Does Traffic Distance Affects Shanghai Free Trade Zone's GTFP Spillover Effects? – Taking the Yangtze River Delta Region as an Example

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Abstract. Shanghai Pilot Free Trade Zone is the highland of regional development, which will have spillover effects on the high-quality development of the Yangtze River Delta region, but the effects may have boundaries. Based on the data of The Yangtze River Delta region from 2003 to 2019, this paper investigates the impact of the establishment of Shanghai Pilot Free Trade Zone (SPFTZ) on Green Total Factor Productivity (GTFP) in the Yangtze River Delta region by using the Differences-in-Differences (DID) method, and analyzes the impact boundary by using the benchmark regression model. The findings: SPFTZ significantly promoted the improvement of GTFP in the Yangtze River Delta region, that is, SPFTZ has a spillover effect on the high-quality development of the Yangtze River Delta Region, in which GTC is the main driving force. Through the benchmark regression model, it is found that the spatial spillover effect of Shanghai Pilot Free Trade Zone (SPFTZ) on green total factor productivity in the Yangtze River Delta region has a significant boundary. Specifically, the effect of SPFTZ on GTFP in the region of 0–200 km is significantly negative, and the effect of SPFTZ on GTFP in the region of 200–500 km is significantly positive. The spillover effect over 500 km is not significant. This paper provides important policy reference for further improving the relationship between SPFTZ and the high-quality development of the Yangtze River Delta Urban Agglomeration and balancing regional differences in the Yangtze River Delta.

Keywords: Shanghai Pilot Free Trade Zone · Yangtze River Delta region · GTFP · Spillover effects

1 Introduction

At present, China's economy is in the key chapter of transformation and upgrading; for its successful transformation, a stable external economic environment is the guarantee mechanism. However, with continuous external shocks, the prevalence of anti-globalization and trade protectionism, and the deepening of Sino-US trade frictions have all seriously restricted China's economic growth and transformation. In order to promote reform and opening-up and realize economic transformation under the new international situation, China established its first regional pilot Free Trade Zone -- Shanghai Pilot Free

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Trade Zone (SPFTZ) in 2013, thus opening a new round of institutional innovation to promote China's economic transformation and upgrading. As the highland of institutional innovation, SPFTZ should conform to the concept of green development and actively explore the path of regional green and low-carbon sustainable development (Liu et al., 2019) [1], so as to realize domestic and international market connectivity, free flow of factors and optimization of resource allocation at a higher level, and to drive high-quality economic development in the Yangtze River Delta region through radiation effect (Wang et al., 2022) [2].

As achieving integrated development in the Yangtze River Delta has become China's national strategy, collaborative development and green development have become the top priority in this region. As an important growth pole in China, the GDP of the Yangtze River Delta region increased from 9.77 trillion yuan in 2013 to 24.47 trillion yuan in 2020, accounting for 24.1% of China's total GDP (increased from 16.4%). However, the wastewater discharge and carbon dioxide emissions here both accounted for 20% of the total national emissions, showing that it is an urgent problem to realize the high-quality development of green economy in cities in the Yangtze River Delta. As the starting point of China's new round of opening-up and institutional innovation experiment, the effective adjustment and quality improvement of its institutional design can significantly reduce transaction costs and production costs, double the utilization rate of resources, and present institutional dividends, thus injecting new vitality into the green development of the Yangtze River Delta region through spillover effects. At the same time, existing studies have shown that spillover effects will be affected by geographical distance for the following reasons: first, protectionism among local governments leads to the formation of spillover effect boundary to a certain extent (Zheng et al., 2019) [3]; second, the spread of tacit knowledge and technology plays an important role in the spillover effect, and the spread degree of tacit knowledge and technology decreases gradually with the increase of geographical distance, so the spillover effect will weaken as geographical distance increases (Lee et al., 2010) [4]. Does SPFTZ have a spillover effect on the green development in the Yangtze River Delta? Does the effect decrease with as the geographical distance increases? Under the guidance of the above questions, this paper first calculates the GTFP of cities in the Yangtze River Delta region from 2003 to 2019. Then, DID was used to empirically test whether the establishment of SPFTZ has spillover effects on GTFP in the Yangtze River Delta region. Finally, the distance index is constructed and the overflow boundary of GTFP in the Yangtze River Delta region is verified by using the benchmark regression method. The contributions of this paper include: first, it enriches the theoretical results of free trade zone construction and regional agglomeration-spillover effects, and provides theoretical basis for the exploration of green and efficient development mode in the Yangtze River Delta region; second, the influence boundary of SPFTZ on GTFP in the Yangtze River Delta region is tested by integrating spatial factors into the analysis framework, and the geographical distance characteristics of the attenuation of its spillover effect are analyzed, which provides a reference for better playing the driving role of central cities, promoting regional economic transformation and promoting the high-quality development of urban agglomeration.

