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The Effect of Green Urbanization on Forestry Green Total Factor Productivity in China: Analysis from a Carbon Neutral Perspective

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Abstract: Based on panel data from 30 provinces from 2001 to 2018 in China, this paper explores the effects and mechanisms of green urbanization on the forestry green total factor productivity (FGTFP) in the context of carbon neutral strategy using a two-way fixed effects model and instrumental variables. The results show that: Firstly, as a sector with ecological and economic benefits, ignoring carbon sink output tends to make FGTFP overestimated. Secondly, green urbanization has a significant positive contribution effect on FGTFP, and this finding still holds after a series of robustness tests including instrumental variables. Thirdly, green urbanization can indirectly promote FGTFP by stimulating the integration of forestry and tourism and strengthening environmental regulations. Fourthly, there is regional heterogeneity in the impact of green urbanization on FGTFP, i.e., the promotion effect of green urbanization on FGTFP is more significant in non-state forest areas compared with state-owned forest areas. Based on the above conclusions, the following countermeasures are proposed: firstly, attaching importance to green urbanization and strengthening environmental constraints; secondly, relying on green urbanization to drive the integration of forestry and tourism; thirdly, actively promoting the construction of green urbanization and green development of forestry in non-state forest areas, while vigorously developing the carbon sink economy to crack the transformation dilemma of backward state forest areas.

Keywords: green urbanization; forestry; green total factor productivity; carbon sink; carbon emissions

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1. Introduction

The continuous increase of greenhouse gases, mainly carbon dioxide, has led to an increasingly serious global climate problem. China, as a responsible country, has indicated that it will adopt stronger policies and measures to reduce its emissions or the double carbon target. China strives to peak its carbon emissions by 2030 and achieve carbon neutrality by 2060, while additionally mentioning that forest stock will increase by 6 billion cubic meters compared to 2005. When the Kyoto Protocol introduced the Clean Development Mechanism (CDM), it also highlighted the mechanism and concept of forest carbon sinks. Forestry, as a complete system encompassing primary, secondary, and tertiary industries, has both ecological and economic benefits and plays an important role in emission reduction and carbon sequestration [1–4]. According to the classification of the China Forestry Statistical Yearbook, forestry, primary industry, mainly refers to the cultivation and harvesting of timber, economic forests, and other forest products. The secondary industry refers to the processing and manufacturing of wood and non-wood forest products. The tertiary industry indicates other services such as forestry tourism and leisure services, ecological services, and technical services. The forestry industry referred to in this paper is the overall forestry sector that includes three industries. As shown in Figure 1, China's total forestry output value maintained a continuous growth trend between 2000 and 2019, mainly in the form of a halving of the forestry primary industry sector share over the two decades, from 67.2% in 2000 to 31.2% in 2019. The secondary sector grew rapidly, with a share of over 50% at one point, but has been declining since 2012. The tertiary sector has the smallest output, but its share has increased nearly sevenfold from 3.7% in 2000 to 23.9% in 2019, and it shows a continuous upward trend.

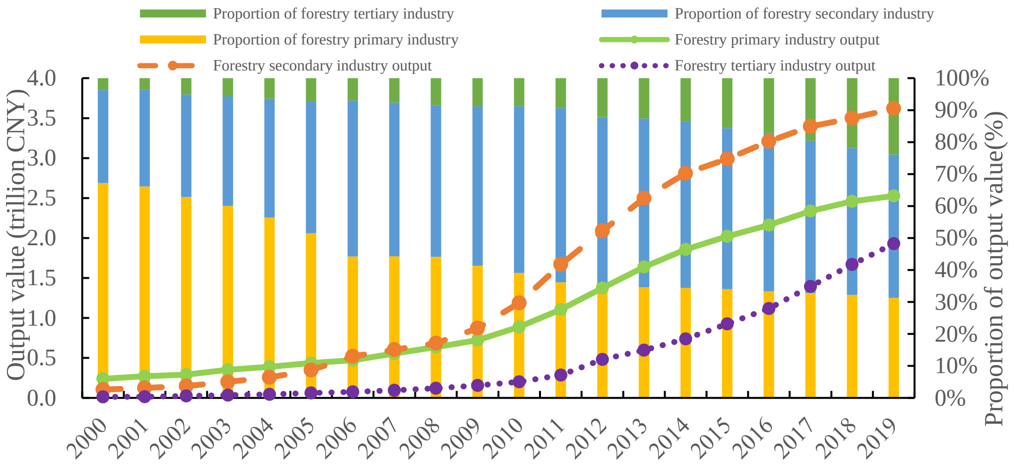

Figure 1. Output value and share of the three forestry industries from 2000 to 2019. Data Source: National Forestry and Grassland Administration, China.

In the context of the reality that China has a huge share of forestry secondary production, the carbon emission of the forestry secondary industry cannot be ignored. Studies have shown that although the forest products sector is generally clean compared to other sectors, some developing countries, including China, still have high carbon intensity emissions [5]. In particular, the paper industry in the forestry secondary industry, the world's fourth-largest energy-consuming industry, the average greenhouse gas emissions of 1 ton of paper are about 950 kg of carbon dioxide equivalent [6], which accounts for about 5.7% of the world's total industrial energy consumption [7], and its carbon emissions account for about 2% of the global industrial direct carbon emissions [8]. Moreover, China is the world's largest country in terms of total paper production and consumption. The development of the forestry secondary industry is often dependent on rapid urbanization, with China's urbanization rate rising from 17.9% in 1978 to 64.72% in 2021, creating a global miracle of rapid urbanization [9]. The boost of urbanization to the forestry secondary industry is mainly manifested in the rapid expansion of the consumer market: On the one hand, the scale of new urban housing demand so that housing renovation and decorative wood market scale; on the other hand, the scale of new urban industry demand, including paper, edible seasoning, pharmaceutical, and other industries, the rapid development of forestry chemical industry. The rapid development of forestry secondary production has brought about huge carbon emissions. Likewise, the drawbacks of traditional urbanization in China are becoming increasingly serious. Urbanization has dramatically changed land-use patterns and can have a significant impact on total carbon emissions and carbon emission efficiency, leading to a rapid increase in carbon emissions and associated climate change risks [10–13]. The consequence of these is a decline in environmental quality and the degradation of ecosystems [14]. To alleviate the severe environmental problems, the National New Urbanization Plan (2014–2020) published in China in 2014 revealed a new urbanization path with Chinese characteristics that pursues compatibility with the carrying capacity of resources and the environment [15], focusing on green and low-carbon development. Therefore, the essence of new-type urbanization is green urbanization.

