI), population density (POD). The independent variable includes fiscal decentralisation (FID), as this study intends to investigate the impact of different financial decentralisation scenarios on green production efficiency.

Economic development level (EDEL): As both the resource consumption situation and the concept of sustainable development will constantly evolve with the change of the economic development stage, the matching green production behaviour will also undergo adaptive adjustment. Per-capita GDP is used as an indicator to measure economic development.

Industrial structure (INDS): In addition to economic development, the industrial structure is another economic factor closely related to green production behaviour. Industrial structure determines the type and intensity of energy consumption and affects green production efficiency. As the "factory of the world," adjusting its industrial structure and eliminating the "three high" (high pollution, high energy consumption, and high emission) industries have become one of the essential means of competition for local governments. We introduce the control variable of industrial structure and use the ratio of the secondary industry's added value to the regional GDP as the calculation method of industrial structure.

Foreign direct investment (FDI): two competitive conclusions can introduce the impact of foreign direct investment on regional green production efficiency. Weakening concept, foreign investment introduced by provinces of developing countries may be the major projects to undertake industrial transfer, dragging the overall green total factor productivity (Wang et al., 2020). The other is to promote a concept; namely, foreign investment may bring advanced production technology and green concept, promote regional green production

TABLE 2 Variable definitions

Variable		Variable symbol	Variable declaration
Dependent variable	Green total factor productivity	GTFP	Green total factor productivity was assessed comprehensively using the SBM-GML model
Independent variable	Fiscal revenue decentralisation	FIRD	Per capita fiscal revenue in regional budget/(per capita fiscal revenue in regional budget + per capita fiscal revenue in central budget)
	Fiscal expenditure decentralisation	FIED	Per capita fiscal expenditure in the regional budget/(per capita fiscal expenditure within the regional budget + per capita fiscal expenditure in the central budget)
Control and regulation variables	Economic development level	EDEL	GDP per capita
	industrial structure	INDS	The added value of the secondary industry/regional GDP
	Foreign direct investment	FDI	Ln (regional actual utilisation of foreign direct investment)
	Population density	POD	Ln (number of regional permanent resident population/area of urban administrative division)
	Local government competition	LOCP	Total regional import and export volume/regional GDP
	Year	Year	Set the year virtual variable, this year take 1, otherwise take 0
	Provincial variables	Province	Set up virtual variables for the 30 provinces and cities involved in China

(source: China Statistical Yearbook and China Financial Statistical Yearbook).

efficiency improvement (Qiu et al., 2021). The region's utilised foreign direct investment logarithm measures the control variable.

Population density (POD): denser areas are associated with more frequent human and industrial activities, which lead to increased pollutant emissions affecting green total factor productivity (Zhuo et al., 2022). In order to control the potential impact of regional industrial and commercial activities on green total factor productivity, the population density was introduced, and the ratio of the number of permanent residents to the area of urban administrative divisions was expressed in logarithm.

Regulated variable

Local government competition (LOCP): Foreign investment can bring impetus to regional economic growth, so attracting foreign investment has become an essential manifestation of local government competition (Sun and Wang, 2014). In the case of free trade, it may stimulate the competition level of local governments, improve regional trade environment with administrative orders (Fan et al., 2019), and bring about changes in green production efficiency. The adjustment variable is expressed by the proportion of total imports and export to regional GDP. Table 2 is the definitions and descriptions of each variable.

Sample selection and data source

Due to the lack of data in the Tibet Autonomous Region, Hong Kong, Macao, and Taiwan, thus to select 30 provinces and cities in China. At the same time, in June 2019, the Chinese central government officially issued the Regulations on the Central Ecological and Environmental Protection Supervision Work, implementing the ecological and environmental protection supervision system, and setting up a full-time supervision agency. Considering the central government will strengthen ecological and environmental protection supervision after 2018, it may affect the inter-provincial green total factor productivity. In order to eliminate the possible impact of non-financial decentralisation on the green total factor productivity of China's provinces, we choose the research period from 2012 to 2018, with a total of 7 years. The data used in this paper are from the website of the China National Bureau of Statistics, China Statistical Yearbook, China Financial Statistical Yearbook, China Environmental Statistical Yearbook, and other official authorities. A few missing values were interpolated for 210 observations to complement the balanced panel data.

