Research on the Impact and Mechanism of Producer Service Industry Agglomeration on Green and High-Quality Development of Chinese Cities

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Abstract. With the deepening and refinement of industrial division of labor, the agglomeration of productive service industries with the characteristics of high degree of specialization, knowledge-intensiveness, wide service area and high comparative benefits has become an important driving force. Based on the panel data of 271 prefecture-level cities in China from 2006 to 2020, this research uses a two-step mediation effect analysis based on the heterogeneity of industry, region and city levels to empirically research the impact and specific mechanism of the agglomeration of productive service industries on the green and high-quality development of cities represented by the Green Total Factor Productivity (GTFP) index. The research are: (1) Agglomeration of producer services has a significant positive effect on the improvement of urban GTFP in general; (2) Agglomeration of producer services achieves the improvement of urban GTFP through two paths, promoting green technology innovation and promoting the rationalization of industrial structure; (3) Promotion effect has obvious differences in different producer service industries, regional locations and city levels: high-end producer services are significant, but not in the middle and low end; the central and western regions and non-provincial capital cities are significant, but not in the eastern region and provincial capital cities. And relevant policy recommendations are put forward for the agglomeration of producer services to better promote the green and high-quality development.

Keywords: Productive Service Industry Agglomeration; Urban GTFP; Industrial Structure Rationalization; Green Technology Innovation

1 Introduction

As the world economy shifts from an "industrial economy" to a "service economy", the social division of labor is deepening and the degree of specialization is further deepening. The service industry, especially the productive service industry, is gradually separated from the original manufacturing function through outsourcing, and its industrial agglomeration degree is also constantly improving [1]. In 2023, China's large-scale productive service enterprises will achieve operating income of 11.9 trillion yuan, with an

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average annual growth of 12.1% from 2020 to 2023 [2]. However, the rapid economic development of my country has also brought about serious problems of resource and energy depletion and environmental pollution. Under the macro-policy background of green development concepts, high-quality development and the "dual carbon" goal, how to give full play to the supporting role of productive service industry clusters in the green and high-quality development of regions, especially urban areas, and promote both industrial efficiency improvement and GTFP improvement, is a realistic strategic issue related to China's future transformation of development mode, transformation of growth momentum and even the stable, coordinated and sustainable development of the entire economy.

Regarding the relationship between the agglomeration of producer services and the green and high-quality development of cities, many scholars have made remarkable achievements from different perspectives: Li et al (2021) [3] pointed out that the current agglomeration development of producer services has become an important way to alleviate overcapacity and environmental constraints and achieve the green transformation of urban economy. Through its external economic effects such as labor reservoir effect, intermediate input effect and knowledge and technology spillover effect, it can promote the technological innovation and development quality of cities. In addition, against the background of the increasingly obvious trend of global economic serviceization, the role of service industry, especially producer services, in promoting technological progress and pollution reduction has become more and more apparent. As a clean energy and knowledge-intensive industry, the agglomeration of producer services can reduce the scale of pollution emissions, improve environmental quality and promote the green development of urban economy [4-5]. However, the contribution and driving force of positive externalities such as scale effect brought about by the agglomeration of producer services to urban green development is likely to vary depending on the economic strength and development level of the city itself, and the boosting effect of the agglomeration of producer services of different subcategories may also be very different. The specific path mechanism of this study is shown in Figure 1 below

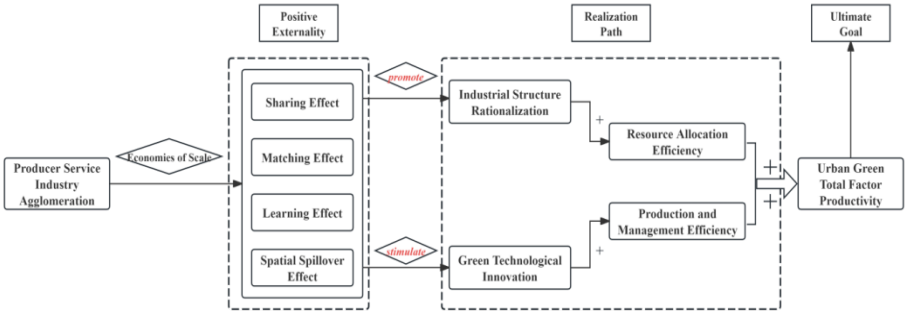

Fig. 1. Path mechanism of productive service industry agglomeration on green and high-quality urban development

