Research on Spatial Spillover Effect of Total Factor Productivity in Construction Industry: Evidence from Yangtze River Delta Region in China

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Abstract

Based on the panel data of construction industry in The Yangtze River Delta region from 2007 to 2020, the Malmquist index method was used to measure the Total Factor Productivity of construction industry in the Yangtze River Delta region, and the Spatial Durbin Model was constructed to study the spatial spillover effect of total factor productivity of construction industry. The empirical results show that the average growth rate of Total Factor Productivity is 1.39% when the technological progress index of construction industry increases by one percentage point, and technological innovation is the inexhaustible source of promoting the growth of Total Factor Productivity. The Total Factor Productivity of construction industry in Yangtze River Delta region has significant Spatial correlation, environmental regulation, human capital, industrial scale, industrial structure and the level of open has a positive influence in promoting the total factor productivity, while the spillover of economic level will hinder the growth of total factor productivity in the construction industry in the region but promote the neighboring regions. Improving the intensity of environmental regulation can help to force enterprises to realize independent innovation, increase research and development investment and human capital investment, maintain reasonable factor allocation, speed up innovation-driven high-quality development, and promote comprehensively technological level of China's construction industry.

Keywords

Yangtze River Delta Region, Construction Industry, Malmquist Index, Spatial Spillover Effect

1. Introduction

It is difficult to achieve both economies of scale and competitive vitality (Marshall & Paley, 1879). So, how to efficiently utilize economies of scale in the industry while maintaining market vitality has become a hot issue all over the world. At this stage, China is in the key period of industrial transformation. Most scholars focus on improving the development mode of emerging industries, but pay less attention to some traditional industries. The traditional industries still occupy the main body status in China, as one of the pillar industries is construction industry, By the long-term dependence on high investment, high emission and low output of extensive development pattern, there is distortion of the allocation of resources inevitably behind the prosperity, which is also the main reason for its uneconomical scale, and then it leads to the problem of low production efficiency. The report of the 19th Communist Party of China National Congress clearly pointed out that should comprehensively improve total factor productivity (TFP) to promote high-quality development. Based on data envelopment analysis to measure TFP and its decomposition index, we can intuitively analyze the reasons hindering the growth of TFP and improve it. Meanwhile, as research and development investment is one of the key factors for economic growth (Romer, 1986), the regions which possess more research and development activities have higher development vitality. Therefore, studying and promoting the development of TFP in the construction industry in the Yangtze River Delta region has a positive impact on improving the overall production efficiency of China's construction industry. However, what is the level of TFP of construction industry in Yangtze River Delta? Are there the spatial spillover effects on TFP of construction industry? What is the impact of technological innovation on TFP in construction industry? There are few systematic studies to answer these questions.