Data analysis

Descriptive statistics

Table 3 shows the descriptive statistics of the main variables. The mean GTFP of the green total factor productivity of the dependent variable is 1.027, the minimum value is 0.716, and the maximum value is 1.628, indicating some differences in the sustainable development performance among the 30 provinces and cities in China. In addition, Table 4 gives the data description of input and output variables of green total factor productivity, and the results based on measurement software are shown in Table 5. According to the green total factor productivity measurement index of China's provinces from 2012 to 2018,

TABLE 3 Descriptive statistics of the main variables.

Variable	Sample size	Mean value	Standard deviation	Minimum	Maximum
GTFP	210	1.027	0.111	0.716	1.628
FIRD	210	0.517	0.121	0.327	0.835
FIED	210	0.860	0.037	0.793	0.937
EDEL	210	1.608	0.413	0.679	2.641
INDS	210	0.439	0.083	0.186	0.577
FDI	210	3.686	1.793	-2.215	6.016
POD	210	0.489	0.757	0.008	4.182
LOCP	210	0.267	0.297	0.017	1.441

TABLE 4 Input and output variables of green total factor productivity.

Variable type	Variable	Sample size	Mean value	Standard deviation	Minimum	Maximum
Input variables	The annual number of employees in the region (ten thousand people)	210	936.556	798.569	66.537	4585.192
	Average annual balance of net fixed assets in the region (million yuan)	210	17228.053	11474.002	1883.422	55202.720
	Total regional energy consumption (ten thousand tons)	210	14922.178	8822.078	1687.980	40581.000
Output variables	Real GDP (million yuan)	210	24535.848	18925.084	1893.540	97277.770
	Wastewater discharge (ten thousand tons)	210	235141.344	183574.296	21953.030	938261.100
	Exhaust emissions (ten thousand tons)	210	150.523	101.203	9.533	450.005
	Solid waste emissions (ten thousand tons)	210	22194.367	18682.985	697.675	91684.590

most of the green total factor productivity is higher than 1, the overall performance is improved year by year, and the eastern region is better than the central and western regions.

Among the independent variables of financial decentralisation, the average FIRD is 0.517, and the standard deviation is 0.121, indicating a certain amount of fiscal revenue decentralisation in the 30 provinces and cities in China. The other independent variable, FIED decentralisation, is 0.860, with a minimum value of 0.793 and a maximum value of 0.937, indicating the different characteristics of fiscal expenditure decentralisation in the sample. Regarding control variables, the average economic development level (EDEL) and the industrial structure (INDS) of the 30 provinces and cities were 1.608 and 0.439 each, indicating that the sample region has a specific scale of per-capita GDP and the added value contribution of the secondary industry. The average FDI and POD are 3.686 and 0.489, respectively, which have the economic implication of foreign investment with a certain proportion and the economic implication of a large overall population density. As a regulatory variable, the average LOCP is 0.267, and the standard deviation is 0.297, showing the reality that different local governments have competition. In general, the descriptive statistical results are consistent with the financial and development reality at the provincial level in China. Finally, before the standard regression, we also did the variable correlation coefficient analysis, which showed that most variables' correlation coefficient was less than 0.5, the variance expansion factor was less than 10, and no obvious collinearity problem was observed.

Benchmark test and heterogeneity analysis

Based on the model (3), the whole-sample benchmark regression and heterogeneous regression analysis were performed, and the results are shown in Table 6. Column (1) ~ (2) examines the impact of fiscal revenue and expenditure decentralisation on green total factor productivity in 30 provinces and cities in China, and columns (3) ~ (6) examines the role of fiscal decentralisation on green total factor productivity from the perspective of regional heterogeneity. From the regression results, columns (1) and (2) suggest that the decentralisation of fiscal revenue and fiscal expenditure that constitute the two dimensions of financial decentralisation is significantly negative, indicating that both the decentralisation of fiscal revenue and fiscal expenditure generally suppresses green total factor

TABLE 5 China provincial green total factor productivity (GTFP) in 2012–2018.

