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Effects of Vertical Fiscal Imbalance on Green Total Factor Productivity—Evidence from China

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Abstract: Green development is the key to safeguarding and improving people's livelihoods and promoting sustainable development. Based on the provincial data of China for 2004–2019, we developed a general panel model and spatial Durbin model to test the effects of vertical fiscal imbalance (VFI) on green total factor productivity (GTFP). The results show that VFI has a significant inhibitory effect on GTFP; decomposing GTFP into the green technical efficiency change (GEC) and green technological change (GTC) indices reveals that the inhibitory effect of VFI on the GEC and GTC indices is significant and non-significant, respectively; the dampening effect of VFI on GTFP is more significant in regions with high economic growth target, low marketization, or high levels of VFI, and in Midwest, resource-based, or non-municipalities regions. The results of the spatial spillover effect analysis show that VFI has a suppressive effect on GTFP in regions with similar levels of economic development. This study enriches the existing literature by exploring the institutional causes affecting GTFP levels and provides theoretical and practical implications for comprehensively promoting a new round of fiscal system reforms in China and building a modern fiscal system with clear authority and responsibility, thereby promoting sustainable development.

Keywords: vertical fiscal imbalance; green total factor productivity; marketization; spatial spillover effect

1. Introduction

With rising global ecological and environmental problems and challenges in sustainable development, countries are considering green development as a national strategy, highlighting the importance of a comprehensive green transformation of economic and social development for the sustainable development of each country, and this is especially true for China. In the past 40 years since the reform and opening up, China has achieved high economic growth, accompanied by the problems of high pollution and energy consumption [1]. According to the "National Ecological Environment Quality Profile 2022" released by the Chinese Ministry of Ecology and Environment, the average percentage of good air quality days in 339 prefecture-level and above cities in China will be 86.5% in 2022; however, the annual average PM2.5 concentration will be 29 $\mu g/m^3$, which is still higher than the standard value of 10 $\mu g/m^3$; set by the World Health Organization. Moreover, China's energy carbon emissions have increased from 8.84 billion tons in 2012 to 9.46 billion tons in 2019 [2]. Serious environmental pollution reduces labor productivity, detriments human capital accumulation, poses serious challenges to long-term economic and social development, and raises potential threats to people's lives, health, and property security. Therefore, balancing economic growth with resource conservation and environmental protection and gradually resolving the paradox between people's pursuit of a better life and inadequate development is the focus of all sectors within China at present. For example, the report of the 20th National Congress emphasizes efforts to improve total factor productivity (TFP) to promote high-quality development.

As traditional factors, such as labor, land, and energy, are constraining economic growth, the adoption of green total factor productivity (GTFP) instead of traditional TFP is

better for measuring and evaluating the quality of an economy's economic development. Several studies have discussed the factors influencing GTFP; however, as GTFP, considered a "public good", has strong public attributes and benefits the whole society, it should be the responsibility of the government to enhance GTFP and whether the government can fulfill this function is closely related to the institutional arrangements that affect the behavior of local governments. Unlike the highly decentralized political and economic model of Western countries, such as the United States, since the implementation of China's tax-sharing reform in 1994, the Chinese decentralized model has distinctive features of political centralization and economic decentralization, that is, the power to collect and manage fiscal revenues is vested in the central government [3], whereas the responsibility for fiscal expenditure is assumed by local governments. Furthermore, economic growth and an increase in fiscal revenue are the core indicators to measure the government performance or promotion qualifications of local government officials [4]. Under such a decentralized system, the mismatch between fiscal affairs and fiscal powers among local governments has become increasingly prominent, resulting in vertical fiscal imbalance (VFI). More critically, China has implemented a "dual-track" model of economic and social governance by local governments and the market, which means that China's fiscal policy has an important strategic position in macroeconomic regulation. Therefore, along with China's economic development goal of shifting from a quantitative to a qualitative stage, how to release the institutional dividend through fiscal system reform to enhance the vitality of micro subjects to stimulate the transformation of old and new economic dynamics is crucial to promote the overall green transformation of China's economic and social development.

We first interpret the crux of VFI's impact on GTFP at the theoretical level and then empirically examine the impact of VFI on GTFP based on provincial panel data for 2004–2019. We find that VFI significantly reduces GTFP and green technical efficiency change (GEC) with no significant effect on green technological change (GTC). According to the heterogeneity test, the suppressive effect of VFI on GTFP is more significant in regions with high economic growth targets, low marketization and high VFI or in Midwest, resource-based, or non-municipalities regions; according to the spatial spillover effect, regression estimation based on a spatial econometric model constructed from the spatial weight matrix of economic distance reveals evidence of a negative spatial spillover effect of VFI.

The remaining study is structured as follows: Section 2 presents a literature review. Section 3 introduces the theoretical mechanism of the effect of VFI on GTFP, Section 4 provides the empirical research design, and Section 5 reports the main empirical results. Section 6 presents the conclusions and discussion, followed by Sections 7 and 8, providing the theoretical and practical implications and policy implications, respectively.

2. Literature Review

There are several studies on GTFP. In terms of connotation, GTFP focuses on the coupling of the two systems of "economy–ecology", that is, the goal of obtaining higher economic efficiency and reducing "undesired" output by minimizing the unit of energy input [5]. The academic research on GTFP presents the following views. First, they depict the dynamic evolution of GTFP. The average value of efficiency at the city level follows the characteristic of "East > West > Central", while the GTFP at the inter-provincial level is at a lower level [6], showing an upward trend overall [7]. However, the imbalance of GTFP between provinces is still prominent, specifically showing a "fast south and slow north" trend. Second, they focus on the influence mechanism of GTFP [8]. Scholars have analyzed the intrinsic mechanisms of internal structural transformation, market integration, the establishment of carbon trading pilots, and environmental regulation from the perspective of multi-dimensional heterogeneity [9–12]. In addition, key factors, such as trade openness, innovation level, urbanization, and human capital structure, affect GTFP [13–16]. Finally, they examine the association of GTFP with other systems based on a coupled coordination perspective. Specifically, it covers the coordinated operation of GTFP and digital economy,

industrial structure upgradation and new urbanization, the transformation of economic dynamics, and innovation in trade and distribution.