2. Literature Review

The construction industry is an important part of the national economy, which is closely related to China's economic development and the improvement of people's life. However, due to the long-term lack of attention to the production efficiency of the construction industry, the evaluation research on the production efficiency of the construction industry has been ignored which may have an adverse impact on the development of the construction industry (Liu, 2009). Solow residual method is usually used to measure TFP (Wang et al., 2013). According to the estimation results of total production function, the residual of output growth rate after deducting the growth rate of various input factors is used to measure the growth of TFP, without considering the dynamic differences caused by the changes of returns to scale or technical efficiency under actual operation. Most foreign scholars build static models to evaluate the production efficiency of construction enterprises from the perspective of microeconomic theory based on data envelopment analysis. For example, Jan (1996) measured and evaluated the labor productivity of construction enterprises through 104 construction engineering data in Sweden from 1989 to 1992, and found that there are significant differences in production efficiency among construction enterprises; Based on the sample of Norwegian construction enterprises in 2001, Edvardsen (2003) found that economies of scope showed negative growth on the production efficiency of construction enterprises. These conclusions are objectively conducive to the balanced development of construction enterprises and provide suggestions for improving production efficiency. However, the research conclusions based on the enterprise section are only responsible for the envelope decision-making unit. In addition, there is a certain subjectivity in the selection of decision-making unit, resulting in the conclusion is often relatively adaptive but not popularized, and can only be used as an effective means of enterprise management to reduce input redundancy or increase output. Since the reform and opening up, China's Foreign Direct Investment index has increased significantly, and the competition among enterprises is fierce. Affected by the macro environment such as regional economic development level and industrial monopoly, the construction industry can only rely on repeated input to maintain output. The phenomenon of diminishing marginal utility emphasized in "Gossen's first law" also confirms the essence of "Marshall conflict". The diseconomy of scale gradually produced by most construction enterprises not only reduces the output, but also leads to different production efficiency of regional construction industry, resulting in different regional development levels. It is necessary to introduce various indicators of regional construction industry and take the region as the main decision-making unit to measure the production efficiency, so as to balance the development of construction industry. Taking the construction industry data from 2001 to 2011 as a sample, Li and Zhao (2013) used Malmquist index method to calculate the TFP of regional construction industry, and put forward improvement suggestions on improving the operation and management level, labor quality and production efficiency of construction industry. By calculating the TFP level of regional construction industry, Liu et al. (2013) found that science and technology investment, human capital and economic level can significantly promote production efficiency. Tan et al. (2015) empirically tested the impact of changes in economic environment, industrial technological capacity and industrial market structure on the growth of TFP on the basis of calculating the TFP of regional construction industry from 1993 to 2012. The above conclusions prove that TFP is comprehensive and effective as a yardstick to measure the production efficiency of the construction industry, but scholars have some differences in empirical research on the factors affecting TFP growth, including restricted variable model (Dai & Chen, 2010), multiple linear regression (Liu, 2009), grey correlation analysis (Tan et al., 2015). It is worth mentioning that with the expansion of the scale of the construction industry, interregional cooperation and exchanges are becoming more and more frequent, and industrial alliances are becoming closer. The technology and efficiency spillovers caused by the spatial agglomeration of the construction industry cannot be ignored. Considering that some scholars (Wu & Deng, 2018; Xiang et al., 2019) discussed the spatial effects of carbon emissions from industrial clusters and construction industry from a low-carbon perspective, it is of great significance to quantitatively analyze the spatial spillover effects of construction industry TFP in the Yangtze River Delta on the basis of comprehensive measurement.

3. Research Method

3.1. Malmquist Index of Data Envelopment Analysis Method

Malmquist index was originally proposed by Malmquist (1953). Fare et al. (1992) improved it to make it have the ability of empirical test, and formed Malmquist productivity index based on Data Envelopment Analysis. Malmquist index method can compare the dynamic changes of efficiency and productivity of similar decision-making units in a specific period of time. The mathematical expression is:

$$M_i^{t,t+1}\left(x^{t+1},y^{t+1},x^t,y^t\right)=\left[\frac{D_i^t\left(x^{t+1},y^{t+1}\right)}{D_i^t\left(x^t,y^t\right)}\times\frac{D_i^{t+1}\left(x^{t+1},y^{t+1}\right)}{D_i^{t+1}\left(x^t,y^t\right)}\right]^{\frac{1}{2}}$$

In order to measure the change of efficiency, TFP index is usually divided into catch-up effect and frontier shift. The catch-up effect represents the change effect of Decision-making unit (DMU) technical efficiency. The frontier movement reflects the movement of the production frontier referenced by DMU in the two periods and represents technological progress. The Malmquist index is converted to:

$$M_i^{t,t+1}\left(x^{t+1},y^{t+1},x^t,y^t\right)=\frac{D_i^{t+1}\left(x^{t+1},y^{t+1}\right)}{D_i^t\left(x^t,y^t\right)}\times\left(\frac{D_i^t\left(x^{t+1},y^{t+1}\right)D_i^t\left(x^t,y^t\right)}{D_i^{t+1}\left(x^{t+1},y^{t+1}\right)D_i^{t+1}\left(x^t,y^t\right)}\right)^{\frac{1}{2}}$$

The first part on the right of the equation is the technical efficiency index (ECH), and the second part is the technical progress index (TCH). When ECH is greater than 1 (less than 1), it indicates that the technical efficiency of DMU increases (decreases); When TCH is greater than 1 (less than 1), it indicates that technology has improved (declined).