Province	2012	2013	2014	2015	2016	2017	2018	Mean
An Hui	1.202	0.985	0.999	0.985	0.969	1.052	1.052	1.035
Bei Jing	1.316	1.039	1.068	1.030	1.040	1.144	1.259	1.128
Fu Jian	0.873	0.999	1.006	0.975	0.989	1.087	1.194	1.018
Gan Su	1.129	0.958	0.968	0.955	0.914	1.002	1.013	0.991
Guang Dong	0.844	0.950	1.053	0.899	0.808	1.136	1.212	0.986
Guang Xi	1.212	0.974	1.003	0.979	0.980	1.029	0.948	1.018
Gui Zhou	1.113	0.979	1.019	0.966	0.994	1.017	1.013	1.014
Hai Nan	0.802	0.923	1.250	0.763	1.056	1.145	1.083	1.003
He Bei	1.204	0.957	0.980	0.977	0.953	1.080	1.084	1.034
He Nan	1.215	1.009	1.054	1.023	1.004	1.121	1.149	1.082
Heilong Jiang	1.001	0.945	0.974	0.982	0.966	0.980	1.006	0.979
Hu Bei	1.246	0.989	1.025	0.991	1.031	1.146	1.125	1.079
Hu Nan	1.144	0.980	1.021	0.987	1.002	1.096	1.092	1.046
Ji Lin	0.821	1.017	1.034	0.990	0.973	1.070	0.951	0.979
Jiang Su	1.370	1.064	1.094	1.075	1.056	1.162	1.279	1.157
Jiang Xi	1.193	0.993	1.001	0.988	0.969	1.031	1.040	1.031
Liao Ning	0.716	1.001	1.020	0.994	1.008	0.820	0.932	0.927
Inner Mongolia	0.754	0.989	0.966	0.939	0.970	0.992	0.887	0.928
Ning Xia	1.106	1.009	0.980	0.968	0.988	1.031	1.072	1.022
Qing Hai	1.142	1.000	1.000	1.000	0.943	1.060	1.000	1.021
Shan Dong	1.120	1.042	1.105	1.033	1.002	1.088	1.114	1.072
Shan Xi (Jin)	1.084	0.927	0.920	0.912	0.927	0.966	1.172	0.987
Shan Xi (Shan)	0.902	1.002	1.012	0.973	0.924	1.014	1.053	0.983
Shang Hai	0.826	1.014	1.049	1.007	1.032	1.163	1.370	1.066
Si chuan	1.306	1.010	1.013	0.988	1.011	1.087	1.153	1.081
Tian jin	1.259	0.962	1.027	0.991	0.982	1.137	1.628	1.141
Xin jiang	1.107	0.938	0.935	0.953	0.903	0.962	1.020	0.974
Yun nan	0.831	1.000	1.024	0.968	0.968	0.981	1.017	0.970
Zhe jiang	0.964	1.039	1.066	1.040	1.036	1.163	1.168	1.068
Chong Qing	0.802	1.012	1.048	1.007	1.009	1.016	1.029	0.989
Mean	1.053	0.990	1.024	0.978	0.980	1.059	1.104	1.027

productivity. The heterogeneity regression of the sub-samples shows that, only the estimated coefficient of column (4), column (6), fiscal revenue decentralisation FIRD(-1) and fiscal expenditure decentralisation FIED(-1) was significantly negative, with-1.155 and-2.898 each. The estimated coefficients of columns (3) and columns (5) are negative but insignificant. The above shows a regional heterogeneity in the influence of fiscal revenue and expenditure decentralisation on green total factor productivity in 30 provinces and cities in China, and it is more evident in the central and western regions.

