Original Paper

Research on the Impact of Regional Innovation Capacity on Total Factor Productivity Improvement

Liwen Xu[1*], Mingyue Yan[2], & Kaiwen Guo[3]

[1] Department of Business Administration, Shandong University of Technology, Zibo, China

[2] Department of Economics, Shandong University of Technology, Zibo, China

[3] Department of Industrial Engineering, Shandong University of Technology, Zibo, China

[*] Liwen Xu, Business Administration, Shandong University of Technology, Zibo, China

Abstracts

In the Party's 20th annual report, it clearly states that we must focus on improving total factor productivity as an important means to promote economic development. Enhancing regional innovation capability is crucially important for increasing total factor productivity. This article selects data from 30 provinces in China over the 11-year period from 2012 to 2022 as a case study, employing various econometric methods to verify the expected theory and explore the impact of regional innovation capability on total factor productivity. The study shows that: Initially, enhancing regional innovation capability significantly boosts total factor productivity at the regional level, and this finding holds true across a range of robustness checks. second, high regional innovation capacity can promote the improvement of human capital level and urbanization level, and then indirectly promote the improvement of regional total factor productivity. Thus, enhancing regional innovation capabilities serves as a vital approach to driving high-quality economic growth and ensuring continuous gains in total factor productivity.

Keywords

Total factor productivity, Regional innovation capacity, Mediation effects model

1. Introduction

In today's increasingly fierce global competition, regional innovation capacity has become a crucial benchmark for assessing a region's economic competitiveness and development potential. Total Factor Productivity (TFP), as a core indicator of the quality of economic growth, relies not only on the increase of factor inputs but also on the comprehensive drive of technological advancement,

organizational innovation, and resource allocation efficiency. The report of the 20th National Congress of the Communist Party of China is far-sighted and explicitly sets forth that the goal of China's future economic development is to achieve new breakthroughs in high-quality economic growth and to significantly enhance the capacity for self-reliance and self-improvement in science and technology. This has illuminated the direction for our progress. Among these goals, improving total factor productivity is placed in a critically important position to promote effective qualitative enhancement and reasonable quantitative growth of the economy.

In this context, the significance of regional innovation capability, which serves as the central driving force for regional economic development, is becoming more and more evident. It encompasses multiple dimensions including the investment in innovation resources, interaction among innovation entities, the creation of an innovative environment, and the output of innovative results, serving as a concentrated reflection of a region's overall strength. In recent years, with the deepening implementation of the innovation-driven development strategy, the regional innovation capability of China has been significantly enhanced, with notable enhancements in scientific and technological strength and innovation capability. However, despite significant achievements, the specific impact mechanisms of regional innovation capabilities on total factor productivity and the differences among different regions still need further in-depth exploration. Given this, this paper conducts research on the role of regional innovation capability in enhancing total factor productivity, explores the underlying relationship, enriches existing studies, and contributes to promoting high-quality economic development.

The remainder of this paper is organized as follows: The second section reviews the relevant literature on regional innovation capability and total factor productivity. The third section provides a detailed theoretical analysis and formulates the research hypotheses. The fourth section introduces the research design, including model construction, variable measurement, and descriptive statistics. The fifth section presents the empirical results and analysis, verifying the research hypotheses and exploring the mechanisms through which the improvement of regional innovation capability affects the increase in total factor productivity. Finally, we draw the conclusions of this paper and offer policy recommendations for the government.

2. Literature Review

Scholars have explored in depth the influence mechanism of innovation factors on economic growth from multiple dimensions. Focusing on key factors such as the scale of human capital investment and the intensity of research and development activities, they have constructed empirical models and utilized rigorous econometric methods to reveal the specific paths of these factors in the process of promoting total factor productivity. Existing research not only focuses on the direct role of innovation factors, but also further analyzes the paths and effects of innovation practices on total factor

productivity in different industries and regions.