The structure of this paper is as follows. In Sect. 2, relevant literature on FTZ is reviewed. Model building and data sources are discussed in Sect. 3. The empirical results are analyzed in Sect. 4. Section 5 is the conclusion and policy recommendations.

2 Literature Review

Since the establishment of FTZ, its economic growth effect on the city has been widely concerned by scholars. Some scholars (Yao and Whalley, 2016 [5]; Xinxin MA& Fan ZHANG, 2020 [6]) believes that FTZ breaks market segmentation and improves financial freedom and openness by virtue of its institutional advantages, thus promoting the economic growth of the city where it locates. Jiang et al. (2021) [7] incorporated the concept of green development into the analytical framework, adopted GTFP as an indicator to measure green economy, and conducted an empirical test by using the synthetic control method. The results showed that the establishment of FTZ had improved the development level of green economy in Shanghai. Wang et al. (2022) [2] analyzed the green economic growth effect of SPFTZ from the green perspective and tested it by breakpoint regression. The results showed that SPFTZ could significantly improve the green development of 26 cities in the Yangtze River Delta urban agglomeration through resource allocation effect, structure-driven effect and demonstration effect.

It can be seen that the Free Trade Zone attracts a large amount of capital, talent and technology with its policy advantages, and becomes a growth pole of regional development, which has a significant spillover effect on regional economy and helps promote regional integration. The first law of geography proposed by Tobler (1970) [8] shows that spatial spillover effect attenuates with geographical distance between cities, i.e., spillover effect has a boundary. Existing studies mostly measure the boundary of spillover effects of factors like technology, knowledge and financial agglomeration. In terms of technology spillover, Fu Miao (2009) [9] analyzed the attenuation distance of technology spillover in Europe based on Moreno et al. (2004) [10], carried out continuous regression under different thresholds with Chinese provincial panel data, and found that technology spillover was the strongest within 800 km. In terms of knowledge spillover, Deltas G et al. (2013) [11] used the data of regional patent and R&D expenditure from EU, and found that there was significant spillover effect in regions with similar R&D activities, and when the distance between the place of R&D origin and the place of receiving increased by 500 km, the spillover effect decreased by 55–70%.

Generally speaking, scholars at home and abroad have conducted sufficient theoretical analysis and empirical research on the economic growth effect and spillover effect of the free trade zone, which provides some theoretical support for this paper. However, there are still deficiencies in the existing literature: most of the existing studies on SPFTZ are limited to analyzing its overall spillover effects on surrounding provinces and cities, but do not explore the boundary and characteristics of the impact of SPFTZ on green development in the Yangtze River Delta from the perspective of regional boundary. Based on the first law of geography, this paper calculates GTFP in the Yangtze River Delta region, empirically tests whether SPFTZ construction has spillover effect on green development in the Yangtze River Delta region, and studies the spillover effect boundary. The differences between this paper and existing studies are that: firstly, from the

perspective of research content, the spatial spillover effect of SPFTZ on green economy in the Yangtze River Delta region is emphatically studied, which expands the research boundary of SPFTZ; second, from the perspective of research depth, this paper further studies the impact boundary and characteristics of SPFTZ on the green economy spillover effects in the Yangtze River Delta region, which provides a more comprehensive reference basis and more targeted policy suggestions for improving the synergistic effect between the free trade Zone and the green development of urban agglomeration.