In fact, under China's rapid economic development and fiscal decentralisation system arrangement, local governments in central and western provinces often earn less revenue than expenditure, which quickly leads to local governments paying excessive attention to economic development (Tranter, 2011), which harms green total factor productivity. In addition, compared with eastern China, the Midwest province's overall economy is underdeveloped, sustainable development consciousness is relatively weaker, and local government fiscal spending is more inclined to choose immediate economic benefits projects (Song et al., 2020). Deficiencies in green production advocacy and supervision make the Midwest in the sub-sample regression of fiscal revenue and expenditure decentralisation of green total factor productivity inhibition more significant.

Mechanism test results and analysis

As China's economy transforms and upgrades to high-quality development, the central government increases the assessment and supervision and constraints on the green

TABLE 6 Results of benchmark regression and heterogeneity regression.

Variable name	Full sample		Sub-sample			
	GTFP in 30 provinces		East GTFP	Midwest GTFP	East GTFP	Midwest GTFP
	(1)	(2)	(3)	(4)	(5)	(6)
FIRD (-1)	-0.334* (-1.89)		-0.687 (-0.55)	-1.155** (-2.57)		
FIED (-1)		-0.942*** (-2.60)			0.398 (0.15)	-2.898** (-2.00)
EDEL	0.132** (2.31)	0.115*** (2.62)	0.707 (1.34)	0.284* (1.70)	0.564 (1.13)	0.275 (1.60)
INDS	-0.085 (-0.66)	-0.072 (-0.62)	-3.729** (-2.04)	0.041 (0.09)	-3.574 (-1.97)	-0.100 (-0.23)
FDI	-0.000 (-0.01)	-0.012 (-1.59)	-0.058 (-1.28)	-0.005 (-0.29)	-0.069 (-1.51)	-0.008 (-0.49)
POD	0.024 (1.10)	0.022 (1.17)	-0.751 (-0.70)	-1.034 (-0.32)	-0.604 (-0.57)	-3.060 (-0.94)
Constant	1.069*** (12.34)	1.770*** (5.99)	2.231 (1.13)	1.264*** (5.58)	1.466 (0.50)	3.550*** (2.92)
Year	control	Control	control	control	control	control
Province	control	Control	control	control	control	control
Observations	210	210	70	140	70	140
Adj R-squared	0.242	0.254	0.431	0.262	0.428	0.245

Note: (1) * * *, * * and * indicate significance levels of 1, 5 and 10%, respectively, the same below; (2) all in brackets are the two-tailed T values after cluster processing of provincial level standard robust error, the same below; (3) eastern sub-samples include Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Fujian, Hainan, and other provinces and cities are divided into Midwest sub-samples.

development of local governments. Since 2012, the central government has released the "12th Five-year" comprehensive work plan for energy conservation and emission reduction. Energy Conservation and Emissions Reduction Comprehensive Work Plan Energy Conservation and Emissions Reduction Comprehensive Work Plan put environmental protection and green development as the critical assessment criteria of local officials' promotion, which may even be a "one vote veto". Local governments will strengthen the environmental protection and green development (Pan et al., 2020) and not just focus on GDP growth. In addition, at another level of local government competition, investment attraction is also one of the critical assessment tasks that local governments need to accomplish. In the context of the diminishing margin of financial support in recent years, an excellent ecological environment and sustainable production are all necessary means to attract high-level foreign investment while accelerating the competition of local governments in creating a green production atmosphere and encouraging green development behaviour (Yang et al., 2020). Thus, local government competition weakens the negative effect of fiscal decentralisation on green total factor productivity.

Based on the model (3), this paper include the regulatory variable of local government competition LOCP. It examines the potential role of local government competition in the relationship between fiscal decentralisation and green total factor productivity through FIRD (-1) * LOCP and FIED (-1) * LOCP transfer items. It shows that the local government competition regulation has improved the adverse effect of fiscal revenue decentralisation on green total factor productivity. In the mechanistic test results presented in Table 7 Column (1), the influence of FIRD (-1) on green total factor productivity GTFP is significantly negative. However, with local competition LOCP as the adjustment variable, after the FIRD (-1) * LOCP of local government competition is introduced in the regression equation, the estimated coefficient is positive at 1%.