However, studies on VFI mainly focus on two aspects: the factors affecting VFI and the consequences of VFI. Among the studies on the factors influencing VFI, Lu and Li, 2018 explore the internal mechanism of the existence of vertical imbalance in China's fiscal system from the perspective of state governance, arguing that the lack of political incentives in improving the performance of state governance raises the VFI [17]. Li and Zhang, 2019 show that the soft budget constraint is an important mechanism leading to the increase in VFI [18]. Chu and Chi, 2018 argue that China's transfer system runs counter to traditional transfer theory, resulting in an increased degree of fiscal imbalance in China [19]. Regarding the consequences of VFI, many studies suggest that although VFI can improve the expenditure efficiency and fiscal sustainability of local governments [20,21], it reduces the quality of public services of local governments and inhibits the rationalization of industrial structure [22–26]. Specifically, regarding VFI and green development, most studies conclude that VFIs have negative effects on green development. Using data from 30 Chinese provinces from 2001–2017, Guo et al., 2020 suggest that VFI has significantly suppressed GTFP levels in China by reducing the intensity of environmental governance [27]. Huang and Zhou, 2020, based on Chinese provincial panel data for 1999–2016, find that VFI exacerbates environmental pollution in China, and there exists a positive correlation between the effect of VFI causing environmental pollution and the degree of VFI [28]. Lin and Zhou, 2021 found that VFI significantly inhibits environmental performance in China by inhibiting industrial structural upgrading and technological innovation using data from 266 prefecture-level cities in China from 2004–2016 [29]. Using provincial data for China from 2000–2017, Zhao Na et al., 2021 find that VFI significantly depresses the level of GTFP in Chinese cities by distorting factor prices [30]. In contrast, Xie and Chen, 2022, based on panel data for 246 prefecture-level and above cities in China for 2011–2017, assert that VFI has a significant positive effect on ecological welfare performance, and this enhancement is more pronounced in eastern China [31]. However, the relevant literature has certain shortcomings: (1) The time of the research data. Most data are from prior to 2018. The Chinese State Administration of Taxation issued a notice on "tax cuts and fee reductions" in 2018, triggering a serious local fiscal imbalance dilemma [32]. Therefore, excluding data after 2018 makes it impossible to analyze the impact of VFI on GTFP in the context of China's real-world situation. (2) Research content. Existing studies do not explore green development indicators from the perspectives of GEC and GTC and, thus, cannot provide information for local governments working under the target accountability system in China. (3) Limitations of research methods. The existing studies focus on the linear relationship between VFI and GTFP but do not explore how VFI affects GTFP from the perspective of spatial effects.

Thus, the possible contributions of this study to the existing literature are as follows: (1) It selects the period from 2004 to 2019 and includes important time points, such as the implementation of the "tax and fee reduction" policy in 2018, which helps to better explore the effect of the gradual increase of fiscal pressure on China's GTFP in recent years. (2) It further refines the indicators of GTFP variables, separately examines the effect of VFI on GEC and GTC, and enriches the depth and breadth of research on VFI theory. (3) It empirically examines the relationship between Chinese-style VFI and GTFP, filling the gap in the study of the spatial effects of VFI on GTFP.

3. Theoretical Analysis

As China's fiscal decentralization system is a non-normative de facto decentralization arrangement, local government officials must not only follow the administrative instructions of their superiors but also pursue the maximization of their interests. That is, in the context of VFI, local governments face a dilemma in meeting the functional requirements of improving GTFP and relieving fiscal pressure [33]. Therefore, we argue that, theoretically, VFI can act on GTFP in both positive and negative directions.

3.1. Positive Effect of Moderate Vertical Fiscal Imbalance on GTFP

As China's fiscal system shifted from a highly centralized system under the planned economy to a modern fiscal decentralized system, local governments were given some incentives to gradually increase GTFP under their jurisdictions as the degree of VFI increased. The main reasons for this are the following: (1) Guiding effect. Under the condition of moderate VFI, local governments tend to efficiently use funds to perform their functions, thus optimizing the allocation of public resources and improving GTFP while accomplishing the goals set by the central government. (2) Incentive effect. A moderate VFI also means that local governments face a certain degree of fiscal pressure and have more information advantages than the central government simultaneously, impelling them to formulate economic and social development policies according to local conditions, promote the rational allocation of resources, and, thus, improve GTFP [34]. (3) The regulating effect of special funds. The central government has set up a large-scale transfer payment system to alleviate the gap between local fiscal revenues and expenditures and coordinate the balance of revenues and expenditures of local governments by establishing special funds. These funds are used for developing local economic and social undertakings, such as infrastructure, education and science, social security, and environmental protection, and, thus, promote green production by providing fiscal support to local governments.

3.2. Negative Effect of Excessive Vertical Fiscal Imbalance on GTFP

Excessive VFI can cause distortions in local government's behavior, which is detrimental to their ability to improve governance and efficient market operation. Specific paths include the following: (1) Crowding out effect. When the fiscal pressure increases owing to high VFI, local governments surreptitiously spend most of the fiscal funds on "short and quick" projects, such as infrastructure investment and investment in automobile manufacturing and development of the real estate industry, to quickly obtain obvious political achievements and high revenue to neutralize the fiscal gap. However, this investment bias not only crowds out the local government's fiscal expenditure in the green development area but also leads to duplicate construction and overcapacity, thus negatively affecting GTFP. (2) The "sticky paper" effect. When the central government provides local governments with abundant special fiscal support, it softens the fiscal budget constraints of local governments, leading to strong "fiscal illusion" and "bailout expectations" of local governments. Under the performance appraisal system based on local GDP, local officials deviate fiscal resources heavily toward productive areas to improve their performance, resulting in insufficient investment in education, innovation, and environmental protection, which weakens the drive to improve GTFP in the long run.

However, according to the available literature [35], the level of VFI in China is already above the threshold. Therefore, we propose the following hypothesis:

Hypothesis 1 (H1). *An increase in the level of VFI among governments inhibits the increase in the level of GTFP.*

3.3. Negative Spatial Effect of Vertical Fiscal Imbalance on GTFP

The spatial spillover effect of VFI affecting GTFP is essentially the environmental externality it generates. Faced with the double pressure of "upward responsibility" and "political promotion", local governments under the VFI system not only engage in rough competition to attract investments but also blindly introduce various advanced technologies, talents, and other factors related to green development. This excessive pursuit of the interests of a single administrative division greatly hinders the free flow and efficient use of factors and creates a low-quality distribution of green development factors among different places. Such a state of distribution is not conducive to the formation of a long-term mechanism for green development. Owing to its insufficient division of labor, the low-quality reuse of green development factors among regions cannot guarantee efficient supply for achieving the goals of large-scale economic production and ecological management.

Thus, it cannot form an effective correlation mechanism with the green development of neighboring regions and generates positive spatial spillover effects.