3 Model Setting and Index Selection

3.1 Model Setting

3.1.1 Differences-in-Differences

Compared with traditional methods, Differences-in-Differences method can avoid the endogenous problem of using the policy implementation as an explanatory variable. Therefore, based on the pseudo-natural experimental framework, this paper constructed the Differences-in-Differences method (DID) to explore whether the establishment of SPFTZ has an impact on GTFP in the Yangtze River Delta region. According to the basic principle of DID, Shanghai, where SPFTZ was established in 2013, is set as the experimental group, and the other cities in the Yangtze River Delta are set as the control group. It is assumed that the variables of the first two groups have the same time effect trend. Therefore, after the establishment of SPFTZ, the changes between the experimental group and the control group are the changes caused by the policy effect. Based on this reasoning, the following model is established:

$$GTFP_{it} = \beta_0 + \beta_1 Treat_i + time_t + \beta_2 X_{it} + \mu_{it} + \nu_{it} + \varepsilon_{it}$$

where, i and t respectively represent the city and year. Considering that the establishment time of SPFTZ is 2013, due to the policy delay effect, this paper takes 2014 as the year of policy implementation and sets the research scope in 2003–2019. The research objects are 41 cities in the Yangtze River Delta region. At the same time, this paper selects GTFP as the indicator to measure the development of green economy, and takes 2003 as the base period to carry out the reduction treatment. The explained variable GTFPit represents the green economic development of the city i in the year t. Treati is used to identify whether the city i is listed as a FTZ; if the city i is set up as FTZ, then Treati is 1, otherwise is 0. Yeart is used to identify whether the policy has been implemented. If the observed sample year is within the range of 2014–2019, Yeart is 1; otherwise, it is 0.

3.1.2 Benchmark Regression

The exploration of the boundary of spillover effects of SPFTZ is of guiding significance to realize high quality integrated development in the Yangtze River Delta region, and then drive the development of green economy in China from point to area. This paper chooses standard economic growth models as the basis and sets the following spatial regression model:

$$GTFP_{it} = \beta_0 + \beta_1 distance_{it} + \alpha X_{it} + \eta_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where i represents the city and t represents the year. The explained that the variable GTFP is the cumulative value of GTFP of cities in the Yangtze River Delta region. The core explanatory variable--distance, measures the influence degree of Shanghai's GTFP on the GTFP of peripheral cities with the changes of geographical distances. X_{it} represents control variables including level of economic development (PGDP), human capital (HC), level of government intervention (GOV) and traffic conditions (TI). η_i and λ_t are urban fixed effect and year fixed effect respectively, which respectively control the influencing factors of the city that does not change over time and the macro influencing factors in a particular year. ξ_{it} is the random disturbance term.

(2) Variable selection

1. Explanatory variable: GTFP is set as the explanatory variable of this paper. This paper uses the super efficiency EBM method to calculate GTFP. The input and output indicators required to calculate GTFP are as follows:

(1) Selection of measurement input indicators: ① Labor input: This index adopts the year-end employment number of each city. ② Capital input: By referring to the method of Zhang et al. [12] and other processing methods, using the perpetual inventory method, the formula is $K_i^t = I_i^t/d_i^t + \left(1 - \delta_i^t\right)K_{i(t-1)}$, in which i is city, t is year, K, I, and δ are capital, investment and depreciation rate respectively, taking 2003 as the base period to carry out the reduction treatment. ③ Energy input: it is expressed as the annual electricity consumption of the whole city.

(2) Selection of measurement output indicators: ① Expected output: Gross regional product, using 2003 as the base period. ② Non-expected output: Industrial wastewater discharge, industrial SO_2 discharge and industrial soot discharge are converted into comprehensive pollution index by entropy method.

2. Explanatory variables: In order to study the spillover effect of SPFTZ on GTFP in other cities except Shanghai in the Yangtze River Delta region, this paper constructed a variable *Distance* reflecting radiation degree by referring to The method of Wang Xianbin (2018) [13].

$$Distance_{it} = \frac{lnGTFP\_\_c_{jt}}{lndis_{ij}} \tag{2}$$

In the formula, subscript i represents the peripheral cities, j represents the central city, and t represents the year. Considering that SPFTZ has expanded from the initial 28.78 km^2 to 120.72 km^2, its development trend has affected the whole Shanghai area, and has played a connection and stimulation effect on other industrial areas in Shanghai. At the same time, as SPFTZ has significantly improved Shanghai's GTFP (Wang et al., 2022) [2] through technology spillover, competition and resource allocation effects, this paper selects Shanghai as the central city j. lnGTFP_cjt represents the log value of GTFP in the year t of Shanghai j, and the variable $lndis_{ij}$ represents the traffic distance between Shanghai j and peripheral cities i.