From the dilemma between carbon sinks and economic development in the traditional sense to the current triple entanglement among carbon sinks, economic development, and carbon emissions, how to reconcile the contradictions among the three? Total factor productivity (TFP), which can represent the part of the output that cannot be explained by production inputs, can effectively measure the efficiency and intensity of input-output utilization and has been widely used as a measure of economic efficiency [4,16]. This paper is based on the assumption that the desired output of the forestry sector is output value and carbon sink, and the undesired output is carbon emission. Forestry green total factor productivity (FGTFP) is used as an important indicator to measure the green and low-carbon development of the forestry sector. There are two ways to mitigate the greenhouse effect, one is to reduce the carbon source and the other is to increase the carbon sink [17]. Under the great pressure and challenge of international carbon emission reduction, it has become an important path to achieve the goal of double carbon by promoting green urbanization, avoiding the lock-in effect of high carbon, further enhancing FGTFP, and bringing into play the role of the forestry sector in reducing carbon and increasing sinks. Therefore, based on the FGTFP, considering carbon emissions and carbon sinks, this paper verifies the contribution of green urbanization to FGTFP and further explores the intrinsic influence mechanism. The paper is structured as follows: Section 2 provides the theoretical analysis and presents the research hypotheses. Section 3 describes the research methodology and data sources. Section 4 gives the results of the impact effects and mechanism tests. Section 5 provides the conclusion and discussion.

2. Literature Review

2.1. Measurements and Drivers of FGTFP

The previous research has mainly focused on FGTFP measurement and its drivers. Among them, the early studies on output indicators of FGTFP measurement mostly centered on economic output, that is, forestry TFP, mainly includes data envelopment analysis (DEA) [18–21] and stochastic frontier analysis (SFA) [22–24]. With the increasing constraints on resource carrying capacity and environmental capability, more and more scholars and governments were considering green development as an important indicator for regional economic development assessment. Related research has begun to consider forestry waste gas and wastewater as undesired output [25–27]. In the context of the reality of carbon neutrality in China, carbon emissions from forestry have been less considered by scholars.

The drivers of FGTFP were mostly studied from the aspects of the economic scale, industrial agglomeration, Internet technology, and management system. Zheng, Gao and Lei [25] hold that knowledge spillover, facility sharing, and industry scale effects from industry agglomeration can enhance FGTFP. Wu and Zhang [28] have demonstrated that technological innovation and data sharing resulting from Internet technology upgrades can greatly enhance FGTFP in the short term. Chen and Yao [27] pointed out that the expansion of the economic scale, which represents a higher demand for ecological functions of forestry, is conducive to FGTFP enhancement. Liang et al. [29] based on a three-stage DEA model, it is concluded that the state-owned forest farms under the provincial management system have higher carbon sequestration function and economic performance due to the effective guarantee of financial allocation and policy implementation. In the context of China's new urbanization strategy of vigorously promoting green and low-carbon approaches, can green urbanization contribute to the improvement of FGTFP? The relationship between the two has not yet been studied by scholars.

2.2. Urbanization, Forestry Carbon Emission Reduction and Forestry Carbon Sink

In terms of urbanization as an important driver, the comprehensive indicator of FGTFP was rarely used, mostly concentrated on the relationship between urbanization and forestry emission reduction or sink enhancement. The results of the current study can be broadly summarized into three aspects. Firstly, urbanization has a negative impact on forestry emission reduction and sink enhancement. Urbanization has led to a significant increase in energy consumption, and energy development requires a large amount of land, especially forest land [30]. Zhu, et al. [31] found that from 1970 to 2010, the rapid urbanization in Zhejiang Province led to the expansion of land for construction and a dramatic decrease in the forest area. 0.86 million ha of land for construction was added in 40 years, and about 25 Tg of carbon was lost from terrestrial ecosystem storage. Urbanization has also significantly increased the rate of deforestation [32], which was detrimental to the function of forestry in reducing emissions and sequestering carbon. Secondly, urbanization has a positive impact on forestry emission reduction and sink enhancement. The improvement of land urbanization quality in the urbanization process was helpful to reduce carbon emissions [33], by promoting the construction of forest cities, which not only directly increased the green space and vegetation carbon sink, but also derived urban green development patterns. Such as green innovation and energy saving and consumption reduction, resulting in indirect effects [34]. Xu, et al. [35] used long short-term memory neural networks based on long time series panel data from 30 Chinese provinces and found that urbanization is actually a positive driver capable of forestry carbon sink growth. Thirdly, the impact of new urbanization on forestry emission reduction and sink enhancement was non-linear. Along with the rapid urbanization, the development boom and real estate boom have led to the massive expansion of construction land, which directly led to the decrease in forest land area and carbon stock. However, with the migration of the agricultural population to cities and the continuous improvement of urban management, the carbon density and forest cover rate have gradually increased again through tree planting and fertilization [36]. The above analysis provides a valuable reference for this paper to identify the relationship between green urbanization and FGTFP. However, unfortunately, the influence mechanism has not been explored in depth.

In summary, the previous literature has been fruitful in terms of reducing carbon emissions and increasing carbon sinks in urbanization and forestry, but three shortcomings remain. Firstly, the development of green urbanization attaches more importance to low-carbon development, and the traditional urbanization indicators are no longer applicable under the double carbon target. Secondly, forestry has both ecological and economic benefits, and both should be considered together. Although there is literature that considers both, most of the undesired outputs focus on forestry wastewater emissions and solid waste, and few consider carbon emissions. Thirdly, most of the studies related to the topic of this paper focus on the impact effect, and the intrinsic mechanism of action still needs further identification and verification.

To break through the limitations of previous studies, this paper attempts to explore and study the following four aspects: (1) A green urbanization index compatible with low carbon development is established, and the FGTFP under the joint constraint of carbon sink and carbon emission is adopted as the measurement index of green and low carbon development of forestry. (2) Expanded research on urbanization construction and forestry green development from the perspective of green urbanization. It enriches the research on the drivers of FGTFP and is an effective complement to the research related to green urbanization. (3) A theoretical and empirical exploration of the mechanism of action of green urbanization construction affecting FGTFP, combined with heterogeneity analysis, attempts to deconstruct the internal logical relationship between the two. (4) The application of Bartik's instrumental variables method better solves the endogeneity problem and ensures the robustness of the article's conclusions, thus providing a solid empirical basis and decision reference for better utilization of the ecological and economic benefits of the forestry sector.

3. Materials and Methods

3.1. Impact Mechanism of Green Urbanization on FGTFP

A key focus of green economic growth theory is the impact of resource use and environmental policies on economic growth. Therefore, this paper combines the theory of green economic growth and the reality of China, concluding that green urbanization may affect FGTFP through the forest-tourism integration effect and the environmental regulation effect.