Based on the above analysis, we propose the following hypothesis:

Hypothesis 2 (H2). *Excessive VFI leads the local government to introduce barriers to factor mobility and intensify market segmentation, which adversely affects both local and neighboring regions' GTFP.*

4. Model Setting, Variable Descriptions, and Data Source

4.1. Econometric Model Setting

4.1.1. Effect of VFI on Both GTFP and Its Decomposition Term

To identify the effect of the core explanatory variable of VFI on both GTFP and its decomposition term, referring to the study of Li et al., 2022 [36], we propose the following model:

$$GTFP_{it} = \alpha_0 + \beta_0 VFI_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{1}$$

$$GEC_{it} = \alpha_1 + \beta_1 VFI_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{2}$$

$$GTC_{it} = \alpha_2 + \beta_4 VFI_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{3}$$

where t and i represent the year and province subscripts, respectively. $GTFP_{it}$, GEC_{it}, and GTC_{it} denote GTFP, GEC, and GTC, respectively; VFI (VFI_{it}) is the core explanatory variable in the model; X_{it} denotes the control variable, which includes human capital (EDU), urbanization (URB), industrialization (IND), level of real foreign investment utilization (FDI), and government intervention (GOV); α_0, α_1, and α_2 denote the constant terms; μ_i and λ_t denote the individual and time effects; and ε_{it} denotes the random disturbance term.

4.1.2. Spatial Spillover Effect

Next, spatial factors are included in the effect of VFI on GTFP to verify the role of VFI on GTFP in the surrounding areas. Following the steps of spatial econometric analysis, the spatial autocorrelation of VFI is tested using the global Moran index (Moran's I), as shown in Equation (4):

$$Moran's\ I = \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \left(Y_i - \overline{Y} \right) \left(Y_j - \overline{Y} \right) / S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \tag{4}$$

In Equation (4), $S^2 = \left(\frac{1}{n} \right) \sum_{i=1}^{n} \left(Y_i - \overline{Y} \right)$, $\overline{Y} = \left(\frac{1}{n} \right) \sum_{i=1}^{n} Y_i$, n is the number of provinces, Y_i is the observed value (here, it is VFI) of province i, and W denotes the spatial weight matrix. Moran' I take values within the $[-1, 1]$ interval range, and its index values greater than 0, less than 0, and equal to 0 indicate that the observed variable is spatially positively correlated, spatially negatively correlated, and spatially uncorrelated, respectively. There are three main types of spatial weight matrices to be constructed: first, the geographic distance spatial weight matrix (W^1), where the element W_{ij} in the matrix represents the inverse of the geographic distance between provinces measured based on latitude and longitude; second, the economic distance spatial weight matrix (W^2), where the element W_{ij} represents the inverse of the per capita GDP distance between provinces for 2004–2019; third, the economic, geographic nested spatial weight matrix (W^3), with reference to the study of Han and Li, 2019 [37], $W^3 = 0.5W^1 + 0.5W^2$.

After testing the spatial correlation of VFI, a spatial panel model is constructed to analyze whether there is a spatial spillover effect of VFI on the effect of GTFP. We choose the spatial Durbin model (SDM) to estimate the spatial spillover effect of VFI on GTFP. The basic form of the model is

$$GTFP_{it} = \rho \sum_{j=1}^{N} W_{ij} GTFP_{jt} + \beta_1 VFI_{it} + \beta_2 EDU_{it} + \beta_3 URB_{it} + \beta_4 IND_{it} + \beta_5 FDI_{it} + \beta_6 GOV_{it} +$$
$$\theta_1 \sum_{i \neq j, j=1}^{N} W_{ij} VFI_{it} + \theta_2 \sum_{i \neq j, j=1}^{N} W_{ij} EDU_{it} + \theta_3 \sum_{i \neq j, j=1}^{N} W_{ij} URB_{it} + \theta_4 \sum_{i \neq j, j=1}^{N} W_{ij} IND_{it} + \quad (5)$$
$$\theta_5 \sum_{i \neq j, j=1}^{N} W_{ij} FDI_{it} + \theta_6 \sum_{i \neq j, j=1}^{N} W_{ij} GOV_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$
$$\varepsilon_{it} = \varphi \sum_{i \neq j, j=1}^{N} W_{ij} \varepsilon_{jt} + \xi_{it}$$

where W_{ij} is the spatial weight matrix, ρ represents the spatial autoregressive coefficient, φ represents the spatial autocorrelation coefficient, β and θ are the coefficients of the explanatory variables and their spatial lagged terms, respectively.

4.2. Variable Descriptions

(1) Explained variable: GTFP. Accurate measurement of GTFP is the key to validating results from the empirical analysis. Referring to the existing study [38], we use the Global Malmquist–Luenberger index method based on the SBM directional distance function, which is an input–output analysis method, to calculate GTFP.

In the input and output screening indicators, physical capital, human capital, and energy consumption are used as inputs, gross regional product as desired output, and industrial sulfur dioxide, wastewater, and general industrial solid waste emissions as undesired outputs. Human capital consumption is measured by the number of people employed at the end of the year in each province, and the capital stock is measured using the "perpetual inventory method" [39]. The calculation formula is $K_{it} = I_{it} + (1 - \delta_{it}) K_{it-1}$. The regional GDP, which represents the desired output, is expressed in real terms using 2004 as the base year after converting the GDP index for each location.

(2) Core explanatory variable: VFI. Given the significant asymmetry of Chinese decentralization under political centralization and the fact that this asymmetry of decentralization leads to a relatively higher VFI in China than that in Western federal countries, this study defines VFI as the asymmetric gap between local government's revenues and expenditures under the decentralized system. Drawing on the measurement method proposed by Chu and Chi, 2018 [19], the formula for measuring VFI indicators in this study is shown in Table 1.

Table 1. Vertical fiscal imbalance measurement formulas.

Indicator Name	Formula	Variable Meaning
Fiscal vertical imbalance	$VFI = 1 - \frac{FRD}{FED} \times (1 - LBD)$	VFI: Fiscal vertical imbalance FE_i: Local government public budget expenditure FR_i: Local government public budget revenue FE_c: Central government public budget expenditure FR_c: Central government public budget revenue FED: Fiscal expenditure decentralization FRD: Fiscal revenue decentralization LBD: Local government fiscal self-sufficiency gap rate POP_i: Total local population POP_n: Number of people in the country

(3) Control variables: Based on the principles of data availability and validity, and drawing on Guo et al., 2023 [40] and Liu et al., 2023 [41], we identified the control variables from the micro and macro perspectives as follows. From a micro perspective, human capital (EDU) and urbanization (URB) have an important effect on GTFP, and the average years of education of the population above 6 years and the share of the urban population in the total population in each province are selected to measure the human capital status and urbanization level, respectively. From a macro perspective, industrial structure, the level of real foreign capital utilization, and government intervention are the important factors that affect GTFP. For measuring industrialization (IND), we use the output value of the secondary industry as a percentage of GDP; for measuring the level of actual foreign

investment utilization (FDI), we use the total actual foreign direct investment utilization as a percentage of GDP; and for measuring government intervention (GOV), we use the share of government fiscal expenditure in GDP.

