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Evaluation of Innovation-driven Effect of Chinese Free Trade Pilot Zone Construction

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Abstract

The development of pilot free trade zones not only facilitates trade, but also enhances regional innovation capacity, which is an important measure to achieve high-quality economic and social development in China.This paper uses the multi-period difference-in-differences model to discuss the influence mechanism of the construction of Chinese free trade experimental zone on regional innovation capability, and evaluates its specific effect. The results show that the establishment of pilot free trade zones significantly improves regional innovation ability. Resource allocation, industrial structure upgrading and international technology spillover are important channels for the construction of pilot free trade zones to improve regional innovation capacity. With the improvement of institutional quality and infrastructure level, the construction of pilot free trade zones has a more obvious effect on improving regional innovation capacity. The establishment of the pilot free trade zone has a positive spillover effect on the surrounding areas.

Keywords

Pilot Free Trade Zone; Regional Innovation Capability; Difference-In-Differences Method; Spatial Spillover.

1. Introduction

In September 2013, the Shanghai Free Trade Pilot Zone (FTZ) was established, and since then, other FTZs in Guangdong, Fujian, Tianjin, Zhejiang, Chongqing, Hubei, Henan, Sichuan, and Shaanxi have been approved. By the end of 2022, 21 provinces (including municipalities and autonomous regions) had established FTZs. In September 2023, President Xi Jinping emphasized the importance of further advancing the FTZ construction, calling for the development of higher-level FTZs and greater exploration in broader and deeper areas based on ten years of experience.

As pioneers of reform and opening-up, FTZs serve as important drivers of regional economic growth by optimizing the business environment, gathering advanced resources, fostering emerging industries, and extending international industrial chains. FTZs improve the efficiency of resource allocation, promote industrial structure upgrading, and ultimately enhance regional innovation capacity. Therefore, accurately understanding and scientifically evaluating the innovation-driven effects of FTZ construction is of great practical significance for the implementation of China's innovation-driven development strategy.

Since the inception of FTZs, their policy effects have attracted significant attention from scholars. Jiang et al. [1] Wang Z et al. [2] and Wang P et al. [3] used the synthetic control method to compare pre- and post-FTZ policies in Shanghai, Guangdong, and Fujian, respectively, finding that FTZ policies significantly promote green total factor productivity, local tax revenues, and trade transformation. Liu Y et al. [4], Wang M et al. [5], Liu P et al. [6] used the difference-in-differences method to study the impact of free trade zone construction on cross-border capital flows, factor resource allocation, and enterprise product exports. The research showed that the

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construction of free trade zones can significantly promote cross-border investment liberalization, resource allocation optimization, and export product quality. In addition, studies have shown that location disadvantages, industrial development levels, and industrial agglomeration can all have an impact on the effectiveness of free trade zone policies [7, 8]. However, overall, there is currently a lack of literature exploring the relationship between free trade zone policies and regional innovation capabilities.

This study seeks to address the following questions: How does FTZ construction impact regional innovation capacity? What are the mechanisms driving this innovation? Do different institutional and infrastructural conditions alter the effects? Does FTZ construction influence the innovation capacity of neighboring regions? Based on this, this study uses a multi-period difference-in-differences (DID) model to explore the relationship between FTZ construction and regional innovation capacity, with an analysis of heterogeneity and spatial spillover effects.

2. Literature Review and Hypothesis Development

2.1. Mechanisms of Impact

The construction of FTZs promotes the reallocation of resources and factors of production. The distortions in the factor markets lead to "non-productive rent-seeking" activities, which distort corporate R&D investment decisions and reduce the willingness of firms to engage in innovation activities, thus constraining regional innovation [9]. The construction of FTZs can effectively improve the distortions in the factor markets. First, FTZ construction promotes market-oriented reforms, reduces transaction costs, and enhances the mobility of production factors, allowing them to flow to emerging fields quickly and at low cost. Second, FTZ construction removes policy barriers, attracts high-quality foreign talent and foreign investment, and alleviates the mismatch between the supply and demand of high-quality production factors in the region. Finally, FTZ construction creates a fair competitive environment, strengthens competition among market players, and improves resource misallocation through the process of "survival of the fittest" [10]. Therefore, FTZ construction promotes the reallocation of resources and factors of production by creating a transparent, open, and competitive market environment, enhancing the innovation motivation of economic agents, and thus improving regional innovation capacity.