Based on the existing research, the current academic research on the role and impact of producer service industry agglomeration on regional GTFP is quite rich and comprehensive, but there are still the following areas for improvement: First, with regard to

the influencing factors and improvement paths of urban GTFP, existing research mainly focuses on government environmental regulation, foreign direct investment (FDI) and digital economy, and few literatures pay attention to the impact of producer service industry agglomeration on it; secondly, most of the literature on the analysis of the agglomeration effect of producer service industry is based on the perspective of coordinated development with manufacturing industry or improvement of manufacturing efficiency. Some studies based on the city or urban agglomeration level mostly consider the single economic growth effect, and rarely involve the mechanism of action on the green development of cities. Therefore, this research uses the panel data of 271 prefecture-level cities in my country from 2006 to 2020, and uses a two-way fixed effect model to empirically research the impact of producer service industry agglomeration on the green high-quality development of cities represented by GTFP indicators, and discusses the heterogeneity and specific mechanisms.

2 Research Methods and Data Sources

2.1 Research Methods and Model Construction

The hypothesis deduction method is the process of proposing a hypothesis to explain the problem through reasoning after raising a question based on observation and analysis, and then conducting deductive reasoning based on it, and then testing the conclusion of deductive reasoning through empirical evidence. This research uses this method to sort out the relationship and channel path between the explained variables, core explanatory variables, and mechanism variables before constructing the main econometric model, as shown in Figure 2 below.

The core variables of this research are the agglomeration of productive services (APSI) and the GTFP (GTFP) of cities. To verify whether the agglomeration of productive services promotes the green and high-quality development of cities, which whether it improves the GTFP of cities, a panel two-way fixed model is used to set the following benchmark model for empirical testing:

$$GTFP_{i,t} = \beta_0 + \beta_1 \mathrm{APSI}_{i,t} + \beta_2 Controls_{i,t} + c_i + v_t + \varepsilon_{i,t} \quad (1)$$

In formula (1), i represents city, t represents year, c_i and v_t represent city and year fixed effects respectively, and $\varepsilon_{i,t}$ represents random error term. $GTFP_{i,t}$ is the explained variable urban GTFP, $\mathrm{APSI}_{i,t}$ is the core explanatory variable productive service industry agglomeration, *and* $Controls_{i,t}$ is the control variable group selected in this research, including foreign investment level, government intervention degree, economic development level, environmental regulation, urbanization level and urban economic density. On this basis, Stata18.0 is used to process and further analyze the data.

2.2 Data Sources

The urban panel data used in this research includes 271 prefecture-level cities, and the sample year ranges from 2006 to 2020. The city-level data are all from publicly published yearbook materials, such as the China City Statistical Yearbook, the China Statistical Yearbook, and the statistical yearbooks of various provinces and cities.

3 Data Analysis

3.1 Hypothesis and Research Framework

producer service industry agglomeration in promoting high-quality urban development is achieved through a variety of externalities, such as sharing effect, matching effect, learning effect, and spatial spillover diffusion effect. The rationalization of industrial structure prompts production factors to flow from low-productivity production sectors to high-productivity sectors, guides resources to gather in green development industries, optimizes resource allocation, and thus achieves green and high-quality development of the urban economy [6-7]. In addition, industrial agglomeration improves the technological innovation capabilities within the agglomeration area, and green technological innovation promotes the upgrading and improvement of traditional production technologies, improves green production efficiency and management efficiency, and ultimately promotes the improvement of urban GTFP [8]-[11].

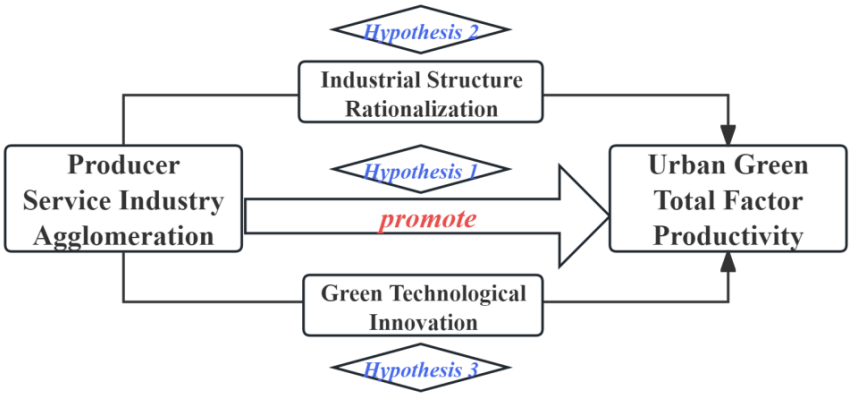

Fig. 2. Research concept model

In summary, this research proposes the following three research hypotheses:

H1: The agglomeration of productive services promotes the high-quality development of cities represented by urban GTFP.