4.3. Data Source

The province-level data used in this study is mainly from the China Statistical Yearbook, China Energy Statistical Yearbook, China Population and Employment Statistical Yearbook, and provincial statistical yearbooks for all years. As specific data on the three industrial wastes (i.e., related to undesired output) in each province are unavailable after 2019, our study period is 2004–2019. We excluded data for Tibet, Hong Kong, Macau, and Taiwan due to data unavailability and processed missing values using linear interpolation. To eliminate the effect of price factors, the data measured in monetary terms are deflated using the GDP index of each province (2004 = 100). The descriptive statistics of each variable are shown in Table 2.

Table 2. Descriptive statistics of variables.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GTFP	480	1.449	0.564	0.608	4.979
VFI	480	0.681	0.194	0.149	0.938
IND	480	0.457	0.084	0.162	0.615
EDU	480	8.765	1.017	6.378	12.782
GOV	480	0.231	0.108	0.089	0.758
FDI	480	0.025	0.022	0	0.121
URB	480	0.535	0.141	0.263	0.896

5. Results

5.1. Analysis of the Results of GTFP Measurement

We measure the GTFP index of 30 Chinese provinces with the help of MATLAB 2021b software and further decompose it into the GEC and GTC indices to elaborate on the green development status and analyze the reasons for the change in GTFP.

5.1.1. Trends in GTFP

Figure 1 indicates that China's GTFP shows an overall upward trend throughout the sample period. The slow decline of GTFP from 2004 to 2006 may be attributed to China's accession to the WTO in 2000, becoming the world's largest factory, and undertaking rough economic growth; for example, heavy industry accounted for 69% of total industrial output in 2005 [42], indicating the characteristics of over-industrialization; after 2007–2014, it increased every year mainly because China increased environmental regulation and focused on energy conservation and emission reduction in 2006, prompting some polluting enterprises to reduce production or withdraw from the market or increase the use of green technology due to the push-back mechanism, thus increasing GTFP. The decomposition results of GTFP show that the cumulative growth rates of GTC and GEC were 138.9% and 1.1%, respectively. Thus, we observe that the change of GTFP in China relies more on the "growth effect" of technological progress and lacks the "horizontal effect" of technical efficiency.
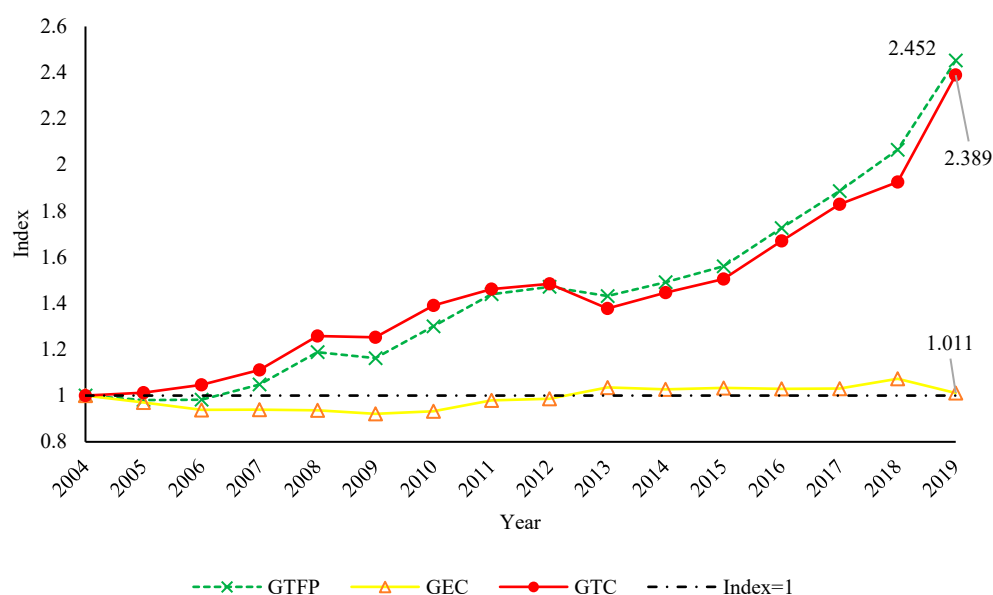
Figure 1. Changes in China's GTFP index and its decomposition term from 2004–2019.

5.1.2. GTFP Measurement Results and Its Decomposition

Table 3 shows the GTFP indices and their decomposition indices for 30 provinces in China during the sample period. All provinces show different degrees of growth in all types of indices. Most provinces indicate different degrees of increase in GTFP throughout the sample period. Among them, Inner Mongolia has the highest average annual growth rate of GTFP (126.5%), and Heilongjiang has the lowest average annual growth rate of GTFP (−8%). We further observe that the technical efficiency of most provinces declined significantly while the technical progress of all provinces improved significantly throughout the sample period, again confirming that the change in China's GTFP relies more on the "growth effect" of technical progress than on the "horizontal effect" of technical efficiency.

Table 3. GTFP index and its decomposition term for 30 Chinese provinces.

Province	GTFP	GEC	GTC	Province	GTFP	GEC	GTC
Beijing	1.776	1	1.776	Henan	1.13	0.847	1.332
Tianjin	1.76	1.125	1.51	Hubei	1.388	1.02	1.34
Hebei	1.386	0.994	1.387	Hunan	1.377	1	1.357
Shanxi	1.185	0.828	1.424	Guangdong	1.307	0.971	1.361
Inner Mongolia	2.265	1.311	1.695	Guangxi	1.154	0.874	1.316
Liaoning	1.551	1.121	1.355	Hainan	1.384	0.893	1.564
Jilin	1.287	0.917	1.375	Chongqing	1.795	1.225	1.428
Heilongjiang	0.92	0.748	1.27	Sichuan	1.387	1.022	1.339
Shanghai	1.679	1	1.679	Guizhou	1.4	0.989	1.404
Jiangsu	1.816	1.017	1.706	Yunnan	1.098	0.849	1.298
Zhejiang	1.367	0.903	1.545	Shaanxi	1.404	1.044	1.335
Anhui	1.329	1.008	1.317	Gansu	1.075	0.827	1.326
Fujian	1.144	0.87	1.317	Qinghai	1.594	0.932	1.712
Jiangxi	1.543	1.103	1.398	Ningxia	1.913	1.31	1.425
Shandong	1.764	1.07	1.637	Xinjiang	1.288	0.883	1.484