3.1.1. Forest-Tourism Integration Effect

Green urbanization stimulates the integration of forestry and tourism, and thus further exploits the economic benefits of forestry on the basis of maintaining the ecological benefits of forestry and realizing the improvement of FGTFP. Forest tourism refers to sightseeing, vacation, and health tourism activities that people carry out based on resources and the environment such as forests and wetlands. The development of forest tourism is nature-based, local-led, and market-dominated, and is a process in which all three interact together. Therefore, green urbanization may influence the degree of forest tourism integration through the following three channels. (1) Environmental foundation: Green urbanization represents an adjustment to the basis of traditional urbanization, with a good ecological environment and abundant green resources as the focus. Afforestation, forest transformation, and wetland protection are actively carried out [37]. (2) Government support; There are two prerequisites for the coexistence of forestry and tourism, the first being good planning and the second being management actions that take into account the visual quality and recreational value of the environment [38]. Based on the big picture view of green urbanization, it can provide guiding, binding, and special planning for forest tourism construction from the perspective of local government, and realize integrated management of forestry, tourism, and ecological environment. (3) Consumer market: The urbanization characteristics of green urbanization itself can promote economic development, improve residents' income and optimize infrastructure, which can generate spiritual and cultural demands such as tourism. At the same time, its green connotation has led to increasing public demand for environmental services in general and a rapidly growing demand for forest services such as forest recreation activities [39].

The development of forest tourism can promote FGTFP, and the essence of forest tourism integration should be recognized: On the one hand, it is the integration based on the sustainable development of forestry. It is mainly manifested by protecting the existing natural forest vegetation and wetlands and restoring the forest resources that have suffered damage [40]. The carbon sink function of the forest is realized. Realize the ecological benefits of forestry. On the other hand, it is the broadening of the multifunctionality of forestry and the extension of the forestry industry chain. The main manifestation is that forest tourism has become the third forestry pillar industry whose annual output value exceeds trillion yuan after economic forest products and wood processing manufacturing [41]. Therefore, the economic benefits of forestry have been realized.

The above theoretical analysis suggests that green urbanization may promote forest-tourism integration by laying environmental foundations, providing government support, and opening up consumer markets. Further forest–tourism integration can enhance the ecological and economic benefits of the forestry sector, and FGTFP is enhanced. Therefore, the first research hypothesis is proposed.

Hypothesis 1 (H1): *Green urbanization can promote the integration of forestry and tourism to achieve economic and ecological benefits, which in turn promotes FGTFP.*

3.1.2. Environmental Regulation Effect

Green urbanization will increase the intensity of local environmental regulation, thereby increasing the clean production capacity of forestry, reducing forestry carbon emissions, and ultimately increasing the FGTFP. Environmental regulation tools in China are mainly divided into formal environmental regulation and informal regulation. The former includes command-and-control and market-based incentives [42]. The latter mainly relies on the level of environmental awareness of the public [43]. Green urbanization may affect the intensity of environmental regulations through the following two channels: (1) green urbanization promotes a low-carbon economy and accelerates the structural adjustment of industrialization. Formal environmental constraints from the government are further strengthened to meet the development speed and requirements of green urbanization. (2) Green urbanization enhances the concept of green, low-carbon, and sustainable development, and the informal environmental constraints are further accentuated in terms of ideology.

Under the effect of high environmental regulation, the increase of FGTFP is mainly manifested in two aspects. On the one hand, based on Porter's hypothesis theory, some enterprises meet the environmental regulation requirements through technological innovation or by changing the production structure of products to achieve carbon emission reduction while maintaining the output value. On the other hand, based on the pollution haven hypothesis, some enterprises have difficulty meeting environmental regulatory requirements and relocate to provinces with lower environmental regulation intensity by changing the production location of their products [44]. The exodus of high carbon-emitting enterprises has led to an increase in the FGTFP of the region. In addition, the increase in the intensity of environmental regulations has fundamentally reduced deforestation and maintained the carbon sink stock [45]. Therefore, the second research hypothesis is proposed.

Hypothesis 2 (H2): *Green urbanization can strengthen environmental regulations to achieve the reduction of carbon emissions and the conservation of forest resources in the forestry sector, which in turn promotes FGTFP.*

The theoretical analysis framework is shown in Figure 2.

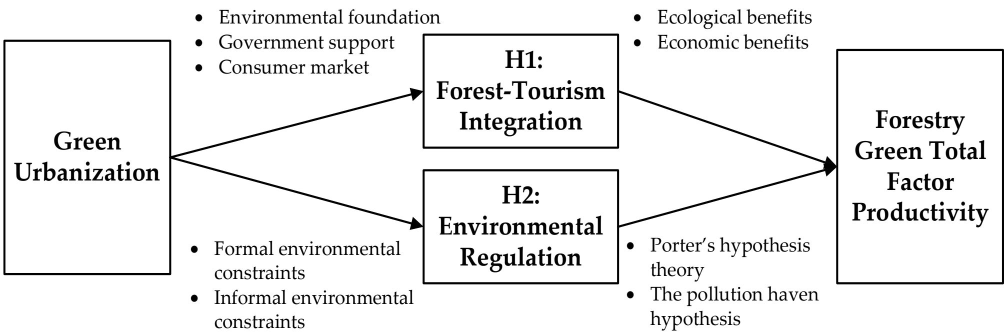

Figure 2. Theoretical framework for the impact of green urbanization on FGTFP.

3.2. Measurement of FGTFP

All The inputs of production factors in the forestry sector generate both desired outputs such as economic returns and carbon sinks, and undesired outputs such as CO_2 due to the use of fossil energy. To provide a comprehensive and realistic picture of the forestry production process, this study refers to relevant studies [46,47]. The non-radial and non-angular Super-SBM model incorporating non-desired outputs and the GML index were chosen to measure FGTFP. The method fully considers the issue of eco-efficiency and is able to reflect the dynamic changes in GTFP values between the current year and the previous year.

Assuming the existence of n provinces and construct the production frontier by treating each province as a decision unit. Each decision unit uses m input $x \in R^m$ to obtain s_1 desired output $y^g \in R^{s1}$ and s_2 undesired output $y^b \in R^{s_2}$. The matrix X, Y^g, Y^b are respectively defined as follows $X = [x_1, x_2, \cdots, x_n] \in R^{m \times n}$, $Y^g = \left[y_1^g, y_2^g, \cdots, y_n^g\right] \in R^{s1 \times n}$, $Y^b = \left[y_1^b, y_2^b, \cdots, y_n^b\right] \in R^{s2 \times n}$.

Assuming $X > 0, Y^g > 0, Y^b > 0$, the set of production possibilities can be defined as:

$$P = \left\{ \left(x, y^g, y^b\right) \middle| x \geq X\lambda, y^g \leq Y^g\lambda, y^b \leq Y^b\lambda, \lambda \geq 0 \right\} \tag{1}$$

λ is the weight vector. The three inequality equations in the production possibility function indicate that the actual input level is not lower than the frontier input level, the actual desired output level does not exceed the frontier desired output level, and the actual non-desired output level is not lower than the frontier non-desired output level. The expressions are as follows:

$$\begin{gathered}\rho^* = \min \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{S_i^-}{x_{ik}}}{1+\frac{1}{s_1+s_2}\left(\sum_{r=1}^{s1}\frac{S_r^g}{y_{rk}^g}+\sum_{r=1}^{s2}\frac{S_r^b}{y_{rk}^b}\right)} \\ \text{s.t.} \\ x_k = X\lambda + S^- \\ y_k^g = Y^g\lambda - S^g \\ y_k^b = Y^b\lambda - S^b \\ \lambda \geq 0, S^- \geq 0, S^g \geq 0, S^b \geq 0\end{gathered} \quad (2)$$

where ρ^* is the super-efficiency value of decision unit k with variable payoffs to scale, that is, the FGTFP efficiency value of province k. S^-, S^g, S^b are slack variables for input, desired output and undesired output, respectively. When $\rho^* \geq 1$ is greater than 1, the evaluated decision unit is relatively valid; when $\rho^* < 1$ is less than 1, the decision unit is relatively invalid.