Similarly, column (2) FIED (-1) * LOCP, after introducing fiscal expenditure decentralisation to compete with local

TABLE 7 Results of mechanism testing.

Variable name	GTFP	
	(1)	(2)
FIRD (-1)	-0.423* (-1.88)	
FIED (-1)		-1.441*** (-3.41)
LOCP	-0.501*** (-3.51)	-1.425* (-1.81)
FIRD (-1)*LOCP	0.900*** (4.20)	
FIED (-1)*LOCP		1.568* (1.69)
EDEL	0.111* (1.74)	0.154*** (3.14)
INDS	0.131 (0.72)	-0.044 (-0.41)
FDI	0.007 (1.75)	-0.015* (-1.94)
POD	-0.074** (-2.29)	0.010 (0.52)
Constant	1.056*** (9.82)	2.162*** (6.30)
Year	Control	control
Province	Control	control
Observations	210	210
Adj R-squared	0.360	0.274

TABLE 8 Results of robustness testing.

Variable name	GTFP	
	Fixed effect model regression	Random effect model regression
	(1)	(2)
FIFD	-1.368*** (-3.30)	-0.416*** (-2.70)
EDEL	0.244*** (3.46)	0.152*** (3.74)
INDS	0.669** (2.36)	0.028 (0.23)
FDI	-0.034* (-1.84)	-0.003 (-0.41)
POD	0.805 (1.20)	0.031* (1.75)
Constant	0.890** (2.44)	1.014*** (12.44)
Year	Control	uncontrolled
Province	Control	uncontrolled
Observations	210	210
Adj R-squared	0.364	0.109

governments, has an estimated coefficient of 1.568 and is significant at 10%. It shows that the local government competition improves the relationship between fiscal expenditure decentralisation and green total factor productivity. To sum up, local government competition weakens the negative role of fiscal decentralisation on green total factor productivity.

Robustness test

The robustness test is a series of tests to investigate and evaluate the reliability of conclusions, and its purpose is to ensure that the research conclusions do not change with alternative indicators and model transformation (Ajmi et al., 2015). In order to ensure the reliability of the above conclusions, we also conducted a series of robustness tests from the perspective of variables and model robustness. First, change the variable. Cheng et al. (2021) measure financial decentralisation from the perspective of financial freedom, with the degree of financial freedom (FIFD) of revenue and expenditure decentralisation as the core independent variable, and the provincial fiscal revenue divided by the provincial financial expenditure is used to measure the regression, and the conclusion is unchanged. Secondly, change the model and regress again. In order to avoid possible estimation bias in the model setting, we refer to the practice of Qian et al. (2019) and regress based on the fixed effect model and random effect model, respectively. As shown in Table 8, no matter whether the fixed effect model or the random effect model is used, the core conclusions of this paper have not changed fundamentally.

Discussion

Implications to theory

"High growth and high pollution" in developing countries have caused substantial waste of resources and environmental pollution, motivating these countries to implement sustainable development solutions in recent years. Likewise, green total factor productivity factors have aroused scholars' interest. Some studies shed light on environmental regulation, foreign direct investment, technological progress, etc., but they ignore the impact of fiscal decentralisation on green total factor productivity. This paper uses China as an example to study the relationship between fiscal decentralisation and green productivity and its impact by using SBM-GML and IV Model. This study not only improves the traditional DEA model, but also adopts the SBM-GML model with more transitive and global characteristics to measure green total factor productivity. Moreover, the empirical results enrich the literature on whether and how fiscal decentralization affects sustainable development in developing countries, and help scholars understand the "black box" of fiscal decentralization and green total factor productivity from the perspective of regional heterogeneity and local government competition.

Implications to policy

According to the green efficiency results in Chinese provinces from 2012 to 2018, the eastern region is better than the central and western regions, meaning better economic development

might lead to higher green efficiency. While policy makers may consider environmental protection outcomes from pollutants such as CO and NOx, they seldom consider the issues from the input-output analysis. This study offers them alternative views on these issues when they review the effectiveness of environmental policies. The results can also be generalised to other policy issues as most policy makers simply consider the output (outcomes) but ignore the inputs when implementing different policies. Besides, the study results imply that win-win economic and environmental development co-exists when we perceive the environmental issues from green efficiency perspectives.