5.2. Analysis of Regression Results

5.2.1. Analysis of Baseline Regression Results

Based on Equations (1)–(3), the test results of the relationship between VFI and GTFP are shown in Table 4. We conducted the fixed effects F test, LM test, and Hausman test, and the fixed effects model is the optimal model (Table 4). The regression results of columns (1)–(3) show that the effect of VFI on GTFP has a 1% significance level, indicating that VFI

in China has a negative inhibitory effect on GTFP. This is mainly reflected in the negative effect on the GEC index but not on the GTC index, indicating that VFI in China mainly reduces GTFP through the path of suppressing the GEC index, which is consistent with the conclusion of Wei, Gu, and Wei, 2021 [43]. That is, VFI can lead to negative technology spillovers. Hence, hypothesis 1 is verified. This is because, in the face of the fiscal gap caused by VFI, local governments increase macro-taxes in order to obtain more fiscal revenue, which can offset the incentive of enterprises to develop new products and apply new technologies, thus reducing the GEC of the whole society. Another reason may be that because innovation and inventions have large externalities, the region receives less than the society as a whole, which leads to the reluctance of local governments to invest a larger proportion of their fiscal resources in green science and technology innovation, which is detrimental to GTC but has not yet developed to the point of inhibiting GTC (Zhao, 2008) [44]. It is worth noting that the negative impact of VFI on GEC is more significant compared to the negative impact of VFI on GTFP, suggesting that the current imbalanced fiscal system in China is in a more severe state of suppression of GEC, which is a key point of concern for the Chinese authorities.

Table 4. Test of the relationship between VFI and GTFP.

	(1)	(2)	(3)
	GTFP	**GEC**	**GTC**
VFI	−1.112 **	−0.688 ***	−0.165
	(0.445)	(0.169)	(0.256)
IND	1.400 ***	0.817 ***	0.293
	(0.404)	(0.153)	(0.233)
EDU	0.208 ***	0.023	0.141 ***
	(0.073)	(0.028)	(0.042)
GOV	−0.623	−0.483 ***	0.263
	(0.387)	(0.147)	(0.223)
FDI	−5.728 ***	−1.739 ***	−1.861 ***
	(1.059)	(0.402)	(0.610)
URB	−2.075 ***	0.010	−2.326 ***
	(0.625)	(0.237)	(0.360)
Year	Yes	Yes	Yes
Province	Yes	Yes	Yes
_cons	0.612	1.025 ***	0.890 **
	(0.763)	(0.290)	(0.440)
F-test	19.01	27.13	15.67
(prob)	(0.000)	(0.000)	(0.000)
LM-test	575.90	1121.03	255.65
(prob)	(0.000)	(0.000)	(0.000)
Hausman-test	108.63	31.64	121.47
(prob)	(0.000)	(0.000)	(0.000)
N	480	480	480
R^2	0.746	0.307	0.870

Note: ** and ***, respectively, represent significance at the level of 5% and 1%.

5.2.2. Robustness Tests and Endogeneity Issues

To ensure the robustness of the baseline regression results, we use the following approach to perform robustness tests. First, shrink the explained variable. We reject the explanatory variables at the 1% and 99% quartiles to mitigate the effect of outliers on the estimation results, and the results are presented in column (1) of Table 5. Second, change the core explanatory variable. We select the fiscal gap rate as a proxy variable for VFI, and the result is shown in column (2) of Table 5. Third, change the sample. The observations in 2004 and 2019 are excluded, and the regression result is shown in column (3) of Table 5. Finally, the exogenous shocks test. We choose the implementation of the "business tax replaced with VAT reform" policy in 2016 as the exogenous policy shock and define the

relevant dummy variable (year_2016): 0 in 2004–2016 and 1 in 2016–2019, and the result is shown in column (4) of Table 5. The results of the above four robustness tests show that the parameter estimates and significance levels of the main explanatory variables do not change significantly compared to the baseline tests, confirming the robustness and reliability of the conclusions of the previous baseline tests.

Table 5. Tests on robustness and endogeneity.

	(1)	(2)	(3)	(4)	(5)	(6)
	Shrunken the Explained Variable	Change the Core Explanatory Variable	Change the Sample	Consider Exogenous Shocks	IV	Lag Control Variables
VFI	−1.559 ***	−1.326 ***	−1.316 ***	−1.174 ***	−4.750 ***	−0.971 ***
	(0.323)	(0.409)	(0.288)	(0.444)	(1.586)	(0.294)
IND	1.082 ***	1.486 ***	1.368 ***	1.271 ***	0.647	1.280 ***
	(0.295)	(0.394)	(0.263)	(0.407)	(0.730)	(0.261)
EDU	0.064	0.206 ***	0.037	0.175 **	0.196	0.099 **
	(0.054)	(0.073)	(0.047)	(0.075)	(0.162)	(0.047)
GOV	−0.487 *	−0.427	−0.336	−0.477	−1.232	−0.266
	(0.279)	(0.384)	(0.244)	(0.392)	(0.749)	(0.247)
FDI	−3.964 ***	−5.724 ***	−3.766 ***	−5.592 ***	−9.017 ***	−3.329 ***
	(0.781)	(1.032)	(0.705)	(1.057)	(2.714)	(0.717)
URB	−0.792 *	−1.871 ***	−0.901 **	−1.413 **	−3.269 *	−0.810 *
	(0.468)	(0.617)	(0.415)	(0.701)	(1.937)	(0.424)
year_2016				1.865 ***		
				(0.192)		
VFI × year_2016				−0.363 **		
				(0.176)		
Year	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
_cons	1.596 ***	0.356	1.522 ***	0.661		0.738
	(0.557)	(0.676)	(0.467)	(0.761)		(0.486)
N	472	480	420	480	450	450
R^2	0.817	0.748	0.850	0.748	0.702	0.827

Note: *, ** and ***, respectively, represent significance at the level of 10%, 5% and 1%.

Measurement errors, omitted variables, and two-way causality may lead to endogeneity problems. Therefore, 2SLS estimation with a one-period lagged VFI as the instrumental variable is considered for the test, and the over-identification test is not conducted owing to the appropriate identification of the instrumental variable. The test result is shown in column (5) of Table 5. The Cragg–Donald Wald F-statistic is 83.134, which is greater than the critical value of the Stock–Yogo weak instrumental variables test of 16.38, which indicates that there is no problem with weak instrumental variables. In addition, this study lags control variables other than VFI by one period to test the effect of VFI on GTFP, as shown in column (6) of Table 5. The regression results show that the effect of VFI on GTFP is still significant and negative after controlling for endogeneity, indicating that our conclusion always holds regardless of endogeneity. These results again validate hypothesis 1.