Traffic distance can more completely reflect the connectivity of economic activities between cities. Therefore, this paper chooses the traffic distance between cities as the measurement of influence range. The measurement results of traffic distance between the central city Shanghai and cities in the Yangtze River Delta are as follows (Table 1).

3. Control variables: To obtain more accurate empirical results, some factors affecting GTFP should be controlled. Regional economic development level (PGDP) reflects the

Table 1. Traffic distances

Classification of distances	City
0–100	Jiaxing
100–200	Wuxi, Changzhou, Suzhou, Nantong, Zhoushan, Shaoxing, Huzhou, Ningbo, Hangzhou
200–300	Nanjing, Yancheng, Yangzhou, Zhenjiang, Taizhou, Jinhua, Taizhou, Xuancheng
300–400	Wuhu, Chuzhou, Lishui, Tongling, Huai'an, Wenzhou, Quzhou, Huangshan
400–500	Hefei, Anqing, Chizhou, Lianyungang, Suqian, Bengbu, Huainan, Lu'an
500–600	Suzhou, Xuzhou, Huaibei, Fuyang
600–700	Ma'anshan, Bozhou

factor structure and innovation capacity of a region to a certain extent, and the level of economic development is closely related to GTFP. Human Capital (HC) is the main driving force of endogenous economic growth, which determines the ability to learn and absorb advanced technology, and can promote technological progress through scientific and technological innovation, thus improving regional GTFP. The level of government intervention (GOV) indicates the degree of government regulation on the direction of economic development, which can affect the allocation of resources in the market, and then affect the regional GTFP. Transportation Index (TI) is closely related to the flow of factors. Convenient transportation can improve the efficiency of resource allocation, accelerate the dissemination of knowledge and technology, and thus improve the regional GTFP (Table 2).

(3) Data sources

The variable index data in the model mainly come from the *Chinese City Statistical Yearbook*, the statistical yearbooks of prefecture-level cities and the corresponding issues of the statistical bulletin of national economic and social development of prefecture-level cities. Urban traffic distance is obtained from baidu Map open platform; variables related to price factors in the model, such as PGDP, are all reduced through the corresponding price index to eliminate the influence of price factors.

4 Empirical Results Analysis

4.1 Empirical Results

In this part, the author investigates whether the establishment of SPFTZ promotes the development of green economy in the Yangtze River Delta region. Based on the DID model, the criterion regression results of DID are presented. As shown in Table 4 (1) and (2), at the level of GTFP, when only time effect and individual effect were controlled, the estimated coefficient of the explanatory variable $Treat_i \times Year_t$ was 0.167, and passed the

Table 2. Main variables and the formulas for calculation

Variables	Indicators (symbols)	Formula
Explained variables	GTFP	Labor input: Year-end employment number; Capital input: Fixed capital stock; Energy input: Electricity consumption of the whole society Expected output: Gross regional product; Unexpected output: Comprehensive pollution index
Explanatory variables	Distance	$Distance_{it} = \frac{lnGTFP\_c_{jt}}{lndis_{ij}}$
Control variables	Level of economic development (PGDP)	Gross regional product per capita
	Human Capital (HC)	Years of education per capita
	Level of Government Intervention (GOV)	Ratio of fiscal expenditure to regional GDP
	Transportation Index (TI)	Road area per capita

significance test at the level of 1%, and the estimated coefficient is 0.138. At the GTC level, when only the time effect and individual effect were controlled, the estimated coefficient of $Treat_i \times Year_t$ was 0.067 and passed the significance test at the level of 5%. This result passed the 10% significance test after the addition of control variables, and the estimated coefficient was 0.054. At the GEC level, the estimated coefficients of the explanatory variable $Treat_i \times Year_t$ failed the significance test. This part confirms that the establishment of SPFTZ promotes the development of GTFP in the Yangtze River Delta region, and GTC is the main driving force. With its own policy advantages and Shanghai's location advantages, Shanghai Free Trade Zone has gradually become the green growth pole of urban agglomeration in the Yangtze River Delta. Through trade and cooperation and exchange among enterprises, technology spillover has been generated, thus continuously driving the green development of the Yangtze River Delta region (Table 3).