The GML index was further used to evaluate the dynamics of FGTFP in the provinces. The expressions are as follows.

$$GML_k(t,s) = \frac{1 + D^G\left(x_k^t, y_k^{gt}, y_k^{bt}; y_k^{gt}, -y_k^{bt}\right)}{1 + D^G\left(x_k^s, y_k^{gs}, y_k^{bs}; y_k^{gs}, -y_k^{bs}\right)} \quad (3)$$

where, $D^G\left(x_k^t, y_k^{gt}, y_k^{bt}; y_k^{gt}, -y_k^{bt}\right), D^G\left(x_k^s, y_k^{gs}, y_k^{bs}; y_k^{gs}, -y_k^{bs}\right)$ denotes the distance function of the decision units in t and s periods when the set of production possibilities consisting of all input-output values in the study sample period is used as a common reference technology set for the different periods. When $GML_k(t,s) > 1$ means that FGTFP increases, $GML_k(t,s) = 1$ means that FGTFP remains unchanged, and $GML_k(t,s) < 1$ means that FGTFP decreases.

3.3. Model Setting

To test the impact of green urbanization on FGTFP, the following fixed-effects model is constructed.

$$fgtfp_{\text{it}} = \alpha_{it} + \beta gur_{it} + \gamma X_{it} + \mu_i + \text{v}_t + \varepsilon_{it} \quad (4)$$

Fixed effects models fix individual differences across time points, thus effectively excluding the effects of unobserved omitted variables on the dependent variable and confounding effects on the relationship between the independent and dependent variables. Estimation bias caused by missing variables can also be addressed to some extent [48]. Here, $fgtfp$ is forestry green total factor productivity; i represents region; t represents time; $gur_{i,t}$ represents green urbanization; X is a series of control variables including economic development level (*pgdp*), technology level (*tech*), industrial structure level (*stru*), forestry economic development level (*fgdp*), natural endowment level (*nature*), cultural quality level (*edu*), and government intervention level (*gov*); μ_i and v_t are individual and time fixed effects, respectively; $\varepsilon_{i,t}$ is a random perturbation term.

3.4. Variables Selection

3.4.1. Dependent Variable

(1) Input indicators

Input indicator mainly involves land, capital, and labor. Land and labor input are selected as forest land area and the number of employees in the forestry system respectively, while capital input is selected as the amount of investment in forestry fixed assets [28]. In addition, energy investment is another input factor that cannot be ignored, and its indicator is derived by calculating the ratio of forestry output to industrial output and industrial energy investment [27].

(2) Output indicators

Desired output. The special characteristic of forestry is that it can produce economic and ecological benefits at the same time. Therefore, the output value and carbon sink are both chosen as the desired output. Among them, the output value is measured by the total output value of the primary, secondary and tertiary forestry industries and the forest carbon sink can be estimated according to IPCC 2006, as shown in Equation (5):

$$C = A \times V \times BEF \times D * (1 + R) \times (1 + RDW) \times CF \quad (5)$$

where C is the carbon sink, A is the remaining land area of the same land use type, V is the marketable growth stock, $A \times V$ is the total forest stock. BEF is the biomass expansion factor, D is the basic wood density, R is the ratio of belowground biomass to aboveground biomass, RDW represents the ratio of life to mortality, and CF represents the carbon fraction of dry matter. Due to the different parameters of different tree species, the weighted average method was used to calculate each parameter [4].

Undesired output. Since this study is based on the discussion of the dual carbon target, carbon emissions are chosen as the undesired output. Forestry carbon emissions are mainly from the secondary industry of forestry, which are subdivided into (i) wood processing and wood, bamboo, rattan, palm, and grass products industry; (ii) furniture manufacturing industry; (iii) paper and paper products industry; and (iv) printing industry. The furniture manufacturing industry contains a large number of plastic and metal products, so the furniture manufacturing industry is not considered in this study. Carbon emissions are mainly obtained by calculating the use of coal, natural gas, and oil for classified industries [49]. The descriptive statistics of the input-output variables are shown in Table 1.

Table 1. Statistical analysis of input-output variables.

Variable	Definition	Mean	Std. Dev	Min	Max
Inputs					
Land	Forest land area	931.599	895.015	2.250	4499.170
Capital	Forestry fixed-asset investment	12.002	43.607	0.009	469.432
Labor	Number of employees in forestry system	44,912.677	62,100.011	704.000	470,317.000
Energy	Forestry energy investment	15.122	43.732	0.028	438.191
Desired output					
Economic benefits	Forestry output value	969.187	1425.666	2.038	8167.577
Ecological benefits	Forestry carbon sink	16,326.196	20,831.662	14.707	87,281.959
Undesired output					
Carbon emissions	Forestry carbon emissions	470.182	629.846	0.406	3256.067

3.4.2. Core Independent Variable: Green Urbanization

From the perspective of system theory, green urbanization is a comprehensive, coordinated, and sustainable urbanization development model covering the ecosystem, economic system, and social system. Therefore, this paper refers to relevant studies [9,50,51] and selects 23 indicators from five dimensions: ecological, demographic, economic, social, and spatial to build a comprehensive evaluation system of green urbanization indicators, as shown in Table 2, and uses principal component analysis [1] to calculate the weight score of each province.

Table 2. Comprehensive index evaluation system of green urbanization level [2].

Criteria Layer	Specific Indicator	Unit	Attributes
Ecology urbanization	• Forest Cover	%	+
	• Forest Park Area	10,000 hm^2	+
	• Forest ecological area in nature reserves of forestry system	10,000 hm^2	+
	• Wetland ecological area in nature reserves of forestry system	10,000 hm^2	+
	• Percentage of the land area of nature reserves in forestry system	%	+
	• Environmental regulation intensity	%	+
	• Energy carbon emission intensity	t/10,000 Yuan	-
Population urbanization	• Non-agricultural population	People	+
	• Urban population density	People/km^2	+
	• Natural population growth rate	%	+
Economic urbanization	• GDP per capita	10,000 Yuan	+
	• Tertiary industry output/GDP	%	+
	• Tertiary industry output/Secondary industry output	%	+
	• Urban disposable income	10,000 Yuan	+
	• Urban Engel's Coefficient	%	-
Social urbanization	• Number of public vehicles for 10,000 people	Vehicle	+
	• Number of health technicians per 10,000 people	People	+
	• Public library holdings per capita	Book	+
	• Sewage treatment rate	%	+
	• Domestic waste treatment rate	%	+
Spatial Urbanization	• Building size	km^2	+
	• Road area per capita	km^2	+
	• Public green space per capita	km^2	+