FTZ construction also promotes industrial structure upgrading. FTZ construction reduces trade barriers and creates an open economic environment. By participating more deeply in international divisions of labor, traditional industries are driven to climb from the low end of the value chain to high-end segments such as advanced manufacturing and productive services [11]. At the same time, the high-end and emerging industrial clusters brought about by FTZ construction help to improve internal regional industrial chains, forming effective agglomerations of related industries. Through spillover and competition effects, this leads to internal structural changes in traditional industries, promoting industrial structure upgrading [12]. Industrial structure upgrading provides a good platform for the application of advanced technologies and cutting-edge knowledge. The more knowledge- and technology-intensive the industrial structure, the more effective the absorption and utilization of new knowledge, thus forming stable and continuous innovation capacity [13]. In summary, FTZ construction fosters the cultivation of technology- and knowledge-intensive industrial clusters, accelerates the advancement of regional industrial structure, and effectively absorbs new technologies and knowledge, converting them into regional innovation capacity.

Finally, FTZ construction enhances the level of international technology spillovers. Through international technology spillovers, China can narrow the technological gap with advanced economies, achieve faster technological accumulation, and thus provide more technical resources for independent R&D and innovation. International technology spillovers have

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become an important way for China to acquire advanced foreign technologies [14]. On the one hand, FTZ construction promotes two-way openness in financial and capital markets, encouraging domestic companies to "go global." In the process of R&D interactions with foreign technological leaders, domestic firms obtain reverse technology spillovers [15], enhancing regional innovation capacity. On the other hand, the negative list system and pre-entry national treatment system lower the barriers and uncertainties for foreign investment, expanding the scale of foreign direct investment. Multinational companies, as representatives of advanced technologies, will diffuse advanced technological knowledge to domestic firms when integrating into the local market through backward and forward linkages and demonstration effects [16], strengthening the innovation capabilities of domestic companies.

Therefore, this study proposes the following hypotheses:

Hypothesis 1: FTZ construction improves regional innovation capacity by optimizing resource allocation.

Hypothesis 2: FTZ construction improves regional innovation capacity by promoting industrial structure upgrading.

Hypothesis 3: FTZ construction improves regional innovation capacity by enhancing international technology spillovers.

2.2. Heterogeneity

The effectiveness of Free Trade Zone (FTZ) policies depends on the institutional quality of the region where the FTZ is located. An "active" local government can effectively mitigate market failures and play a guiding role in the development and layout of industries [17], ensuring the implementation of policy objectives. High institutional quality implies low uncertainty and institutional barriers, and a convenient, efficient "soft environment" can better serve corporate innovation and breakthroughs [18]. High-quality institutions can form a region's "comparative advantage," which can be further expanded by FTZ policies, making it more likely to enhance regional innovation capacity.

The innovation-driven effect of FTZ policies also depends on sound infrastructure. Infrastructure development can reduce information asymmetry in the technology market, lower the costs of factor mobility and diffusion for innovation [19], and improve the efficiency of knowledge dissemination and exchange. By facilitating the aggregation, reorganization, creation, and spillover of knowledge [20], infrastructure promotes increasing returns to technology. Additionally, it helps overcome temporal and spatial barriers to innovation activities, strengthens regional technical exchanges and R&D cooperation [21], and drives the technology spillover effect of the FTZ.

Therefore, this study proposes the following hypotheses:

Hypothesis 4: The higher the institutional quality, the more significant the effect of FTZ construction on improving regional innovation capacity.

Hypothesis 5: The more developed the infrastructure, the more significant the effect of FTZ construction on improving regional innovation capacity.

2.3. Spatial Spillover Effect

The impact of industrial policies on economic activities exhibits spatial correlation. Xu H et al. [22] found that bonded zones could create institutional advantages, radiating to surrounding areas through channels such as industrial transfer and technology spillover, promoting the expansion of industrial scale and efficiency improvements in neighboring regions. When Zeng Z et al. [23] examined the effects of Special Economic Zone policies, they found that the economic zones in Guangdong had spatial spillover effects, primarily through forms like joint park construction, industrial transfer, and corporate relocation, facilitating the diffusion of technological innovation. Wu X et al. [24] considered the "third-party effects" of Free Trade

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Agreements (FTAs) and found that FTAs could have direct positive effects on FDI inflows in some regions while generating indirect negative effects in others.