H2: The agglomeration of productive service industries helps cities achieve green and high-quality development by accelerating the rationalization and upgrading of industrial structure.

H 3: The agglomeration of productive service industries promotes the green and high-quality development of cities by promoting green technology innovation.

3.2 Variable Selection and Description

(1) Green Total Factor Productivity (GTFP)

This research selects urban GTFP as a measure of the level of green and high-quality urban development. GTFP incorporates "energy consumption" and "environmental pollution" into the analytical framework of traditional total factor productivity (TFP). It is a refinement of total factor productivity in the traditional sense and is more in line with the current development goals of green city construction and win-win economic and ecological benefits. Therefore, the improvement of urban GTFP means a dual improvement in the quality of development in both economic and environmental aspects. This research selects the non-radial SBM model proposed by Färe et al (2007), which can significantly solve the slack variable problem and comprehensively consider the relationship between input, output and environmental pollution. The form of the non-radial SBM model including non-expected output is as follows:

$$GTFP = \min \frac{\frac{1}{M}\left(\sum_{i=1}^{M} \frac{\overline{X}}{X_{iq}}\right)}{\frac{1}{S+V}\left(\sum_{s=1}^{S} \frac{\overline{D}}{D_{sq}} + \sum_{v=1}^{V} \frac{\overline{U}}{U_{vq}}\right)} \tag{2}$$

$$s.t.\begin{cases} \overline{X} \geq \sum_{j=1,\neq q}^{n} X_{ij}\theta_j; \overline{D} \leq \sum_{j=1,\neq q}^{n} D_{sj}\theta_j; \overline{U} \geq \sum_{j=1,\neq q}^{n} U_{vj}\theta_j \\ \overline{X} \geq X_q; \overline{D} \leq D_q; \overline{U} \geq U_q \\ \theta_j \geq 0, i = 1,2,\ldots,M; j = 1,2,\ldots,n, j \neq 0 \\ s = 1,2,\ldots,S; v = 1,2,\ldots,V \end{cases} \tag{3}$$

The above formula, *GTFP* represents the GTFP of the city, *X* represents input, *D* and *U* represent expected output and undesired output respectively, and θ represents the weight of each input and output indicator. The specific input-output indicator setting and calculation method are shown in Table 1 below.

Table 1. Input-output indicators and calculation methods for GTFP measurement.

Variable		Calculation method
Input indicators [12]	Labor Input	Number of employees and industrial enterprises above designated size at the end of the year
	Capital investment	Fixed asset investment, urban construction land area, fiscal science and technology expenditure
	Energy input	Total water supply, total gas supply, and total electricity consumption
Expected Output	Real GDP	Taking 2006 as the base year, the city GDP deflator is calculated based on the GDP index of the province where the city is located over the years. The city's nominal GDP is deflated to eliminate the impact of price factors, and the city's real GDP over the years is obtained.

	Total social consumption per capita	Ratio of total retail sales of consumer goods in cities to population
	Urban green area	Green area of the city that year (square kilometers)
Undesirable output [13]	Industrial wastewater discharge	Urban industrial wastewater discharge (tons)
	Sulfur dioxide emissions	Urban sulfur dioxide emissions (tons)
	Industrial dust emissions	Urban industrial dust emissions (10,000 tons)

(2) Producer Service Industry Cluster (APSI)

The core explanatory variable of this research is the agglomeration of productive service industries (*APSI)*. Considering the availability of data and the operability of measurement, this research refers to the research of Feser et al. (2002) and constructs the following indicators:

$$S_j = \sum_j \frac{E_{ij}/E_i}{E_j/E}$$

Where *Eij* represents the number of employees in *the* producer service industry in city *i, Ei* represents the number of employees in city i, $_E$ *is the* number of employees nationwide, and $_{Ej}$ *is* $_{the}$ number of employees in industry *j* nationwide.

3.3 Benchmark Regression Results

Table 2 reports the baseline regression results of the degree of concentration of producer services on the green high-quality development of cities measured by urban GTFP. When no control variables are added, which only the core explanatory variable, the degree of concentration of producer services, is considered, as shown in column (1) of Table 2, the concentration of producer services has a significant positive impact on urban GTFP at the 1% statistical level, which preliminarily verifies the positive and positive correlation between the two. Column (2) is the regression result after adding various control variables on the basis of column (1). It can be found that the magnitude of the coefficient of the degree of concentration of producer services has only changed slightly, and the sign and significance level have not changed. It can be seen that the positive promotion effect of the core explanatory variables on urban GTFP is relatively stable. In terms of control variables, the coefficient of the level of economic development is significantly positive at the 1% statistical level, indicating that with the improvement of the level of economic development, the ability of funds, technology, etc. to improve the environment and achieve coordinated development of the economy and ecology has been enhanced, the urban GTFP has been improved, and the level of urban green high-quality development has been improved. The impact coefficient of the degree of government intervention is significantly positive at the statistical level of 5%, and it also has a positive impact on the GTFP of cities, indicating that an appropriate

degree of government intervention is conducive to alleviating market failures and negative externalities caused by public goods such as "environmental pollution" and promoting the green and high-quality development of various cities.