3.4.3. Control Variables

In order to control the factors affecting FGTFP as exhaustively as possible, the following control variables were set: (1) Economic development level (*pgdp*) is measured by nighttime light brightness representation; the raster data have been processed into panel data [52]. The nighttime light intensity can objectively reflect the industrial production, commercial activities, and energy consumption of human society, and is used to measure the development level of the regional economy. (2) Technology level (*tech*) is measured by the number of professional and technical personnel in the forestry system. (3) Industrial structure level (*stru*): Environmental issues, such as forestry carbon emissions, are dominated by industry and manufacturing in the secondary industry, so the proportion of forestry secondary industry to total forestry output is used to reflect the impact of industrial structure change on the ecological environment [53]. (4) Forestry economic development level (*fgdp*) is measured by the total forestry output value as a proportion of GDP. (5) Natural endowment level (*nature*). *fgdp* is measured by forest area per capita. (6) Cultural quality level (*edu*): Educational attainment affects the degree of acceptance of scientific information and new technology learning in forestry, thus positively affecting forestry productivity [54]. It is measured by years of education for grassroots forestry workstation personnel. (7) Government intervention level (*gov*) is measured by local governments' attention to green development, i.e., the frequency of environmental words appearing in the government report as a proportion of the total word frequency.

3.5. Data Source

The data source is from 30 provinces in China from 2001 to 2018. Due to the lack of forestry-related data in Tibet, Hong Kong, Macao, and Taiwan, they are not included in this study. In addition, because the latest year of the *China Forestry Statistical Yearbook* is 2019, the research period of this paper is 2001–2018. In this paper, data related to green urbanization indicators were obtained from the *China Statistical Yearbook*, energy investment and carbon emissions data were obtained from the *China Industrial Statistical Yearbook*, and the remaining data for each indicator was obtained from the *China Forestry Statistical Yearbook (2002–2019)*. A few missing data were filled in by interpolation, and the descriptive statistical analysis of the main variables is shown in Table 3.

Table 3. Descriptive statistics of variables.

Variable	Mean	Std. Dev	Min	Max
fgtfp	1.267	1.495	0.102	30.798
gur	1.225	0.435	0.054	2.840
pgdp	8.885	6.189	0.729	27.500
tech	2279.591	1537.735	39.000	7404.000
stru	33.288	27.468	0.012	89.625
fgdp	6.041	4.615	0.112	28.214
nature	0.186	0.201	0.001	1.08
edu	12.675	1.262	6.793	14.893
gov	0.117	0.082	0.013	1.022

4. Results

4.1. Interannual Variation Characteristics of FGTFP

Figure 3 showed the average FGTFP values for 30 provinces from 2001 to 2018 based on the SBM-GML method. It can be seen that carbon sink-based FGTFP values have maintained a steady trend over the past 18 years, while there was a period of increase after 2012. FGTFP based on output value increased rapidly between 2009 and 2012, and then declined sharply. The reason was that in 2012, China put forward a major strategic decision to vigorously promote the construction of ecological civilization: provinces and cities implemented policies such as afforestation subsidies and grain for green. The aim was to increase the growth rate of forest reserves, and in the process, timber production decreased and forestry carbon sink production increased. As a result, the FGTFP based on output value declined significantly and the FGTFP based on carbon sink showed an upward trend.

In addition, three points were worth noting. Firstly, when the FGTFP based on output value had a significant upward trend, the carbon sink-based FGTFP values tended to show a downward trend. Secondly, related studies indicated a decreasing trend of FGTFP in China during 2008–2009 [4,28]. However, the FGTFP values based on carbon sink or output value, both of which showed an increasing trend at this time, seem to contradict the relevant findings. After considering both together, FGTFP showed a decreasing trend, which was consistent with the existing conclusions. Thirdly, the FGTFP, which integrated output value and carbon sink, was basically located in the middle of economic benefits and ecological benefits. From this, it is assumed that the FGTFP values that used to consider only economic benefits were inaccurate. When ecological benefits were considered, the FGTFP estimation value will shift downward as a whole, i.e., the current FGTFP was overestimated.

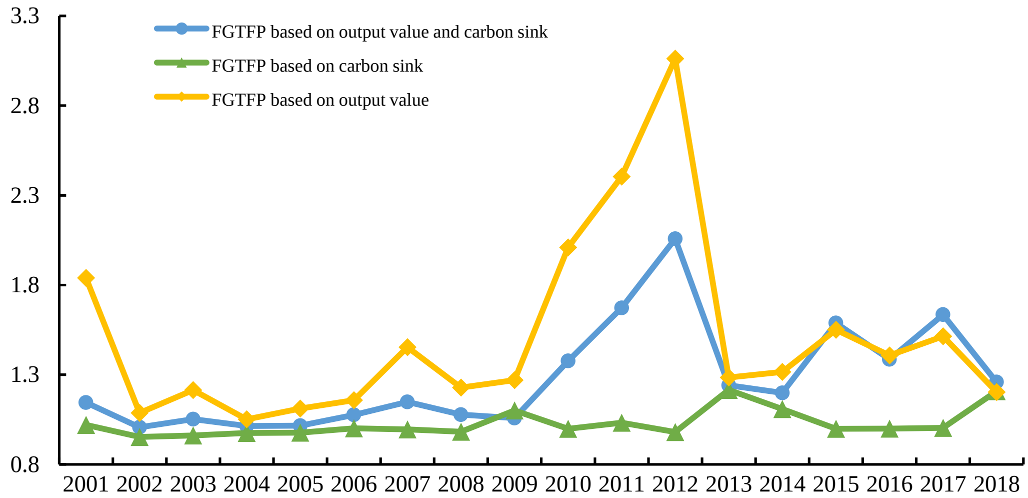

Figure 3. Average FGTFP values of 30 provinces from 2001 to 2018.

4.2. Baseline Regression Results

To eliminate possible heteroskedasticity in the data, the natural logarithm was taken for all variables, and the variance inflation factor test showed a maximum VIF of 2.56, which implies that there is no multicollinearity. The Hausman test results were significant at the 1% level, indicating that fixed effects are appropriate. As shown in Table 4, columns (1)–(3) show the estimation results for ordinary least square (OLS), random effect (RE), and fixed provinces only, respectively, indicating that green urbanization can enhance FGTFP. Column (4) shows the estimated results controlling for both time and province fixed effects, indicating that for every 1% increase in the level of green urbanization, the FGTFP can rise by 0.1632%. As for the control variables, the level of technology and the level of forestry economic development significantly affect FGTFP. The former provides technical support and the latter enhances capital support, which together promote innovation in forestry cleaner production technologies. The level of industrial structure and the level of natural endowment have inhibiting effects on FGTFP, indicating that an increase in the share of forestry secondary production tends to bring more carbon emissions. Similarly, regions with good natural resource conditions in forestry tend to have rough development and poor sustainability, both of which are detrimental to FGTFP.