In addition, relative to the coefficient of VFI in column (1) of Table 4, which has an absolute value of 1.112, we find that the coefficients of VFI in columns (4) and (5) of Table 5 are larger, with absolute values of 1.174 and 4.750, respectively. This suggests that (1) since China's policy of "business tax replaced with VAT reform" in 2016, local governments are under increasing fiscal pressure to actively invest in energy conservation and environmental protection, and areas with more profitable growth have become their primary choice. (2) There is a lag in the inhibitory effect of VFI on GTFP.

5.2.3. Heterogeneity Test

To deeply analyze the diversified characteristics of the effect of VFI on GTFP and empirically test the heterogeneous effect of VFI on GTFP, we classify and regress the economic growth target, market environment, and the degree of VFI separately in panel A of Table 6.

Table 6. Heterogeneity test.

	Panel A					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Low Target	**High Target**	**Low Marketization**	**High Marketization**	**Low VFI**	**High VFI**
VFI	0.749	−2.519 ***	−2.555 ***	−0.370	−0.803	−2.753 ***
	(1.002)	(0.451)	(0.592)	(0.779)	(0.753)	(0.656)
IND	1.355	0.673 *	1.374 ***	−0.175	0.416	1.540 ***
	(0.996)	(0.376)	(0.492)	(0.782)	(0.812)	(0.378)
EDU	0.268 *	−0.034	−0.083	0.365 ***	0.332 ***	−0.010
	(0.142)	(0.072)	(0.085)	(0.124)	(0.127)	(0.075)
GOV	−1.067	−0.047	−0.198	1.706	0.902	−0.179
	(1.119)	(0.302)	(0.398)	(1.514)	(1.310)	(0.360)
FDI	−2.354	−4.302 ***	−5.947 **	−4.796 ***	−4.861 ***	−4.960 **
	(2.059)	(1.262)	(2.364)	(1.620)	(1.548)	(2.171)
URB	−2.566 *	1.317 *	1.345	−1.780 *	−1.490	−0.274
	(1.345)	(0.746)	(1.084)	(0.941)	(0.997)	(0.737)
Year	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−0.793	2.293 ***	2.717 ***	−0.867	−0.612	2.804 ***
	(1.675)	(0.723)	(0.921)	(1.254)	(1.304)	(0.867)
N	229	251	240	240	240	240
R^2	0.636	0.777	0.776	0.765	0.740	0.848
	Panel B					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Eastern	**Midwest**	**Resource-Based**	**Non-Resource Based**	**Municipalities**	**Non-Municipalities**
VFI	0.483	−2.335 ***	−1.683 **	−0.648	0.123	−1.168 ***
	(0.876)	(0.502)	(0.709)	(0.616)	(1.715)	(0.443)
IND	−1.885	1.622 ***	1.899 ***	0.739	0.179	1.401 ***
	(1.147)	(0.363)	(0.555)	(0.638)	(1.842)	(0.387)
EDU	0.355 **	0.060	0.016	0.256 ***	0.462	−0.007
	(0.155)	(0.068)	(0.113)	(0.098)	(0.290)	(0.076)
GOV	0.898	−0.459	−0.239	−0.316	0.643	−0.337
	(1.541)	(0.347)	(0.836)	(0.493)	(2.459)	(0.356)
FDI	−3.277 *	−9.232 ***	−7.878 ***	−5.152 ***	−6.569 *	−5.017 ***
	(1.719)	(1.901)	(1.921)	(1.431)	(3.870)	(1.031)
URB	−1.130	0.124	−0.201	−2.257 **	0.600	−0.023
	(1.220)	(0.752)	(0.934)	(0.888)	(1.938)	(0.759)
Year	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−0.658	1.819 **	1.502	0.298	−3.679	1.440 *
	(1.646)	(0.754)	(1.224)	(1.030)	(2.372)	(0.809)
N	176	304	176	304	64	416
R^2	0.726	0.844	0.834	0.717	0.880	0.762

Note: *, ** and ***, respectively, represent significance at the level of 10%, 5%, and 1%.

Chinese government departments at all levels annually release various economic growth targets to manage the economy of the regions under their jurisdiction, such as the "doubling of gross national product" as the central theme of the policy agenda promulgated by the 12th–18th Party Congresses. The Chinese central government's economic growth target for 2023 is approximately 5%, and local governments usually set their economic growth target higher than the benchmark targets of the higher government levels and reflect them in the government work reports issued at the beginning of each year. The competition among local governments due to VFI intensifies, and the economic management policies of local governments, which "focus on ensuring rapid GDP growth while ignoring resource conservation, pollution control, and environmental protection," become evident owing

to the economic growth target constraint [45]. To examine whether differences in the economic growth targets set by local governments affect the relationship between VFI and GTFP, referring to related studies [46,47], we set the economic growth target variable based on each province's annual government work report. Specifically, the values are derived directly when the province has a clear expected regional GDP growth target (i.e., GDP growth target) for the year, and the average value is considered when the GDP growth target for the year is an interval target. We run group regressions according to the median of the economic growth target variables differentiated into a low economic growth target group and a high economic growth target group. The regression results are shown in columns (1) and (2). In the low economic growth target group, the estimated coefficient of VFI is non-significant; in the high economic growth target group, the estimated coefficient of VFI is significantly negative at the 1% level. The above results indicate that the economic growth target constraint exacerbates the inhibitory effect of VFI on GTFP, and the higher the pressure of economic growth faced by local governments, the more they expend limited fiscal revenues on short-term investment projects to achieve economic growth targets ignoring sustainable economic development, which hinders the improvement of GTFP.

The advancement of marketization affects local fiscal competition, fiscal budget cycle, and fiscal policy cycle [48]. Therefore, we adopt the marketization index from the NERI INDEX of Marketization of China's Provinces Report (Wang et al., 2021) [49] to measure the market environment. We use the 50% quantile of the marketization index for 2004–2019 as the cut-off line, where a larger value indicates a weaker intensity of local government intervention in the market, and a smaller value indicates a stronger intensity of local government intervention in the market. The regression results, shown in columns (3) and (4), reveal that the coefficient of VFI of the sample group with a low marketization index is negative and passes the significance test, while the coefficient of VFI of the sample group with high marketization index is also negative but non-significant. This reflects that VFI in highly marketized areas does not hinder the growth of GTFP, while VFI in low marketized areas inhibits the growth of GTFP. This is because in areas with a high degree of marketization, as the government gradually withdraws from intervention in economic activities, the macro market environment improves, the market's ability to allocate resources increases, and the structure of fiscal expenditure aligns with the requirements of green development, thus weakening the negative effect of VFI.