Table 2. Benchmark regression results

	(1) SBM	(2) SBM
APSI	0.015***	0.015***
	(2.767)	(2.808)
Foreign investment level		-0.101
		(-0.452)
Degree of government intervention		0.133**
		(2.050)
Economic Development Level		0.047***
		(2.808)
Environmental Regulation		-0.000
		(-0.439)
Urbanization level		-0.012
		(-0.660)
Urban economic density		0.006
		(0.589)
_cons	0.938***	0.545***
	(38.704)	(2.835)
years	control	control
City	control	control
N	4046	4046
R ^{2}	0.088	0.090
Adj. R ^{2}	0.019	0.020

Note: ***, **, * indicate significance at 1%, 5%, and 10% statistical levels, respectively; the data in brackets are t statistics.

3.4 Heterogeneity Analysis

The results are shown in column (3) of Table 3 below. Although the concentration of producer services in provincial capitals has a positive effect on urban GTFP, it is not significant, while non-provincial capitals have a significant positive impact. This may be because the capital, technology and preferential policies in provincial capitals are relatively concentrated, reaching a certain threshold, and their urban environment has entered the stage of improvement and optimization. Therefore, the concentration of producer services has a relatively limited positive marginal contribution to them. However, non-provincial capital cities are still in a rapid growth stage of development.

Table 3. Heterogeneity regression results

	(1) Industry Heterogeneity		(2) Regional heterogeneity		(3) Heterogeneity of city tiers	
	High-end	Low-end	east	Midwest	Capital city	Non-provincial
APSI_UP	0.048***					
	(4.908)					
APSI_MID		0.001				
		(0.176)				
APSI			0.003	0.019***	0.013	0.015**
			(0.281)	(3.073)	(1.343)	(2.515)
Foreign investment level	-0.113	-0.077	0.036	0.037	-0.130	-0.057
	(-0.510)	(-0.346)	(0.105)	(0.112)	(-0.379)	(-0.230)
Degree of government intervention	0.136**	0.136**	0.085	0.210**	-0.038	0.127*
	(2.094)	(2.089)	(0.774)	(2.470)	(-0.112)	(1.857)
Economic Development Level	0.054***	0.045***	-0.041	0.119***	0.004	0.046**
	(3.200)	(2.670)	(-1.390)	(5.378)	(0.085)	(2.568)
Environmental Regulation	-0.000	-0.000	0.000	-0.000	-0.001	-0.000
	(-0.476)	(-0.552)	(0.321)	(-0.992)	(-1.521)	(-0.299)
Urbanization level	-0.012	-0.013	-0.099	-0.013	-0.016	-0.014
	(-0.679)	(-0.744)	(-0.858)	(-0.728)	(-0.591)	(-0.700)
Urban economic density	0.004	0.005	0.008	-0.044	0.003	0.008
	(0.473)	(0.479)	(0.678)	(-1.012)	(0.138)	(0.780)
_cons	0.460**	0.637***	1.982***	-0.134	1.072**	0.568***
	(2.391)	(3.347)	(2.654)	(-0.585)	(2.215)	(2.751)
years	control	control	control	control	control	control
City	control	control	control	control	control	control
N	4046	4046	1500	2546	390	3656
R^2	0.094	0.088	0.081	0.114	0.302	0.087
Adj. R^2	0.024	0.018	0.001	0.042	0.208	0.016

Note: ***, **, * indicate significance at 1%, 5%, and 10% statistical levels, respectively; the data in brackets are t statistics.

3.5 Mechanism Analysis

In the mechanism analysis section of this article, to avoid the endogenous problems that may arise in the traditional "three-step method" test process, this article chooses to refer to the two-step method proposed by Jiang Ting (2022) [14] in "China Industrial Economy" for the test of the intermediary mechanism. It is only necessary to focus on and test whether the core explanatory variables can have a significant impact on the intermediary variables (rationalization of industrial structure and green technology innovation) to verify whether the intermediary mechanism is established.