4.3. Robustness Tests

Robustness tests for the three benchmark regression models are given in Table 5. (1) Taking into account the differences in indicator measurement methods, the entropy weighting method (EW M), which is also objectively assigned, is used to recalculate the green urbanization indicators and introduce them into the baseline regression model as the core independent variables. (2) Considering the time lag effect, the first-order lag term (*L. gur*) and the second-order lag term (*L2. Gur*) of green urbanization are used as the core independent variables. (3) Considering the differences in regression methods, panel quantile regressions with two-way fixed effects are used, and 0.25, 0.50, and 0.75 are chosen for re-estimation. After three robustness tests, the regression coefficient of green urbanization on FGTFP is still significantly positive, indicating that the findings of this paper are reliable.

Table 4. Results of the baseline model regression.

Variable	**(1)**	**(2)**	**(3)**	**(4)**
	fgtfp	*fgtfp*	*fgtfp*	*fgtfp*
gur	0.1106 ***	0.1106 ***	0.5824 **	0.1632 **
	(0.0324)	(0.0281)	(0.2691)	(0.0714)
pgdp	−0.0154	−0.0154	−0.0480	0.1134
	(0.0274)	(0.0169)	(0.1047)	(0.1985)
tech	0.0337 *	0.0337 *	0.1336 ***	0.1224 **
	(0.0185)	(0.0174)	(0.0461)	(0.0479)
stru	−0.0409	−0.0409 **	−0.0373 *	−0.0515 **
	(0.0292)	(0.0196)	(0.0199)	(0.0208)
fgdp	0.0851 ***	0.0851 ***	0.2766 ***	0.2946 ***
	(0.0236)	(0.0245)	(0.0650)	(0.0641)
nature	−0.0491 ***	−0.0491 ***	−0.1796 *	−0.1995 **
	(0.0144)	(0.0145)	(0.0931)	(0.0895)
edu	−0.0554	−0.0554	−0.2597	−0.2725
	(0.1093)	(0.1135)	(0.1874)	(0.1975)
gov	0.0322 *	0.0322 ***	0.0197	0.0284
	(0.0181)	(0.0114)	(0.0154)	(0.0223)
Constant	0.2398	0.2398	0.5157	−2.6596
	(0.5422)	(0.3950)	(1.9178)	(3.3019)
Year	No	No	No	Yes
Province	No	No	Yes	Yes
R^2	0.0421		0.0814	0.1217
N	540	540	540	540
Hausman				0.0014

Note(s): Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Results of the robustness tests.

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	EW M	***L. gur***	***L2. Gur***	**0.25**	**0.50**	**0.75**
gur	0.4808 **	0.2093 ***	0.1448 **	0.0783 ***	0.0925 ***	0.0743 ***
	(0.2246)	(0.0657)	(0.0575)	(0.0089)	(0.0048)	(0.0063)
Constant	−0.3964	−3.7005	−2.1620	-	-	-
	(3.7495)	(3.3001)	(4.2408)	-	-	-
CV	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
N	540	510	480	540	540	540
R^2	0.1192	0.1258	0.1209	-	-	-

Note(s): Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$.

4.4. Endogenous Discussion

The baseline estimation of the impact of green urbanization on FGTFP may have endogeneity problems. One is the omitted variable problem, as the factors affecting FGTFP are multifaceted, and although a series of possible factors have been controlled, there is no guarantee that other possible factors are completely excluded from the residual term. The second is the two-way causality problem, where the increase in FGTFP leads to enhanced ecological and economic benefits, instead of promoting the development of green urbanization. For this reason, this paper mitigates the core independent variables by selecting instrumental variables, which should be chosen to satisfy exogeneity and relevance requirements. (1) The first-order lagged term of green urbanization is directly selected as the instrumental variable. (2) Referring to Bartik [55], a "Bartik instrument" is constructed: $gur_{i,t-1} + \Delta gur_t$[3]. The reasons are as follows: on the one hand, the national green urbanization index is derived from 30 provinces (mean), so its trend is not significantly affected by individual provinces and the differential term can be considered as exogenous relative to individual provinces. On the other hand, the FGTFP of a province may be influenced by other unobserved shocks, but as long as such shocks are not important enough to affect the national green urbanization index, then this instrumental variable is valid [56].

Table 6 shows the results of the instrumental variables estimation. Columns (1) and (3) show the results of the first stage estimation, indicating that there is a significant positive correlation between the instrumental variables and green urbanization. Columns (2) and (4) show the results of the second stage estimation, indicating that the coefficients of green urbanization are both positive and significant at the 5% level, consistent with the baseline estimation results, and both pass the instrumental variable under-identification and weak identification tests. The promotion effect of green urbanization on FGTFP is verified again.

Table 6. Regression results of instrumental variables.

Variable	**iv_*L. gur***		**iv_*bartik***	
	(1)	**(2)**	**(3)**	**(4)**
	First-Stage	**Second-Stage**	**First-Stage**	**Second-Stage**
gur		0.2498 **		0.3277 **
		(0.1234)		(0.1453)
IV	0.8377 ***		5.1822 ***	
	(0.0945)		(1.1122)	
Constant	−1.1090	0.2498 **	3.9648	−0.2705
	(0.8502)	(0.1234)	0.5216	(0.9557)
CV	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Kleibergen-Paap rk		21.556		18.772
LM		[0.0000]		[0.0000]
Kleibergen-Paap rk		78.656		21.710
Wald F		[16.38]		[16.38]
R^2		0.1376		0.0173
N	510	510	510	510

Note(s): Kleibergen-Paaprk LM test with *p*-values in parentheses. Kleibergen-Paaprk Wald F test with critical values at 10% significance level in parentheses. *** $p < 0.01$, ** $p < 0.05$.

4.5. Mechanism Tests

Based on the above theoretical analysis and research hypotheses, this paper explores the possible explanations of green urbanization promoting FGTFP from two paths: forest-tourism integration and environmental regulation.

(1) Forestry-tourism integration effect

In theory, green urbanization can have an impact on the cross-fertilization and interpenetration of forestry and tourism. The driving force of green urbanization on the integration of forestry and tourism is multi-faceted, on the one hand, it basically follows the law of "Paddy Clark": the labor force is first transferred from the primary industry to the secondary industry, and then to the tertiary industry, which is also the specific performance of urbanization development. Related studies have also shown that deforestation rates increase in the early stages of urbanization but decline as urbanization progresses. This curvilinear relationship is attributed to the influence of the growing dominance of services in urban areas [57]. On the other hand, according to the theory of ecological modernization, its basic connotation is a win-win situation of preventive innovation and recycling, that is, a win-win situation of the economy and environment [58]. Ecotourism as one of the important precautionary principles, low-carbon green development as the rightful meaning of green urbanization, forestry development from the original focus on the economic benefits of the forest to the integration of economic, ecological, and social benefits of the whole up, and ultimately the integration of forestry and tourism to develop.