To verify the differential impact of different degrees of VFI on GTFP, we use the 50% quantile of the VFI indicator for 2004–2019 as the cut-off line and include provinces above this value in the high VFI group and those below this value in the low VFI group for group regression. The regression results are shown in columns (5) and (6), indicating that the estimated coefficient of VFI for the high VFI group is significantly negative, while the VFI for the low VFI group, although negative, does not pass the significance test. This indicates that the negative effect of VFI on GTFP becomes considerably significant as the degree of VFI deepens.

Additionally, we create subsamples and conduct a multi-dimensional heterogeneity analysis of the effect of VFI on GTFP from three perspectives: economic development level, resource endowment, and administrative level. The regression results are shown in panel B of Table 6. According to the regression results in columns (1) and (2), VFI significantly reduces GTFP in the central and western regions, which are the economically underdeveloped regions in China, while it has no significant effect on GTFP in the eastern region, which is the economically developed region in China. This is because the eastern region has an early start in economic development, a high level of economic development, and sufficient fiscal resources; therefore, when local governments respond to the national economic transformation and development requirements to focus on ecological and environmental protection, their fiscal strengths accompanying their economic advantages mitigate the negative impact of VFI on GTFP. According to the regression results of resource endowment heterogeneity in columns (3) and (4), the inhibitory effect of increasing the degree of VFI is more pronounced for GTFP in resource-based cities relative to non-resource-based

provinces. This is because with the widening fiscal gap caused by VFI, local governments in resource-based provinces have more incentives to develop resource-based industries to promote their economic growth with the comparative advantage of the region, leading to excessive energy consumption and increased pollutant emissions, thus inhibiting the green development of resource-based provinces [50]. According to the regression results of administrative level heterogeneity in columns (5) and (6), VFI is inhibited by a significant effect on GTFP in non-municipality areas, while there is no significant effect on GTFP in Chinese municipalities. This is because most municipalities in China have new industries, such as artificial intelligence and satellite applications, and the relationship between their regional output value and energy consumption and environmental pollution is weak, which weakens the impact of VFI on GTFP.

5.2.4. Analysis of Spatial Spillover Effect

Table 7 reports Moran's I of VFI, which shows that the VFI has a positive spatial correlation regardless of the spatial weight matrix and passes the significance test. This indicates that VFI has a significant "contagion" characteristic; that is, an increase in VFI in one region will significantly drive the level of VFI in neighboring regions. This finding provides data support for constructing a panel spatial econometric model later to empirically test the spatial effect of VFI on GTFP.

Table 7. Moran's I of VFI.

Year	W^1		W^2		W^3	
	Moran's I	p-Value	Moran's I	p-Value	Moran's I	p-Value
2004	0.371	0.000	0.398	0.000	0.550	0.000
2005	0.403	0.000	0.421	0.000	0.604	0.000
2006	0.382	0.000	0.405	0.000	0.583	0.000
2007	0.372	0.000	0.428	0.000	0.594	0.000
2008	0.366	0.000	0.424	0.000	0.584	0.000
2009	0.362	0.000	0.426	0.000	0.583	0.000
2010	0.374	0.000	0.414	0.000	0.587	0.000
2011	0.370	0.000	0.429	0.000	0.595	0.000
2012	0.380	0.000	0.417	0.000	0.593	0.000
2013	0.386	0.000	0.417	0.000	0.595	0.000
2014	0.371	0.000	0.417	0.000	0.584	0.000
2015	0.400	0.000	0.422	0.000	0.607	0.000
2016	0.394	0.000	0.428	0.000	0.596	0.000
2017	0.398	0.000	0.421	0.000	0.588	0.000
2018	0.389	0.000	0.418	0.000	0.579	0.000
2019	0.401	0.000	0.423	0.000	0.580	0.000

Table 8 reports the results of the spatial regression models of VFI on GTFP under three different spatial weight matrices. The regression results show that the coefficient of the spatial lag term ρ is significantly positive under both the geographic distance spatial weight matrix (W^1) and economic–geographic nested spatial weight matrix (W^2), while the coefficient is non-significant in the corresponding model estimation under the economic distance weight matrix (W^3). This is because regions with similar levels of economic development usually have competitive relationships in attracting factors of production, such as labor, capital, and technology. With the improvement of network and transportation facilities among regions in China and the construction of universities and a unified market, the regions with more competitive advantages in terms of policy and location are more likely to form a "siphon effect" when the total supply of various factors of production is certain for a fixed period, and, thus, cannot show significant positive spatial spillover effects. In the three models, the coefficients of VFI are significantly negative, and the coefficients of the spatial lag of VFI are mostly negative and pass the significance test in the W^2-based model. This indicates that VFI suppresses both the increase of local GTFP

and GTFP in provinces with similar economic development levels to some extent. This conclusion is consistent with the predictions of the previous theoretical section, and thus, hypothesis 2 is verified.

Table 8. Spatial Durbin model regression results for VFI and GTFP.

	(1)	(2)	(3)
	W^1	W^2	W^3
VFI	−1.351 ***	−0.812 *	−0.899 **
	(0.406)	(0.423)	(0.407)
IND	1.297 ***	1.343 ***	1.476 ***
	(0.374)	(0.383)	(0.356)
EDU	0.203 ***	0.130 *	0.168 **
	(0.066)	(0.070)	(0.067)
GOV	−0.596	−0.308	−0.101
	(0.391)	(0.371)	(0.368)
FDI	−5.329 ***	−5.173 ***	−4.495 ***
	(0.995)	(0.991)	(0.972)
URB	−0.773	−1.247 **	−0.440
	(0.654)	(0.631)	(0.673)
Wx:			
VFI	0.082	−2.842 ***	−0.356
	(0.982)	(1.055)	(0.746)
IND	−2.478 ***	1.231	−1.288 **
	(0.805)	(1.014)	(0.645)
EDU	0.546 ***	−0.112	0.218
	(0.163)	(0.182)	(0.141)
GOV	−0.341	−4.006 ***	−1.539 **
	(0.773)	(1.440)	(0.666)
FDI	−1.092	−0.568	1.472
	(2.650)	(4.001)	(2.370)
URB	−1.905	−4.998 **	−3.106 **
	(1.326)	(1.968)	(1.351)
Spatial:			
rho	0.368 ***	0.112	0.407 ***
	(0.066)	(0.082)	(0.058)
Variance:			
sigma2_e	0.050 ***	0.055 ***	0.049 ***
	(0.003)	(0.004)	(0.003)
N	480	480	480
R^2	0.292	0.330	0.005

Note: *, ** and ***, respectively, represent significance at the level of 10%, 5%, and 1%.