Moreover, innovation activities involve the exchange and sharing of knowledge and technological resources among economic entities, resulting in the creation of new knowledge and technology, often with spatial correlations. Knowledge, as a public good, tends to spill over across regions unconsciously [25]. Economic exchanges and the inter-regional mobility of R&D factors facilitate and accelerate the dissemination and diffusion of innovative knowledge across regions [26]. Regional collaborative innovation, characterized by the complementarity of innovation resources and low costs of learning and exchange, has become one of the primary models of innovation in the era of an open economy [27]. The process of cross-regional R&D cooperation is also a process of knowledge flow and spillover. The more frequent regional collaborative innovation exchanges, the greater the opportunities for knowledge spillovers and the stronger the spatial linkages.

Therefore, this study proposes the following hypothesis:

Hypothesis 6: FTZ construction has a significant spatial spillover effect on the innovation capacity of surrounding regions.

3. Research Design and Methodology

3.1. Model Construction

This study divides the research sample into a treatment group and a control group based on whether a province has been approved as a FTZ, in order to construct a Difference-in-Differences (DID) model. Since FTZ policies were not implemented at a unified time point, the traditional DID method is difficult to use for effectively evaluating policy effects. This study adopts a multi-period DID method to assess the impact of FTZ construction on regional innovation capacity and sets up the following regression model:

$$inno_{it} = \alpha + \beta_1 \times ftz_{it} + \theta \times X_{it} + \varphi_i + \mu_t + \varepsilon_{it} \tag{1}$$

Where $inno_{it}$ represents the regional innovation capacity of province i in period t, ftz_{it} is the policy variable for the establishment of an FTZ, X_{it} represents other characteristic variables that may affect regional innovation capacity, $\varphi_i$and $\mu_t$respectively control for individual and time fixed effects, and ε_{it} is the error term.

3.2. Variable Selection

Regional Innovation Capacity (inno): Referring to the studies by Jiao J et al. [28]and Li Y et al. [29], this study comprehensively measures regional innovation capacity from three aspects: innovation resources, innovation vitality, and innovation performance. The provincial innovation capacity index is calculated using an information entropy weighting method. The indicator system is shown in Table 1.

Free Trade Zone Policy (ftz). This study uses a dummy variable to indicate whether a province has established a free trade zone. If province i established a free trade zone in year t, the policy variable is assigned a value of 1 in year t and subsequent years; otherwise, it is assigned a value of 0.

Control Variables. Drawing on existing literature [9,12], the following control variables are introduced: economic development level (eco), measured by GDP per capita; physical capital input (rcap), measured by the ratio of fixed asset investment to GDP; financial development (fin), measured by the ratio of loans from financial institutions to GDP; fiscal decentralization

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(fis), measured by the ratio of local fiscal expenditure to GDP; and human capital (edu), measured by the average years of education of the labor force.

Table 1. Evaluation of regional innovation capacity

Target Layer	Guideline Layer	Primary Indicators	Secondary Indicators	Properties of indicators
Region innovation capacity	Innovative resources	Tech manpower	Full time equivalent of R&D personnel	Positive
			Number of students enrolled in regular higher education institutions per 10,000 people	Positive
		Funding for science and technology	Internal expenditure of research and development funds	Positive
			Expenditures on technology and science	Positive
	Innovation vitality	Technology diffusion	Technology Market, Technology Flow, Regional Contract Amount	Positive
			Expenditures on technology introduction	Positive
		Absorptive capacity	Expenditures for technology transformation	Positive
			Technological digestion and absorption of expenditures	Positive
	Innovation performance	Number of innovations	Number of patent applications	Positive
		Innovation quality	Number of valid invention patents	Positive
			Revenue from new product sales	Positive

3.3. Data Sources and Descriptive Statistics.

This study selects 30 provinces (including municipalities and autonomous regions) in China from 2013 to 2022 as the sample. Due to severe data deficiencies, the regions of Hong Kong, Macao, Taiwan, and Tibet are excluded. Relevant data are sourced from the China Statistical Yearbook, China Science and Technology Statistical Yearbook, and the EPS Database.