(1) Rationalization of industrial structure

This research uses the Theil Index to measure the degree of rationalization of the industrial structure of each prefecture-level city. The index has the excellent property

of considering the structural deviation of the output value and employment of different industries and the different economic status of various industries [15]. The results are shown in the first column of Table 4 below. The agglomeration of producer services (*APSI)* has a significant positive impact on "rationalization of industrial structure (*Isr)*" at a statistical level of 5%, indicating that the agglomeration of producer services promotes the rationalization of urban industrial structure, increases the proportion of the tertiary industry and the coordinated and integrated development of various industries. In addition, relevant literature has proved that the rationalization of regional industrial structure can significantly improve the GTFP of local cities, proving the existence of "structural dividends" [16-17]. The rationalization of China's industrial structure has made the factor allocation between the secondary and tertiary industries more reasonable, and the coordination between industries and within industries has increased, thereby promoting the improvement of GTFP [18]. Therefore, hypothesis H1 is verified.

(2) Green technology innovation

This research measures green technology innovation by the ratio of green patent authorization to the sum of the number of inventions and utility models obtained in the same year. As shown in column (2) of Table 4 below, the agglomeration of the producer service industry (*APSI)* has a significant positive impact on green technology innovation (*GTI)* at the 5% statistical level, indicating the role of agglomeration in promoting green technology innovation. Furthermore, there are also relevant literatures that confirm the positive role of green technology innovation in urban GTFP. Sheet al (2020) [19] pointed out that technological innovation not only provides a new growth equilibrium point for the current dilemma of weak economic growth, but also provides a new solution path for solving current resource and environmental problems. Therefore, it has become the key to promoting the improvement of GTFP. Feng (2022) [20] also confirmed in the research that green technology innovation has promoted the improvement of GTFP both through direct effects and indirect effects. Therefore, hypothesis H2 is verified.

Table 4. Mechanism test

	(1) Rationalization of industrial structure	(2) Green Technology Innovation
APSI	0.007**	0.001**
	(2.175)	(2.432)
Foreign investment level	-0.324**	-0.018
	(-2.375)	(-1.084)
Degree of government intervention	0.147***	0.019***
	(3.691)	(3.939)
Economic Development Level	-0.068***	0.002
	(-6.578)	(1.527)
Environmental Regulation	-0.000	0.000**
	(-0.040)	(2.354)
Urbanization level	0.002	0.002
	(0.220)	(1.179)

Urban economic density	-0.009	0.001
	(-1.597)	(1.169)
_cons	0.854***	-0.026*
	(7.258)	(-1.832)
years	control	control
City	control	control
N	4046	4046
R^2	0.058	0.072
Adj. R^2	-0.015	0.000

Note: ***, **, * indicate significance at 1%, 5%, and 10% statistical levels, respectively; the data in brackets are t statistics.

4 Conclusion

Through the application of the above model and empirical testing, this research mainly found the following research conclusions: (1) In general, the agglomeration of productive services has a significant role in promoting the improvement of urban GTFP, and has promoted the green and high-quality development of Chinese cities; (2) The results of heterogeneity analysis show that the role of productive service industry agglomeration in promoting urban green and high-quality development is significant in high-end productive services, but not significant in the middle and low-end; it is significant in the central and western regions and non-provincial capital cities, but not significant in the eastern region and provincial capital cities; (3) The results of mechanism analysis show that the agglomeration of productive services achieves the improvement of urban GTFP by promoting green technology innovation and promoting the rationalization of industrial structure, and both play a positive mediating effect.

Based on the above research conclusions, this research specifically proposes the following three policy implications: First, promote the differentiated aggregation of producer services, aim at regional advantages and endowments, and aggregate "according to local conditions", and gradually build a producer service industry agglomeration model that conforms to regional factor endowments and development orientations. Second, break the small-scale regional restrictions of producer service industry agglomeration, improve the circulation efficiency and allocation effect of various factors between different cities and even urban agglomerations, and further form a new benign urban and regional development pattern of "small synergy drives large exchanges, and small agglomeration promotes large development". Third, give play to the dual role of environmental regulation and green technology innovation economic incentives, so that the "visible hand" and the "invisible hand" jointly support the role of producer service industry agglomeration in promoting the green and high-quality development of cities.

However, this research also has limitations, such as the measurement method of urban GTFP needs to be further studied and improved. In addition, the data used is from the public micro data on the Internet, which is second-hand data and lacks first-hand information. Future research may pay more attention to the improvement of empirical methods and the innovation of research perspectives, such as using spatial econometric

models and starting from the perspective of spillover effects, as well as in-depth exploration of the different effects and internal mechanisms of the impact of the agglomeration of psroductive service industries on the green and high-quality development of cities.

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