6. Conclusions and Discussion

6.1. Conclusions

This study interprets the internal mechanism of VFI and GTFP at the theoretical level and empirically tests it using a panel two-way fixed effects model and an SDM based on provincial panel data for 2004–2019 in China. We find that VFI significantly reduces the GTFP and GEC index, while there is a non-significant effect on the GTC index; these results remain robust after conducting a series of robustness tests and addressing endogeneity issues. In regions with high economic growth targets, low marketization, or high VFI and in Midwest, resource-based, or non-municipalities regions, the inhibitory effect of VFI on GTFP is more significant. We further investigate the spatial spillover effects of VFI and find that VFI not only suppresses local GTFP but also negatively affects the increase in GTFP levels in regions of similar economic strength.

6.2. Discussion

First, from the perspective of research, the existing research on the impact of the fiscal system on green development is mainly focused on fiscal decentralization [51–53] while exploring VFI as a phenomenon caused by fiscal decentralization in China [4] and its impact on GTFP is an expansion of the literature on fiscal system. Second, from the research method, most existing studies on VFI use general panel models [31,54]; however, we introduce spatial econometric models to analyze the impact of VFI on GTFP more comprehensively and also to make the regression results closer to reality. Finally, in terms of research findings, our results validate the negative impact of VFI on GTFP and likewise reveal the institutional causes of the lack of incentive for the green transformation of the Chinese economy. This supports the study of Huang and Zhou,2020, and Feng, Liu, and Li, 2023 [28,55] to a certain extent and confirms Chen and Qi's, 2022 [56] view that the "governance" function of fiscal policy in China is under-represented. Furthermore, by introducing marketization indicators, our analysis confirms that VFI has a negative impact on economic and social development by distorting factor allocation (Cui, 2023) [57]. Additionally, our findings from the heterogeneity test by classifying the degree of VFI validate the idea that excessive VFI is detrimental to sustainable economic development [58,59]. We further verify the existence of negative spatial spillover effects of VFI through the spatial weight matrix constructed based on economic distance, which indicates that the current local governments in China are still in the stage of "competition for economic factors and competition for economic growth", or there is "Race to the Bottom competition" among local governments in the field of environmental protection, which is consistent with the existing literature [60,61].

7. Theoretical and Practical Implications

7.1. Theoretical Implications

Based on a comprehensive review of existing research, we closely match the current development trend of GTFP in China, systematically construct a theoretical framework of VFI and GTFP, and empirically test the impact of VFI on GTFP to deepen and expand the existing research results on VFI and GTFP, as well as provide strong theoretical support for improving GTFP and promoting the green development of China's economy.

7.2. Practical Implications

Improving GTFP is an inevitable choice to promote the green transformation of the economy and an inevitable product of the digital economy era. A comprehensive and in-depth study of the current situation, characteristics, and trends of China's GTFP is conducive to accurate understanding and support for the improvement of GTFP from all levels of government; a systematic study of the impact of VFI on GTFP provides scientific theoretical guidance and a realistic basis for the central and local governments to formulate GTFP enhancement strategies and policy measures, thus promoting the effective improvement of GTFP.

8. Policy Implications

Based on the empirical results, we recommend the following:

(1)   The scientific division of governmental affairs at all levels to enhance GTFP. The central government and local governments should establish a reasonable power-sharing balance model according to the spillover and benefits range of different types of public services; for example, the central government and local governments should be responsible for matters related to national and local affairs, respectively, and the matters where both the central government and local governments are jointly responsible should be inclined toward the central government to improve the match between the fiscal power and affairs power of governments at all levels and narrow their fiscal gap to reduce the degree of VFI and guarantee the improvement of GTFP.

(2) Improve the performance evaluation system of officials and optimize the green development environment. The central government should build and strengthen a diversified and multi-dimensional performance appraisal system, change the traditional "GDP-based" appraisal model, and include energy consumption, environmental management, ecological restoration, and other indicators while appraising local government's performance to establish a scientific view of performance, correct the inertia of local governments' expenditure on "more investment" and "fewer people's livelihood," and insist on practicing the concept of sustainable development and continuously improving GTFP.

(3) Scientific planning of central transfer funds allocation to ensure local fiscal revenue. The proportion of general transfer payments should be increased based on region to reduce the gap between the fiscal resources of local governments and their expenditure responsibilities, strengthen the supervision of local governments, clearly define the scope of use of transfer funds, and establish special funds for green development at the central level to strengthen the protection of transfer funds in the field of green environmental protection.

(4) Local governments should choose the best economic growth target according to local conditions and time. For example, the target positioning of relatively developed regions should weaken the economic increment and strengthen the green environment target, thus releasing more spare energy toward the improvement of GTFP. Moreover, local governments need to assess the situation and implement precise measures. The government should continue to strengthen governance capacity building from the "dominant" function to the "service-oriented" function. Additionally, in a scientific, forward-looking study and judgment of the market economy regarding the operation of the problem, governments should allocate resources based on market forces and timely implement corresponding measures to promote sustainable and healthy economic development when necessary.

(5) According to the analysis of the decomposition of GTFP, GTC makes the greatest contribution. Therefore, local governments should pay attention to human capital cultivation and establish incentive mechanisms for innovative talents to enhance their innovation motivation and simultaneously should increase the investment in local technological innovation and build regional innovation alliances comprising universities, enterprises, technology intermediaries, and new R&D institutions to achieve the long-term technological innovation to promote green development.

(6) The central government should actively play a coordinating role to circumvent the problem of vicious competition caused by the short-sightedness of local governments, disintegrate local administrative barriers, actively build a regional innovation cooperation platform, and effectively integrate the green development resources of the region and other regions, thus promoting the improvement of China's overall GTFP.

This study has some limitations. It only focuses on the theoretical and empirical analysis of VFI and its specific effects on GTFP; therefore, there is scope for expansion. The mechanism through which VFI affects GTFP requires further analysis. For example, theoretical and empirical analyses of the mediating role of indicators of the consequences of VFI, such as fiscal expenditure structure, local government competition, or local government debt, and the possible moderating effects of VFI on the impact of drivers, including technological innovation, industrial structure upgradation, or environmental regulation, which are important drivers of green economic development, on GTFP. These issues should be considered as future research directions to propose more specific policy measures for sustainable economic development.

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