4. Empirical Results

4.1. Baseline Model

Table 2 presents the difference-in-differences estimation results. It can be seen that when only the core explanatory variable ftz is included, the coefficient of the free trade zone policy is significantly positive at the 1% level. After further adding the control variables, the regression results show that the coefficient of ftz remains significantly positive at the 1% level. These results indicate that the establishment of free trade zones significantly improves regional innovation capacity.

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Table 2. Baseline Model

Variables	(1)	(2)	(3)	(4)	(5)	(6)
ftz	0.070***	0.055***	0.054***	0.057***	0.057***	0.057***
	(7.079)	(3.118)	(2.988)	(3.204)	(3.198)	(3.209)
eco		0.083***	0.089***	0.101***	0.104***	0.098***
		(5.215)	(5.123)	(5.293)	(5.404)	(3.363)
rcap			-0.022	-0.018	-0.020	-0.019
			(-0.824)	(-0.675)	(-0.738)	(-0.706)
fin				-0.026	-0.044*	0.043*
				(-1.497)	(-1.840)	(1.770)
fis					0.211	-0.187
					(1.095)	(-0.904)
edu						0.053*
						(1.823)
Constant	0.183***	0.058**	0.067**	0.080***	0.048	-0.055
	(8.739)	(2.407)	(2.537)	(2.887)	(1.189)	(-0.171)
Sample size	330	330	330	330	330	330
R^2	0.149	0.208	0.210	0.216	0.219	0.230

Note: ***P<0.01, **P<0.05, *P<0.1, the data in parentheses are t-values.

4.2. Parallel Trend Test

Before using the DID model, it is necessary to test whether the parallel trend hypothesis holds. This study used Beck et al.'s [30] method for parallel trend testing, and the results are shown in Figure 1.

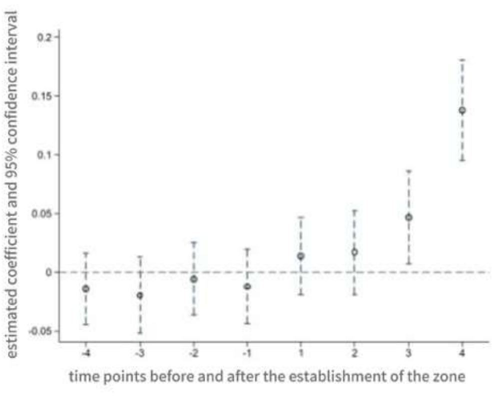

Figure 1. Parallel Trend Test Results

From Figure 1, it can be seen that before the establishment of the free trade zone, the dummy variables in each period were not significant, indicating that the trend of innovation capability in each province was consistent before the implementation of the free trade zone policy, and the parallel trend hypothesis was valid. Meanwhile, after the implementation of the free trade zone policy, the coefficient of the dummy variable significantly increased and became significantly positive after the third period, further indicating that the construction of the free trade zone has a promoting effect on regional innovation capability.

4.3. Placebo Test

The placebo test in this study was conducted using a non parametric replacement test method. Specifically, according to the number of approved free trade zones in each year, provinces were

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randomly assigned to establish free trade zones. This process was repeated 500 times to estimate the ftz coefficient and draw a kernel density map of the estimated coefficient. The results are shown in Figure 2.

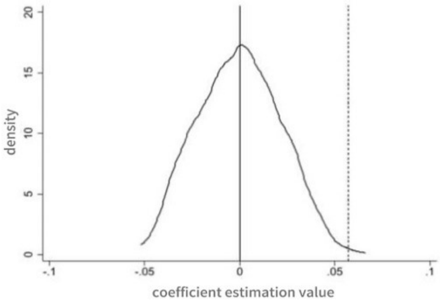

Figure 2. Placebo Test Result

According to Figure 2, the mean value of the FTZ estimation coefficient after random processing is 0.0002, which is very close to 0 compared to the benchmark regression result. At the same time, the FTZ estimation coefficient also approximately follows a normal distribution centered around 0, indicating that there is no serious problem of omitted variables in the model setting. Meanwhile, the estimated coefficients of FTZ under real policy shocks are far from the results of random sampling, further confirming that the improvement of regional innovation capability does indeed come from the construction of free trade zones.