Good economic development is a crucial factor in achieving environmental friendly outcomes. Given the unbalance green efficiency in China with better performance in wealthier parts of China, it informs policy makers in China that apart from spending money on controlling environmentally friendly facilities, they should also spare extra efforts on research and development. Adopting clean energy require a lot of financial resources to a certain extent. Technology like hydrogen used for buses at present, for example, requires research grants for many years. Thus, public finance and expenditures for achieving co-economic and environmental developments require government officials' wisdom.

Limitations and future research directions

Similar to previous research, this paper has some limitations, which need further study in the future. First, this paper takes wastewater discharge, exhaust emission and solid waste discharge as output variables. Given that many different types of water and air pollutants are undesired outputs, future research might consider these. Second, we focus on the relationship and the mechanism between fiscal decentralisation and green productivity in China. The scope can be expanded to other countries in the future based on worldwide data. Since data transparency is one of the global smart cities' movements, big data analysis and data that covers a more extended period may be another future direction. Finally, other models like system dynamics (Mao et al., 2015) might be used to study how changes in some of these factors affect green efficiency. New forecasting and machine learning models (Li et al., 2018) can be used to forecast the changes, bringing practical ideas to policy makers and governments.

Conclusion and discussion

The study found that: 1) the overall green total factor productivity has improved year by year and the eastern region is better than the central and western regions. 2) the overall financial decentralisation has significantly weakened the green total factor productivity increase. 3) From the two dimensions of fiscal revenue decentralisation and fiscal expenditure decentralisation. Detailed investigation of the impact of fiscal decentralisation on sustainable development. 4) From the perspective of regional heterogeneity, we find that the inhibitory influence of fiscal decentralisation on green total factor productivity is more evident in the central and western regions. 5) Taking local government competition as the potential mechanism between fiscal decentralisation and green total factor productivity, the local government competition weakens the negative effect of fiscal decentralisation on green total factor productivity.

The study's conclusion is helpful to enrich the discussion of "the relationship between fiscal decentralisation and green total factor productivity" and provide ideas for China to reform fiscal decentralisation and the development of green science. The policy recommendations in this paper are: 1) Continue to promote the reform of the fiscal decentralisation system. In the existing Chinese-style financial decentralisation, the local government's financial and administrative power is fully matched, which is one of the main reasons financial decentralisation shows an inhibitory effect on green total factor productivity. In the future, the reform of the financial decentralisation system should be further strengthened, and clarify the role between the central and local governments. At the same time, the financial power relationship between the governments below the provincial government deepens the implementation of the concept of green development, strengthens the authority of project approval and financial funds, and promotes the improvement of green total factor productivity; 2) Pay attention to regional heterogeneity, and give full play to the role of fiscal decentralisation in sustainable development according to local conditions. The relatively developed economy of eastern China has considerable financial power and little room for sustainable development and green total factor productivity improvement. The central and western regions are in the process of rapid transformation. It is essential to improve the green sustainable development level and further increase green production, environmental protection supervision, and management personnel. Appropriate restrain and standardise local governments' behaviour and power use, establish and perfect the green production management system; 3) Improve local government and officials' assessment mechanism, and entirely abandon local officials' improper decision-making behaviour "only GDP theory." It is necessary to strengthen the weight of environmental governance and green development

governance in the promotion criteria of local officials, increase the incentives of local governments, deepen the level of local government competition, and actively promote the positive regulatory effect of local government competition to enhance the green total factor productivity.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

XZ: Original writing, Editing and Revise paper. RL: Original writing, Editing and Revise paper, Data curation. XL: Data collection. FH: Editing and Revise paper. MW: Data analysis. YQ: Data analysis. JX: Data collection. WL: Language editing and proof.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling editor ZK declared a past co-authorship with the author RL.

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Supplementary Material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.989194/full#supplementary-material

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