3.2. Construction of the Spatial Econometric Model

To describe spatial correlation, a Spatial Durbin Model (SDM) can be constructed to consider both of the spatial correlation of TFP in construction industry and the spatial correlation of independent variables. The expression for SDM is:

$$TFP_{it}=\rho WTFP_{it}+\alpha_i x_{it}+\beta_i Wx_{it}+\delta_i control_{it}+\varepsilon_{it}$$

In the equation, x_{it} is the influencing factor matrix of TFP in construction industry, ρ is the spatial autocorrelation coefficient, W is the spatial adjacency matrix, $WTFP_{it}$ is the spatial lag term of total factor productivity, and Wx_{it} is the spatial lag term of explanatory variable. ε_{it} is a random error term.

3.3. Data Sources

In the calculation of TFP of construction industry, referring to the research object of Cobb-Douglas production function model, labor force, land and entrepreneur ability are selected as input variables, and the total output value of construction industry is taken as output variable to calculate Malmquist productivity index.

In spatial econometric analysis, TFP of construction industry is selected as the dependent variable. Among the independent variables, The environmental regulation (ER) is measured by the proportion of pollution control investment in GDP, human capital (HC) is measured by the number of employees in the construction industry, and the industrial scale (EN) is measured by the proportion of the number of construction enterprises in the number of industrial enterprises; The level of economic development (GDP) is measured by regional GDP, the industrial structure (IS) is measured by the proportion of the total output value of the secondary industry in GDP, the regional opening level (OPEN) is measured by the proportion of total imports in GDP, and the proportion of foreign direct investment (FDI) in the total investment in fixed assets is measured by the proportion of foreign capital (FDI). Among them, HC and GDP with large data fluctuation are logarithmically processed.

4. Empirical Analysis

4.1. The TFP Measurement of Construction Industry

The TFP is calculated based on the input and output indicators of construction industry in 41 cities in the Yangtze River Delta. The calculation results are shown in Table 1.

4.2. Research on Space Spillover Effect

The Moran's I index of TFP of construction industry in the Yangtze River Delta from 2008 to 2020 is calculated, and the results are shown in Table 2.

According to the TFP distribution of construction industry in 2008, 2012, 2016 and 2020, collect and describe them through geographic information technology, and draw the TFP agglomeration map of construction industry in the above three years, as shown in Figures 1-4.

4.3. The Empirical Results

By describing the distribution and aggregation of construction TFP in the Yangtze River Delta, a Spatial Durbin Model is further constructed to quantitatively analyze the spatial spillover effect of construction TFP. According to the Hausman test results, the original hypothesis should be accepted, that is, the random effect SDM should be selected. The LR test of SLM and SEM is significant at the