4.4. Other Robustness Tests

This study conducts robustness tests on the baseline regression model using three methods. First, the dependent variable is replaced with the comprehensive utility value of regional innovation capacity from the China Regional Innovation Capacity Evaluation Report for robustness testing. Second, the PSM-DID method is employed for re-estimation. To effectively identify the policy effects of free trade zones, this study calculates propensity scores using a Logit regression, then matches the experimental group and control group year by year based on the scores. On this basis, the DID method is used to re-estimate the matched samples. Third, the effects of other policies are excluded. Previous research indicates that the Belt and Road Initiative can promote technological innovation in local enterprises by expanding external markets and integrating innovation elements [31]. To accurately identify the policy effects of free trade zones, this study collects and organizes information on the Belt and Road regions, constructs a policy dummy variable for Belt and Road regions, and includes it in the baseline model for control. Table 3 presents the results of the tests from the three methods mentioned above, where the regression coefficients for ftz are all significantly positive at least at the 10% level. This indicates that, overall, the baseline results of this study are robust.

Table 3. Robustness Tests

Variables	Replace dependent variable	PSM-DID	Exclude other policies
ftz	0.050*	0.040***	0.023***
	(1.772)	(3.989)	(2.841)
Control variables	YES	YES	YES
Sample size	330	144	330
R^2	0.218	0.297	0.212

Note: ***P<0.01, **P<0.05, *P<0.1, the data in parentheses are t-values.

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4.5. Innovation Driven Effects

The impact of free trade zone construction on regional innovation capacity may involve three intermediary mechanisms: resource allocation, industrial structure, and international technology spillover. This study uses a mediation effect model to verify the hypotheses of these three mechanisms of action, with the following model settings:

$$IM_{it} = \alpha + \beta_2 \times ftz_{it} + \theta \times X_{it} + \varphi_i + \mu_t + \varepsilon_{it} \tag{2}$$

$$inno_{it} = \alpha + \beta_3 \times ftz_{it} + \tau \times IM_{it} + \theta \times X_{it} + \varphi_i + \mu_t + \varepsilon_{it} \tag{3}$$

The specific approach for testing is as follows: Based on the significant total effect β_1 of ftz policy on regional innovation capability $inno$ in the free trade zone, a regression equation of FTZ on the mediating variable IM, as well as a regression equation of ftz and the mediating variable IM on $inno$, are constructed to determine whether the mediating effect exists based on the significance of β_2, β_3, and τ.

Resource allocation mechanism. This study draws on the approach of Hsieh et al. [32] to measure the labor mismatch index and capital mismatch index in various provinces of China. Table 4 shows the results of the resource allocation mechanism verification. It can be seen that in columns (1, 3), the estimated coefficient of ftz is significantly negative, indicating that the construction of free trade zones has significantly alleviated labor and capital mismatches. Moreover, the estimation results of columns (2, 4) show that the IM coefficients are significantly negative, indicating that alleviating labor and capital mismatches can help enhance regional innovation capabilities. Thus, it can be concluded that the resource allocation mechanism is valid, indicating that H1 is confirmed.

Table 4. Verification of resource allocation mechanism

Variables	(1)	(2)	(3)	(4)
	Mismatch of labor force	Regional innovation capability IM: labor mismatch	Capital mismatch	Regional innovation capability IM: capital mismatch
IM		-0.216***		-0.041**
		(-4.430)		(-1.989)
ftz	-0.031**	0.030***	-0.032*	0.036***
	(-2.338)	(2.681)	(-1.900)	(3.076)
Control variables	YES	YES	YES	YES
Sample size	330	330	330	330
R^2	0.156	0.268	0.117	0.222

Note: ***P<0.01, **P<0.05, *P<0.1, the data in parentheses are t-values.

Industrial Structure Mechanism. This study selects two indicators to measure industrial structure upgrading. First, drawing on the classification method of low-to-medium-end and high-end manufacturing industries by Fu Y et al. [33], the ratio of employees in high-end manufacturing to those in the overall manufacturing sector is used to measure the upgrading process of the manufacturing structure. Second, the proportion of employees in producer services to the total number of employees in the service sector reflects the upgrading of the service industry structure. Table 5 presents the results of the industrial structure mechanism test. The estimation results in columns (1, 3) show that the coefficient of ftz is significantly

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negative, indicating that the construction of free trade zones significantly promotes the upgrading of both manufacturing and service industry structures. Moreover, the estimation results in columns (2, 4) show that the IM coefficients are significantly positive, suggesting that the upgrading of both manufacturing and service industries contributes to the enhancement of regional innovation capacity. In summary, it can be concluded that the industrial structure mechanism is valid, confirming Hypothesis 2.