As the main manifestation of forest tourism integration, this paper uses the development level of forest tourism to measure the degree of forest-tourism integration. The level of development of forest tourism was selected to measure the income and number of forest tourists, respectively. Columns (1) and (2) in Table 7 shows that green urbanization can significantly increase the income and number of forest tourism, implying that green urbanization promotes the development of forest tourism, that is, the degree of forest-tourism integration is improved. Existing studies are less likely to explore the green efficiency of forest-tourism integration, but basically, confirm the positive relationship between agriculture-tourism integration and green total factor productivity. Jiang [59] and Hu and Zhong [60] argue that agriculture-tourism integration transforms the value of the agriculture-ecological environment into economic benefits, in which low-carbon production behaviors are consciously adopted in order to maintain long-term sustainable economic returns. This minimizes the negative impact of production and business activities on the natural environment and allows ecological benefits to be realized. Chang and Zhang [61] argue that as the value of agroecology is repriced, it is increasingly possible to provide economic protection for natural resources in agriculture. Likewise, considering the carbon sink function of forestry, it can provide greater ecological benefits than agriculture.

Table 7. Test of forest-tourism integration effect.

Variable	**(1)**	**(2)**
	Forest Tourism Income	**Forest Tourism Numbers**
gur	0.5942 **	0.2834 ***
	(0.2833)	(0.1004)
CV	Yes	Yes
Year	Yes	Yes
Province	Yes	Yes
Constant	−33.7765 ***	0.9493
	(8.7464)	(5.9751)
N	540	540
R^2	0.8514	0.8639

Note(s): Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$.

(2) Environmental regulation effect

In theory, green urbanization can have an impact on the intensity of environmental regulations. Green urbanization drives the intensity of environmental regulations from two sources: On the one hand, based on the sustainable city theory, the resource and environmental carrying capacity have become an important indicator of urban development, and green urbanization has emerged to promote a series of new forest-related low-carbon industries, such as forestry carbon sinks and forest biomass energy. Meanwhile, forest-related environmental regulation and low-carbon actions, such as forest management certification, carbon labeling, and carbon certification, are becoming more and more intensive due to phenomena, such as the public goods property of resources and environmental issues themselves and the negative externalities of environmental pollution. On the other hand, the strength of informal environmental regulation depends mainly on residents' awareness of environmental protection and the degree of social development. The green development concept of green urbanization is deeply rooted in people's minds, which triggers the demand for environmental performance by enterprises or governments and the demand or awareness of local residents to improve their quality of life, thus increasing environmental protection. Eventually, there will be a "race to the top" for environmental improvement. With the combination of these two factors, the increase in the level of green urbanization tends to impose stronger environmental regulatory constraints.

Environmental regulatory trade-offs are more difficult in natural resource-based industries [62]. This paper attempts to validate environmental regulatory mechanisms both formally and informally. Considering that the government is the main body that imposes formal environmental regulation, the command-and-control environmental regulation is expressed as the share of pollution control investment in regional GDP. For the "polluter pays" principle of market incentive-based environmental regulation, the emission fee is the most important instrument under this type of environmental regulation in China, expressed as the ratio of emission fee revenue to regional GDP. The strength of informal environmental regulation depends mainly on the level of public monitoring and willingness to participate, so the number of letters and visits is a valid indicator [63]. This paper constructs informal environmental regulation indicators based on this: $ier = \sqrt{pet \times pop}$, pet is the number of petitions for environmental problems and pop is the population density. Columns (1)–(3) in Table 8 show that green urbanization contributes significantly to all three types of environmental regulations, indicating that green urbanization does strengthen the intensity of environmental regulations. Existing studies basically confirm the positive relationship between environmental regulations and green total factor productivity, that is, environmental regulations can effectively reduce carbon emission intensity and improve environmental performance. Ouyang et al. [64] used a mandatory carbon emissions trading scheme as a quasi-natural experiment to verify that mandatory environmental regulation significantly improves the energy efficiency of energy-intensive heavy industries. Wu and Lin [65] and Wang and Zhang [66] demonstrate that environmental regulation is effective in reducing CO_2 emissions at the provincial and city levels, respectively. Söderholm et al. [62] argue that environmental regulation is important for the green transition of the pulp and paper industry.

Table 8. Test of environmental regulation effect.

Variable	(1)	(2)	(3)
	Command-And-Control Type	**Market Incentive-Based Type**	**Public Participation Type**
gur	0.2485 *	0.3861 ***	0.2860 *
	(0.1347)	(0.1380)	(0.1470)
CV	Yes	Yes	Yes
Year	Yes	Yes	Yes
Province	Yes	Yes	Yes
Constant	−26.6582 ***	−15.1670 **	−4.7919
	(8.4207)	(6.9259)	(4.4728)
N	540	540	540
R^2	0.3985	0.6354	0.7227

Note(s): Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Two mechanism analyses suggest that green urbanization enhances FGTFP by promoting forest-tourism integration and strengthening environmental regulations. H1 and H2 are verified.

4.6. Heterogeneity Analysis

In the early days of China, in order to meet the demand for timber and other forest resources for national economic construction, large-scale development was carried out in some forest areas. A number of forestry enterprises specializing in timber harvesting and processing were formed, and a number of state-owned forest areas were formed with these forestry enterprises as the main body. This paper further explores whether there are differences in the effects of green urbanization on FGTFP under heterogeneous conditions between state-owned and non-state-owned forest areas. Based on the regression analysis of Equation (3), as shown in Table 9, the *gur* coefficient is positive but insignificant in column (1), while it is significantly positive at the 5% level in column (2). This means that green urbanization is likely to raise the level of FGTFP in both state-owned forest areas and non-state-owned forest areas, and the enhancement effect is more significant in non-state-owned forest areas. The possible explanations lie in the fact that, one reason is the over-exploitation of natural forest resources, and a single industrial structure, rough production, resulting in state-owned forest areas deep in the resource curse. After that, China started to initiate a total logging ban on state-owned forest areas in 2014, with the halting of logging, and the real conditions, such as a backward regional economy, obsolete industrial structure, and lagging institutional reform, have come to the fore. State-owned forest areas, compared with other forest areas, have instead gradually become backward regions and backward industries, losing the advantage of competing in the industrial market, therefore, the enhancement effect of green urbanization on FGTFP is limited. Compared with state-owned forest areas, non-state forest areas themselves generally have higher levels of economic development and urbanization. Accordingly, with a high level of tourism consumption and many heavy polluting enterprises, the forest-tourism integration effect and environmental regulation effect provided by green urbanization can play a greater potential for carbon reduction and sink increase. Therefore, the promotion effect of green urbanization on FGTFP in non-state-owned forest areas is more obvious.

Table 9. Results of heterogeneity analysis.