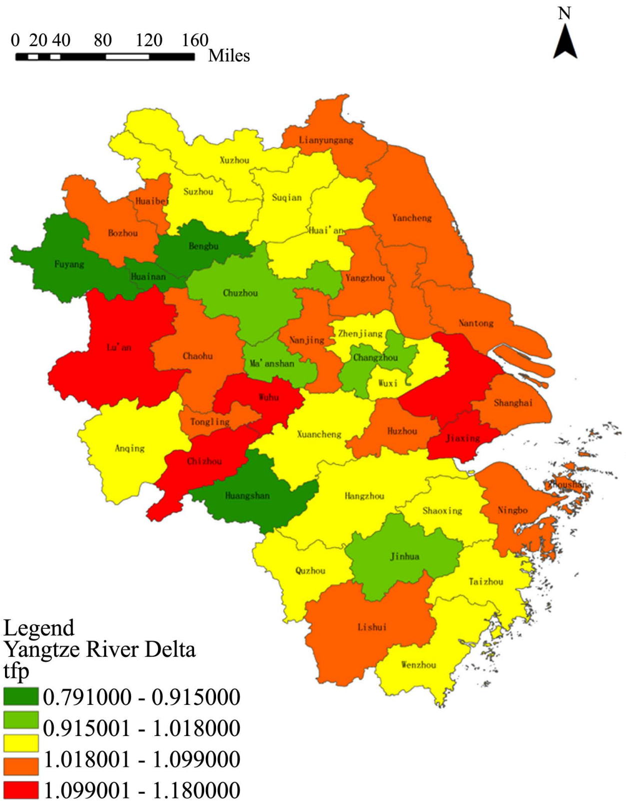

Figure 1. TFP agglomeration of construction industry in the Yangtze River Delta in 2008.

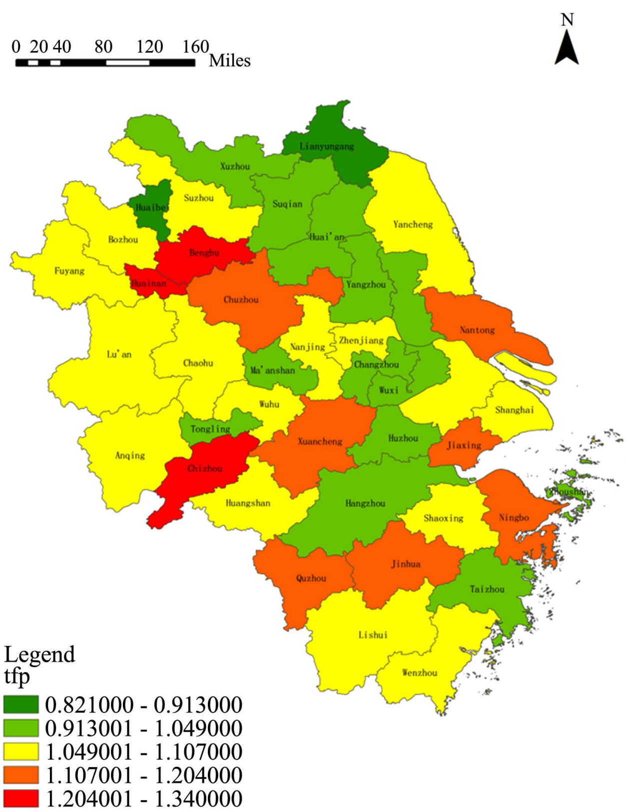

Figure 2. TFP agglomeration of construction industry in the Yangtze River Delta in 2012.

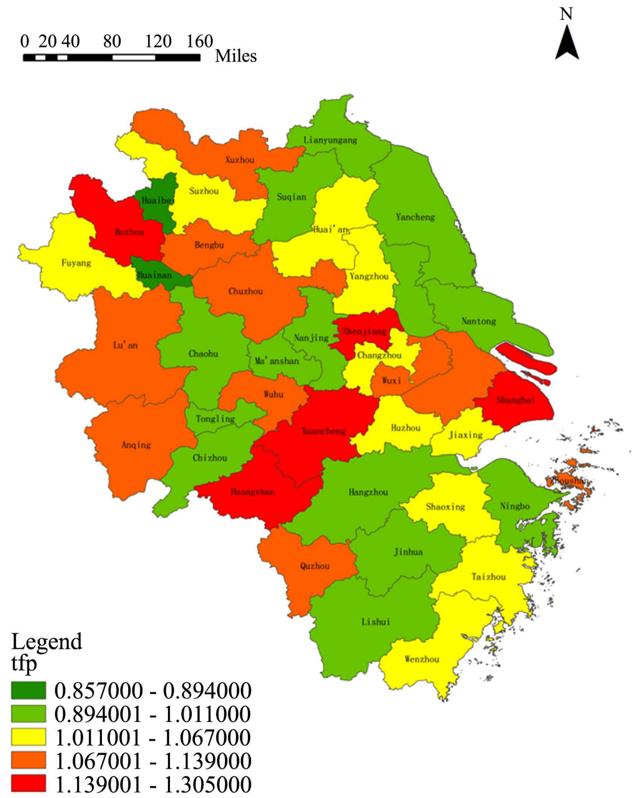

Figure 3. TFP agglomeration of construction industry in the Yangtze River Delta in 2016.