Table 5. Inspection of Industrial Structure Mechanism

Variables	(1) Manufacturing upgrading	(2) Regional innovation capability IM: Manufacturing upgrading	(3) Service industry upgrading	(4) Regional innovation capability IM: Service industry upgrading
IM		0.901***		0.111***
		(4.907)		(3.749)
ftz	0.004***	0.033***	0.004*	0.037***
	(3.101)	(2.965)	(1.750)	(3.160)
Control variables	YES	YES	YES	YES
Sample size	330	330	330	330
R^2	0.371	0.279	0.220	0.220

Note: ***P<0.01, **P<0.05, *P<0.1, the data in parentheses are t-values.

International Technology Spillover. Foreign direct investment (FDI) and outward direct investment (ODI) are two primary channels of international technology spillover. To verify the mediating role of international technology spillover, this study uses the net inflow of FDI and ODI to respectively measure FDI technology spillover and ODI technology spillover. In columns (1, 3) of Table 6, the estimated coefficients of ftz are both significantly positive; similarly, in columns (2, 4) of Table 6, the IM coefficients are also significantly positive. Therefore, it is evident that the free trade zone policy can enhance regional innovation capacity through the mechanism of international technology spillover via FDI and ODI, confirming Hypothesis 3.

Table 6. Inspection of International Technology Spillover Mechanism

Variables	(1) Foreign direct investment	(2) Regional innovation capability IM: Foreign direct investment	(3) Outward direct investment	(4) Regional innovation capability IM: Outward direct investment
IM		0.003**		0.005***
		(2.527)		(2.968)
ftz	0.216***	0.038***	0.055*	0.037***
	(2.799)	(3.225)	(1.758)	(3.185)
Control variables	YES	YES	YES	YES
Sample size	330	330	330	330
R^2	0.268	0.220	0.422	0.221

Note: ***P<0.01, **P<0.05, *P<0.1, the data in parentheses are t-values.

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4.6. Heterogeneity Test

There are significant differences in the soft and hard environments across different regions. Since the construction of FTZs is a policy tailored to specific locations, does its effect on regional innovation capacity also exhibit heterogeneity? To answer this question, this study examines the impact of regional development characteristics on the effectiveness of FTZ policies from the perspectives of institutional quality and infrastructure.

A good soft institutional environment can reduce the hidden costs of business operations, enhance the enthusiasm for import and export trade, and effectively stimulate market vitality. To examine the policy effect of FTZ construction under different levels of institutional quality, this study uses the "Government-Market Relations Index" from the Fan Gang Marketization Index as a proxy variable for institutional quality, classifying regions accordingly. As shown in Table 7, when the institutional quality is low, the impact of the FTZ policy on regional innovation capacity is not significant. However, when the institutional quality is high, the effect of FTZ policy on regional innovation capacity is significantly positive. This indicates that as institutional quality improves, FTZ policies are more conducive to enhancing regional innovation capacity. Therefore, hypothesis 4 is confirmed.

High-quality hard infrastructure, particularly well-developed infrastructure, helps facilitate communication channels and accelerates the flow of knowledge. To investigate the effect of infrastructure differences on the effectiveness of FTZ policies, this study uses the ratio of the length of railways, highways, and inland waterways to the area of each region to measure infrastructure levels, dividing the sample into high and low groups. The regression results of the sub-sample are detailed in Table 7. As shown in Table 7, in regions with low infrastructure levels, the impact of FTZ policies on regional innovation capacity is not significant, while in regions with high infrastructure levels, there is a significant positive effect. This suggests that infrastructure provides physical support for FTZ policies, enhancing their role in promoting regional innovation capacity, consistent with hypothesis 5.

Table 7. Heterogeneity Test Results

Variables	Low institutional quality	High institutional quality	Low infrastructure	High infrastructure
ftz	0.012	0.048**	-0.004	0.033***
	(0.258)	(2.506)	(-0.727)	(2.992)
Control variables	YES	YES	YES	YES
Sample size	165	165	165	165
R^2	0.121	0.466	0.101	0.473

Note: ***P<0.01, **P<0.05, *P<0.1, the data in parentheses are t-values.