4.2 Benchmark Regression Results

To further investigate the pattern of the spillover effect of SPFTZ on GTFP with the change of distances in the Yangtze River Delta region, the spatial panel regression model was used to test. The regression in the Table 4 results show that when the distances between surrounding cities and SPFTZ is 0–200 km, the regression coefficients are significantly negative at the level of 5%; when the distance is within 200–500 km, the regression coefficients are significantly positive at the level of 5%; when the distance is between 500–700 km, the regression coefficients cannot pass the significance test.

The first part is 0–200 km, including ten cities like Jiaxing, Suzhou, Nantong, etc. In this range, the regression coefficient of SPFTZ on the surrounding city's GTFP is

Table 3. DID baseline regression results

	GTFP	GTFP	GTC	GTC	GEC	GEC
	(1)	(2)	(3)	(4)	(5)	(6)
Treat × *Year*	0.167***	0.138***	0.067**	0.054*	0.012	0.004
	(5.18)	(3.43)	(4.88)	(2.76)	(2.66)	(3.12)
Controls		Yes		Yes		Yes
City	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
City × *Year*	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.020***	0.998***	0.767***	0.365***	0.532***	0.301***
	(30.56)	(4.19)	(27.54)	(3.87)	(18.87)	(2.43)
R^2	0.224	0.314	0.132	0.243	0.112	0.325

Table 4. Basic regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	0–100	100–200	200–300	300–400	400–500	500–600	600–700
Distance	−2.09**	−0.538**	0.37**	1.327**	0.31**	0.506	−0.37
	(0.778)	(0.778)	(1.864)	(0.617)	(0.771)	(0.701)	(0.548)
PGDP	0.338*	0.338*	0.761***	−0.949*	0.123**	0.346*	0.779
	(0.385)	−0.385	(1.43)	(0.386)	(0.881)	(0.225)	(0.192)
HC	−0.204**	−0.2048**	0.869	0.233*	0.325***	0.031**	0.067**
	(0.892)	(0.892)	(0.473)	(0.068)	(0.174)	(0.373)	(0.26)
GOV	0.315	0.315	0.698**	−0.668	−0.812*	−0.692*	−0.110*
	(0.548)	(0.548)	(0.481)	(0.104)	(0.234)	(0.222)	(0.146)
TI	−0.013	−0.013	−0.033*	−0.013	0.016*	0.039	−0.222*
	(0.031)	(0.031)	(0.024)	(0.002)	(0.008)	(0.009)	(0.003)
Cons	1.136***	1.136**	4.923***	2.868***	1.301***	0.282***	0.139***
	(0.570)	(0.570)	(2.735)	(0.902)	(0.64)	(0.606)	(0.363)
R-squared	0.544	0.544	0.535	0.719	0.943	0.385	0.588

negative, and passes the significance test of 5%. This indicates that the spillover effect from SPFTZ is weak but the siphon effect is strong, and the siphon effect gradually decreases with the increase of distance. The reason for this phenomenon is that, first of all, SPFTZ allows enterprises to "enter the zone first, declare tax later" and enjoy the status of being "within the boundary but outside the customs" [34]. The status of being "within the boundary but outside the customs" can simplify international trade procedures, reduce international trade costs, improve logistics efficiency, and greatly improve the convenience for products entering and leaving the country. This makes SPFTZ gradually become a hot place for foreign enterprises as well as local enterprises

with overseas business to invest and settle in. Therefore, the surrounding cities are faced with the dual dilemma of local enterprises' out-migration and FDI reduction [14]. On the one hand, it will reduce the flow and application of foreign advanced clean technology and pollution control technology in surrounding cities, so that some enterprises are unable to learn advanced clean technology. Therefore, some enterprises have the problem of "low-end lock-in"-- enterprises still use low-end technology to produce products and cannot reduce carbon emissions. This will hinder the development of GTFP of surrounding cities.