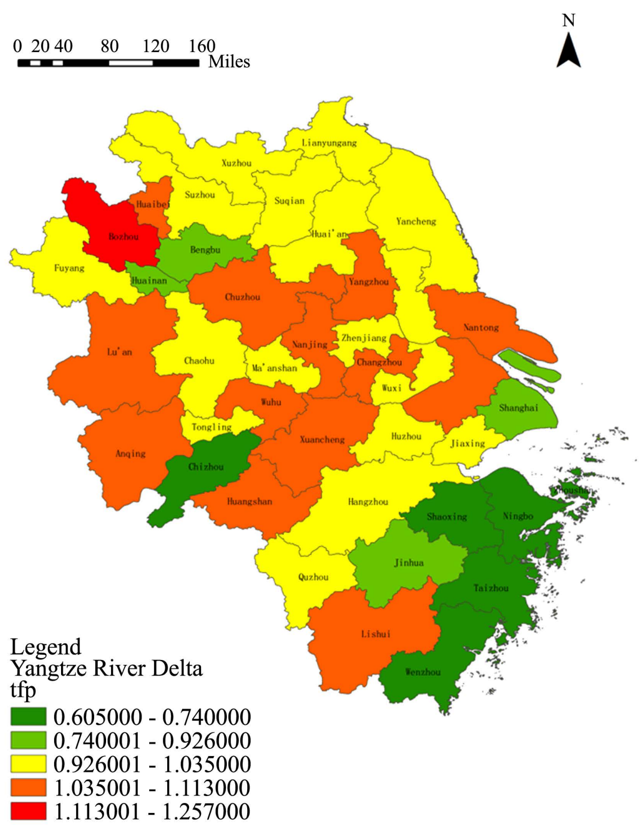

Figure 4. TFP agglomeration of construction industry in the Yangtze River Delta in 2020.

Table 1. TFP and its decomposition index of construction industry in the Yangtze River Delta from 2007-2020.

Region	TFP	ECH	TCH	TFP Ranking
Shanghai	1.100	1.010	1.089	19
Nanjing	1.061	1.001	1.061	38
Wuxi	1.115	1.046	1.066	8
Xuzhou	1.101	1.027	1.072	16
Changzhou	1.079	1.008	1.071	29
Suzhou	1.103	1.049	1.051	15
Nantong	1.118	1.017	1.099	6
Lianyungang	1.069	1.007	1.062	36
Huaian	1.060	1.004	1.055	39
Yancheng	1.100	1.034	1.064	20
Yangzhou	1.105	1.031	1.072	13
Zhenjiang	1.078	1.019	1.057	30
Jiangsu-Taizhou	1.076	0.999	1.078	31
Suqian	1.074	1.006	1.068	34
Hangzhou	1.084	1.013	1.070	28
Ningbo	1.118	1.048	1.067	7
Wenzhou	1.112	1.038	1.071	10
Jiaxing	1.136	1.050	1.082	1
Huzhou	1.101	1.027	1.072	17
Shaoxing	1.085	1.010	1.075	27
Jinhua	1.087	1.004	1.083	26
Quzhou	1.101	1.027	1.072	18
Zhoushan	1.120	1.038	1.079	3
Zhejiang-Taizhou	1.090	1.023	1.066	24
lishui	1.112	1.041	1.068	11
Hefei	1.096	1.019	1.076	22
Huaibei	1.050	1.001	1.049	41
Bozhou	1.119	1.051	1.065	4
Suzhou	1.074	1.010	1.064	35
Bengbu	1.095	1.024	1.070	23
Fuyang	1.064	0.999	1.066	37
Huainan	1.053	0.983	1.072	40
Chuzhou	1.131	1.055	1.072	2