5. Spatial Spillover Effects

To examine whether the construction of FTZs has spatial spillover effects on regional innovation capacity, this study further introduces a spatial econometric model. First, Moran's I index is used to test the spatial correlation of innovation capacity between provinces. The results show that the global Moran's I index of regional innovation capacity is significantly positive at the 10% level, indicating a significant positive spatial correlation in regional innovation capacity and satisfying the conditions for applying a spatial econometric model.

Next, Table 8 presents the estimation results of the spatial lag model (SLM) and the spatial Durbin model (SDM) under two types of spatial weight matrices. It can be observed that the spatial Durbin model fits better than the spatial lag model. In the spatial Durbin model, the

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spatial spillover effect coefficient (ρ) is significantly positive at the 1% level, indicating endogenous interactive effects of innovation capacity across provinces, further proving the rationality of introducing spatial factors. The regression coefficients of the spatial econometric model do not directly reflect the impact of FTZ construction on regional innovation capacity, and it is necessary to decompose them into direct and spillover effects through partial derivative analysis. The spillover effects in Table 8 are all significantly positive, implying that the construction of FTZs significantly enhances the innovation capacity of neighboring provinces. Accordingly, hypothesis 6 is confirmed.

Table 8. Results of Spatial Spillover Effect Test

Variables	Spatial Lag Model		Spatial Durbin model	
	Adjacency matrix	Economic distance matrix	Adjacency matrix	Economic distance matrix
ρ	0.236***	0.402***	0.114**	0.355***
	(3.28)	(4.99)	(2.16)	(4.20)
ftz	0.032***	0.039***	0.027	0.036**
	(2.94)	(2.74)	(1.55)	(2.36)
W×ftz			0.070***	0.115***
			(3.33)	(4.30)
Control variables	YES	YES	YES	YES
Direct effect	0.033***	0.031***	0.019*	0.035***
	(2.91)	(2.71)	(1.71)	(2.91)
Spillover effect	0.009*	0.019**	0.077***	0.185***
	(1.93)	(1.99)	(3.48)	(3.94)
Total effect	0.042***	0.049**	0.095***	0.221***
	(2.86)	(2.58)	(3.99)	(4.15)
LogL	477.217	482.891	497.274	493.161
R^2	0.307	0.303	0.329	0.376

Note: ***P<0.01, **P<0.05, *P<0.1, the data in parentheses are t-values.

6. Conclusion and Policy Recommendations

6.1. Main Conclusion

This study takes the construction of free trade zones (FTZs) as its focal point and employs a multi-period difference-in-differences method to examine the impact of FTZ construction on regional innovation capacity. The study reaches several important conclusions. First, the FTZ policy significantly enhances regional innovation capacity, a result that remains robust after multiple tests for stability. Second, a mechanism analysis reveals that FTZ construction contributes to improving regional innovation capacity by optimizing resource allocation, promoting the upgrading of industrial structures, and enhancing international technology spillovers. Third, a heterogeneity analysis finds that the positive impact of FTZ policies on regional innovation capacity becomes more pronounced as infrastructure and institutional quality improve. Finally, a spatial model analysis demonstrates that the establishment of FTZs generates spatial spillover effects, significantly boosting the innovation capacity of neighboring regions and fostering a pattern of collaborative regional innovation.

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6.2. Policy Recommendations

Based on these conclusions, several policy recommendations can be made. First, policymakers should draw on existing experiences and pursue the development of FTZs in a phased manner, tailored to local conditions. By creating a new landscape of high-level openness, FTZ policies can play a key role in optimizing the allocation of resources, promoting industrial upgrading, and facilitating international technology spillovers. This will continuously drive improvements in regional innovation capacity and contribute to the high-quality socio-economic development of the region. Second, efforts should be made to accelerate the development of service-oriented governments, which are committed to creating an efficient, fair, convenient, and open market environment, thereby improving institutional quality. At the same time, increased investment in infrastructure is necessary to provide the technical foundation for inter-regional technology exchanges and research collaborations, which can stimulate regional innovation activity. Third, the construction of high-quality FTZs with significant spillover effects should be promoted to facilitate channels for innovation cooperation and resource exchange between regions. This will drive the integration of innovation resources and the optimization of resource allocation in surrounding areas, ultimately enhancing regional innovation capacity across a broader scope.

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