The second part is the distance range of 200–500 km, including twenty-four cities such as Nanjing, Jinhua and Taizhou. In this region, the regression coefficients of SPFTZ for the surrounding cities' GTFP show an inverted "U" pattern and passes the significance test of 5%, indicating that SPFTZ drives the development of the cities' GTFP within this distance. However, when the driving effect exceeds a certain distance threshold, it gradually decreases with the increase of distance. The reasons for this phenomenon are as follows: Firstly, with the excellent business environment in the zone, SPFTZ has attracted a large number of foreign-funded enterprises to enter the zone, leading to the coexistence of foreign-funded enterprises and local enterprises. Due to the existence of competition effect, local enterprises can obtain more knowledge spillover and technology spillover. Moreover, SPFTZ is in a different stage of industrial development from the surrounding cities, that is, SPFTZ forms an industrial gradient with the surrounding cities, which provides the possibility for the optimization of the industrial structure of the surrounding cities.

The third part is in the distance range of 500–700 km, including six cities like Suzhou, Xuzhou, Huaibei, etc. The spatial regression coefficient within this distance cannot pass the significance test, which indicates that SPFTZ has no significant effect on GTFP of cities within this region. The reasons for this phenomenon are as follows: Firstly, a long geographical distance will increase the cost of industrial transfer, which is not conducive to the upgrading of the industrial structure of cities, so that cities in this range still maintain the current proportion of industrial structure, and eventually, SPFTZ has no significant impact on GTFP. Secondly, market segmentation and market protection among provinces and cities still exist. The unified large market of goods, finance and labor has not yet formed, and there are some institutional barriers, especially in trade cooperation, scientific and technological innovation and public services, which result in the poor flow of resources and factors and the failure to allocate the optimal factors to enterprises with clean technology and green development concept [15].

5 Policies and Suggestions

The reform and innovation of the free trade zone have entered the deep water zone, and the spatial intersection of the network pattern and the urban agglomeration pattern has brought new impetus to the urban economic development. Starting from the theory of the first law of geography and based on the data of the Yangtze River Delta region from 2003 to 2019, this paper uses DID to investigate the impact of SPFTZ on GTFP in the Yangtze River Delta region, and analyzes its impact boundary with the help of the benchmark regression model. The findings include: SPFTZ significantly promoted the

improvement of GTFP in the Yangtze River Delta region, that is, SPFTZ has a spillover effect on the high-quality development of the Yangtze River Delta region, in which GTC is the main driving force. Through the benchmark regression model, it is found that the spatial spillover effect of SPFTZ on green total factor productivity in the Yangtze River Delta region has a significant boundary. Specifically, the effect of SPFTZ on GTFP in the range of 0–200 km is significantly negative, the effect of GTFP in the range of 200–500 km is significantly positive, and the effect of GTFP in the range over 500 km is not significant. Based on the research conclusions of this paper, the main policy implications are as follows:

(1) We need to expand the radiation effects and coordinate regional development. SPFTZ construction needs strong hinterland support. With SPFTZ as the connection node, the advantages and characteristics of resource endowment and industrial base of each distance range in the region are complementary. We need to focus our efforts on major reform tasks, make concerted efforts, intensify and amplify the effect of SPFTZ, and make a number of new achievements in institutional reform across regions, departments, and levels.

(2) Based on its own reality, promptly incorporate into the SPFTZ. Facing the advantages and challenges brought about by SPFTZ economic circle, if the economy of the Yangtze River Delta region wants to achieve better and faster development, it must identify its advantages and disadvantages comprehensively and objectively on the basis of understanding its own development. On the one hand, the region should actively seize the opportunities and concessions brought by the construction and development of SPFTZ. At the same time, these cities should give full play to the combined force of the government, enterprises and society, and create positive docking with the SPFTZ; in addition, they should learn more and innovate more, and through more understanding of the policies and trade rules.

(3) Actively undertake industrial transfer, promote industrial upgrading, and achieve high-quality development. Cities along the Yangtze River Economic Belt should strengthen industrial cooperation with each other, carry out targeted industrial distribution according to their existing development advantages and resource endowment, develop different industrial types or different links in the industrial chain, and form a mutually supporting and cooperative industrial division pattern. In the industrial development of the Yangtze River Delta urban agglomeration, the radiation driving function of SPFTZ should be highlighted. The SPFTZ should speed up the construction of a modern urban industrial system dominated by the service industry.

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