Continued

Luan	1.106	1.030	1.074	14
Maanshan	1.076	1.014	1.062	32
Wuhu	1.107	1.040	1.065	12
Xuancheng	1.114	1.057	1.053	9
Tongling	1.091	1.036	1.052	25
Chizhou	1.076	1.023	1.051	33
Anqing	1.118	1.055	1.059	5
Huangshan	1.097	1.030	1.065	21

Table 2. Moran's I test of TFP of construction industry in Yangtze River Delta.

Year	Moran's I Index	Z Value
2008	−0.084	−2.344
2009	−0.077	−2.208
2010	−0.086	−2.291
2011	0.018	1.195
2012	0.017	2.189
2013	0.068	2.485
2014	0.036	1.038
2015	0.04	2.409
2016	0.082	3.861
2017	0.08	2.058
2018	1.212	3.133
2019	1.297	2.510
2020	1.288	2.227

5% confidence level, which proves that the random effect SDM does not necessarily degenerate into SLM or SEM. The empirical results are shown in **Table 3**.

According to the regression results in **Table 3**, the decomposition effect of the overall spatial effect is obtained in the form of partial derivative moment (LeSage & Pace, 2009). The results are shown in **Table 4**.

According to the decomposition effect in **Table 4**, the direct effect of ER on TFP in construction industry is 0.1987, and the indirect effect is 0.1135, indicating that environmental regulation contributes to the growth of TFP in construction industry. In other words, improving the intensity of environmental regulation contributes to the growth of TFP not only in local construction industry, but also in adjacent construction industry. Although environmental regulation raises the environmental cost of construction enterprises and increases the pressure of production cost, it can reduce the output of by-products and realize

Table 3. Spatial Durbin model regression results.

Variable	Coefficient	Standard error	T statistic
ER	0.2636***	0.0878	3.0024
LNHC	0.0179***	0.0067	2.6433
EN	0.0097	0.0079	1.2304
LNGDP	−0.2194**	0.0956	−2.2958
IS	0.2914*	0.1454	2.0044
OPEN	0.0034	0.0022	1.5310
FDI	−1.8320	1.4387	−1.2734
W*ER	0.1964*	0.0981	2.0012
W*LNHC	−0.1022***	0.0282	−3.6287
W*EN	−0.1524*	0.0821	−1.8563
W*LNGDP	0.1637***	0.0610	2.6820
W*IS	−0.0011	0.0012	−0.9836
W*OPEN	0.0120*	0.0069	1.7299
W*FDI	−6.9428***	1.9354	−3.5872
ρ	0.1110***	0.0235	4.7195
R^2	0.8033	-	-
LogL	412.0579	-	-
LR-lag	21.3273**	-	-
LR-error	22.6028**	-	-
Hausman test	Hausman test-statistic = −17.3824 *p*-value = 0.1023		

Note: ***expresses 1% significance level, **expresses 5% significance level, *expresses 10% significance level.

Table 4. Effect decomposition result.

Variable	Direct Effect	T statistic	Indirect Effect	T statistic	Total Effect	T statistic
ER	0.1987***	2.9824	0.1135*	1.9833	0.3122**	2.9443
LNHC	0.0154***	2.7762	−0.0921***	2.7852	−0.0767***	5.1001
EN	0.1321*	−1.7934	−0.1110	−1.6032	0.0211−	1.3223
LNGDP	−0.1774***	−4.2732	0.1002**	−2.8436	−0.0772**	−2.1274
IS	0.6237*	1.9802	0.0762**	2.1063	0.6999*	1.8902
OPEN	0.0102*	2.0013	−0.0062	0.8265	0.0040	1.1985
FDI	0.2648**	2.3695	−0.1354**	2.2023	−0.4002***	3.9827

Note: ***, **and *denotes 1%, 5% and 10% significance level, respectively.

the growth of production efficiency by forcing enterprises to innovate independently and improving the technical level, resulting in knowledge spillover and technology flow.