Variable	(1)	(2)
	State Forest Area	**Non-State Forest Area**
gur	0.1272	0.1745 **
	(0.1965)	(0.0746)
Constant	−12.2810	−0.0803
	(8.9336)	(3.0083)
CV	Yes	Yes
Year	Yes	Yes
Province	Yes	Yes
N	162	378
R^2	0.1826	0.1760

Note(s): Robust standard errors in parentheses; ** $p < 0.05$.

5. Discussion

In the dual context of China's new urbanization plan, carbon peaking, and carbon neutrality targets, this paper takes the carbon reduction and sink enhancement function of forestry as the entry point, constructs green urbanization indicators, and more comprehensively accounts for the FGTFP under the joint constraint of carbon emissions and carbon sinks. Further, the effective way of green urbanization for FGTFP was verified. There are several important and interesting findings in this paper, as described below.

The FGTFP measured in this paper is more comprehensive, and the results of existing studies have the shortcomings of exaggerating the economic benefits and weakening the ecological benefits. On the one hand, forestry waste gas and wastewater as major undesired outputs [25,27], focusing on the clean production capacity of the forest industry, do not effectively reflect the ecological function of forestry, i.e., the carbon reduction function. On the other hand, forestry carbon sinks are not considered as one of the desired outputs. It may weaken the carbon sequestration function of forestry and exaggerate the economic benefits of the forestry sector. In addition, Wu and Zhang [28] considered forestry eco-benefits. However, using forest stock directly as a measure would lead to an overestimation of eco-benefit values. Therefore, based on the ecological benefits of forestry, this paper sets the non-desired output as forestry carbon emissions, the fluctuations exhibited by the FGTFP values in this paper are the result of the combined effect of economic and ecological benefits of forestry. This is more in line with China's current carbon neutral target and the green low-carbon living concept of the new urbanization plan.

In essence, the development of green urbanization and its impact on FGTFP reflects the green transformation of the town as a carrier and internal industry, the green development of the carrier is bound to promote the green transformation of the internal industry. This is supported by the results of this paper that the increase in the level of green urbanization can promote the increase of FGTFP. Relevant studies have demonstrated that green urbanization can be coordinated with green finance [50], confirming the function of green urbanization in driving the green economy. Green urbanization also exhibits significant ecological effects [9,67]. Based on previous studies, this paper further verifies that green urbanization can further bring into play the economic benefits of forestry and achieve an increase in FGTFP on the basis of maintaining the ecological benefits of forestry, using the forestry sector as a research sample. From the perspective of influence mechanism, the study of environmental regulation on industrial green development has been more recognized. However, forestry-tourism integration is a new perspective, which is further discussed in this paper.

Forestry-tourism integration has created huge economic, ecological, and social benefits. Two major trends in the transformation of China's forest economy: firstly, a shift in timber resource consumption to heavy reliance on imports and the conservation and restoration of domestic forest resources; and secondly, the rapid popularity of forestry tourism creating a thriving business [41]. Two major trends have achieved a shift in forestry from a purely predatory economic activity to a co-existence of ecology and economy. In addition, scholars have called for more attention to social values in forestry management [68]. Taking China as an example, the green transformation of forestry by forestry tourism is not only reflected in environmental and economic aspects. Likewise, forestry tourism creates significant social benefits. On the one hand, forestry tourism can create a large number of green jobs. Between 2011 and 2020, the total employment in forest park tourism is 5.12 million, of which 2.4 million are directly employed and 2.7 million are indirectly employed [69]. On the other hand, forestry tourism helps in poverty alleviation. From 2016 to 2020, the income of 1.475 million poor people was increased by relying on forest tourism, the number of beneficiaries accounted for 9% of the poor, and the average annual household income increased by about 794.2 US dollars [4].

It needs to be acknowledged that there remain some limitations in this paper. To begin, limited to the serious lack of forestry-related data at the prefecture level, this paper only conducted analysis at the provincial level. Then, the purpose of this paper is to identify the causal relationship between green urbanization and FTGFP. In fact, interaction and spatial spillover effects exist between urbanization and the ecological environment. Therefore, the analysis of spatial effects is one of the directions that can be explored in depth in the future.

6. Conclusions

The main conclusions of this paper are as follows: Firstly, forestry, as a sector with both ecological and economic benefits, makes FGTFP overestimated by considering only economic benefits. China's future forestry development should be both subtractive, to achieve emission reduction in the forestry industry, and additive, to play the function of forestry carbon sink. Secondly, green urbanization focuses more on ecological civilization than traditional urbanization, which is an important way to promote the green transformation of China's forestry industry and help achieve the goal of double carbon. Thirdly, forestry–tourism integration and environmental regulation are effective channels for green urbanization to promote the green development of forestry. Fourthly, state-owned forest areas face serious industrial transformation dilemmas, and green urbanization has a limited role in promoting green forestry development, which is more significant in non-state forest areas.

Based on the above findings, the policy implications are as follows:

(1) Pay attention to green urbanization and strengthen environmental constraints. Participate in the construction of green urbanization with multiple subjects, and strengthen the government's command-based environmental constraints, the market's incentive-based environmental constraints, and stimulate the public's supervision and participation-based environmental constraints. Specifically, the optimization of the forestry industry and energy structure: overall, the transformation from the first and second industries to the third industry. In part, the internal upgrading of the second production structure is the main focus, forcing enterprises to change their energy structure to clean production of green energy, raw materials to green materials, and production methods to intensification, in order to achieve carbon emission reduction in the forestry industry.

(2) Rely on green urbanization and drive forestry-tourism integration. Relying on the green resources, consumption concept, and economic advantages brought by green urbanization, actively guide the extension of the forestry industry chain to tourism, or tourism moves closer to forestry resources, to explore the forestry tourism consumption market. Achieve the coordinated growth of economic and ecological benefits.

(3) Backward state-owned forest areas, government "blood transfusion" and enterprise "blood production" is indispensable. State-owned forest areas face greater challenges of forestry green transformation, requiring joint efforts of the government and enterprises. On the one hand, the government should carry out a thorough reform of the backward system in forest areas and take the initiative to bear the cost. On the other hand, forest enterprises and workers should explore and practice spontaneously and take the initiative to carry out industrial restructuring. On the basis of ensuring the benefits of carbon sinks in forest areas, they should actively cultivate new economic growth points. State-owned forest areas themselves are rich in forestry resources, and vigorously developing a carbon sink economy may be a feasible attempt. This requires that state-owned forest areas need to make efforts to improve forest quality, explore the construction of resource industries that support forestry carbon sinks, and establish sound carbon market transactions.

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Notes

1 The negative indicators in the indicator system are calculated with a positive process.

2 (1) The development of green urbanization is often controlled by local government subjects, so the intensity of environmental regulation is dominated by mandatory government regulations. It is measured by the proportion of investment in environmental pollution control to GDP. (2) Energy carbon emission intensity: the province's total CO_2 emissions of coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, LPG and natural gas divided by GDP.

3 That is, the product term of the lagged first-order green urbanization index and the first-order difference of the green urbanization index.

4 https://www.sohu.com/a/445727316_749700, accessed on 21 October 2022.

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