The direct effect of LNHC on TFP of construction industry is 0.0154, that is, the improvement of human capital level in this region will promote the growth of TFP of construction industry, and human capital level has a positive impact on the development of labor-intensive industry. The indirect effect is −0.0921, indicating that the flow of labor force is limited. When the natural and social conditions of a region can no longer accommodate more labor force, the flow of human capital will show a trend of "one side and the other side" to different regions.

The direct effect of EN is 0.1321, and the indirect effect is −0.1110. When the scale of local construction enterprises increases, a certain scale of agglomeration effect will be generated to realize the sharing of knowledge and technology, reduce the production cost and transportation process, so as to realize the intensive production of construction industry and promote the growth of TFP. However, the local construction industry agglomeration may compress the market share of the construction industry in the neighboring area, thus inhibiting the TFP of the construction industry in the neighboring area.

The direct effect of LNGDP is −0.1774, and the regional economic level shows negative elasticity to the growth of TFP in construction industry, indicating that with the development of regional economy, the transformation process of industrial structure upgrading may offset the development level of industrial industry. The indirect effect of LNGDP is 0.1002, indicating that promoting regional economic development not only contributes to the upgrading of local industrial structure, but also produces economic spillover to promote the growth of TFP in adjacent construction industry.

The direct effect of IS was 0.6237, and the indirect effect was 0.0762, indicating that IS had a positive influence on the growth of TFP in construction industry. Industrial structure has a significant long-term spillover effect on the growth of TFP in construction industry, that is, the greater the proportion of secondary industry development, the more advantageous external development conditions of construction industry.

The direct effect of OPEN on TFP of construction industry is 0.0102, and the indirect effect and total effect are not significant, indicating that the level of openness depends on urban conditions. The level of openness of different cities has no influence on adjacent areas, and there is no spatial interaction between local trade and the development of construction industry in adjacent areas.

The direct effect of FDI on TFP of construction industry is 0.2648, and the indirect effect is −0.1354, indicating that there is also a limit in the flow of foreign capital.

5. Conclusions and Recommendations

Based on the measurement of TFP of construction industry in the Yangtze River Delta, this study systematically discusses the spatial spillover effect of TFP. The results show that the growth of TFP in the construction industry in the Yangtze River Delta mainly comes from TCH, which shows that TCH is the source of promoting the growth of TFP; there is a significant spillover effect of TFP among local cities, which shows that promoting the development of construction industry in the Yangtze River Delta is conducive to promoting the improvement of the production level of China's overall construction industry. According to the above research conclusions, the following suggestions are put forward:

First, maintain appropriate intensity of environmental regulation. Environmental regulation can help restrain the pollution emission behavior of construction industry, and force construction enterprises to carry out technological innovation and reduce emissions. Therefore, it is necessary to improve the environmental protection mechanism, attach importance to the quality of economic growth, constantly improve production technology, reduce pollution emissions, and transform from extensive production mode to intensive production mode.

Second, increase research and development investment and human capital investment, adhere to independent innovation, improve the overall technical level of the construction industry, to ensure the efficient use of construction resources. Raise the educational level of the labor force and transform it from labor intensive to knowledge intensive.

Third, maintain reasonable allocation of factors of production and achieve high-quality regional economic growth. Accelerate the advanced transformation of industrial structure, increase the proportion of producer services, and promote the effective transformation of knowledge achievements. At the same time, ensure the rationality of the industrial structure, balance the first, second and tertiary industry balanced development.

Finally, regional coordination and cooperation should be strengthened. Under the background of trade globalization, regional trade level should be strengthened, regional cooperation should be sought, industry and regional union should be promoted, complementary advantages and mutual benefit should be achieved.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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