2.1 Relevant Studies on Regional Innovation Capacity

Regional innovation capacity is the ability of a region to transform new knowledge into new products, processes and services, and is centred on the promotion of interactions and linkages among innovative institutions, expressed in terms of their capacity to make a contribution to the regional socio-economic structure. Regional innovation capacity is not the equal of scientific and technological capacity or scientific and technological competitiveness, but the latter are the basis of regional innovation capacity. The "Evaluation Report of China's Regional Innovation Capacity 2024" shows that Guangdong Province's comprehensive ranking of regional innovation capacity has been the first in the country for eight consecutive years. The Report establishes a four-tiered system of indicators to comprehensively reflect the performance of each region in terms of knowledge creativity, knowledge capture, business innovation and innovation landscape. Existing studies show that the evolution of the digital economy (Wen, Yan, & Cheng, 2019), the structure and efficiency of financial development (Ran, Xu, & Lu, 2013), regional R&D capital investment (Wang & Jia, 2009), and the infrastructure level, market demand, labor quality and financial environment (Zhang, 2006) have a positive contribution to regional innovation capacity, and there is also a positive impact of enterprises, universities, research institutions, and financial institutions on regional innovation capacity (Gao & Wu, 2015). Wei et al. (2010) proposed that regional innovation capacity is not only affected by the innovation infrastructure such as the scale of R&D initiatives, but also, more importantly, by the regional innovation efficiency (Wei, Wu, & Lü, 2010). The spatial distribution of China's regional innovation capacity is characterized by obvious agglomeration, especially in the eastern part of the country, which has a high level of economic development (Wei et al., 2011). Cao (2012) measured regional innovation capacity by the amount of invention patent applications and the output value of new products of industrial enterprises (Cao & Qin, 2012).

2.2 Relevant Studies on Total Factor Productivity

Total factor productivity, unlike factor productivity, measures the combined productivity of all factors in a production unit when taken as a whole. This variable has an impact on economic growth and can have a negative, zero or positive value. Total factor productivity encompasses a number of aspects, including the direction of economic policy, the role of government in the functioning of the economy, the attitude of workers, the positive externalities associated with a high-quality workforce, and technological learning and application (Chang, 2012). Through existing studies, it is found that the evolution of digital economy (Yang & Jiang, 2021), accelerated structural transformation (Liu & Ling, 2020), optimization of resource allocation (Yang, Li, & Meng, 2023), digital transformation (Zhao, Wang, & Li, 2021), transportation infrastructure (Liu, Wu, & Liu, 2010), trade openness (Xu, Qi, & Zhu, 2006), foreign economic openness and regional market integration (Mao & Sheng, 2012), and the improvements in capital and labor allocation efficiency (Gong & Hu, 2013) all have a positive impact

effect on total factor productivity. Among them, digital economy development, digital transformation and trade openness all increase total factor productivity by acting on human capital. He (2018) proposed that the promotion effect of modernized economic system on total factor productivity improvement has regional differences (He & Shen, 2018). In order to materialize the State Council's "Outline of Action for Promoting the Development of Big Data" and promote the innovative development of big data in China, the construction of the National Big Data Comprehensive Pilot Zone has become a key initiative, and Qiu and Zhou (2021) found that the establishment of a big data pilot zone significantly increased regional total factor productivity, and the promotion of total factor productivity in areas with net labor loss was even greater (Qiu & Zhou, 2021). Gai and Zhu et al. (2015) emphasized that factor market distortion not only reduces total factor productivity directly by affecting the resource allocation efficiency of incumbent firms, but also reduces total factor productivity indirectly by changing the entry and exit behaviors of firms through monopoly power (Gai, Zhu, Cheng et al., 2015). For total factor productivity measurement methods, existing studies have been conducted through the non-desired MinDS super-efficiency-MetaFrontier-Malmquist model (Liu, Ouyang, & Cai, 2021), the SBM model and the GML index (Wu & Song, 2018), the Malmquist-Luenberger index based on the DEA model (Lu & Song, 2017), the globally-referenced Globe- Malmquist-Luenberger (GML) index (Yu & Wei, 2021), and the Solow residual method with DEA-Malmquist index method (Li & Shi, 2020) to measure (green) total factor productivity.

3. Mechanistic Analysis and Research Hypothesis

3.1 Direct Impact Mechanisms and Research Hypotheses

Total factor productivity is a measurement of the efficiency of production in an economy or enterprise. It is a combination of factors that, while not specifically focused on the environmental dimension, provides a comprehensive picture of the efficiency with which inputs are transformed into outputs. Total Factor Productivity (TFP) incorporates all types of factors of production, such as labor, capital, and land, into the production function in order to assess overall production efficiency, and its core perspectives include resource use efficiency, technological innovation, and sustainable economic development through efficient production. A strong regional innovation capacity means that the region has a high level of knowledge creation, technology innovation, and results transformation. This innovative capacity can promote the continuous emergence of new technologies, new processes and new products, which in turn can enhance productivity and resource utilization efficiency.

On the one side, theoretically, the innovation ecosystem theory emphasizes the interaction and interdependence between innovation agents, which jointly promote the development of innovation activities. In the study of the influence of regional innovation capacity on total factor productivity, the theory of innovation ecosystem can be applied to explain how the synergistic cooperation among different innovation subjects in the region can promote the generation and diffusion of new information

and technological innovations, and thus promote the improvement of total factor productivity; and the theory of knowledge and technology spillover suggests that the generation and diffusion of new knowledge and technology will have a positive impact on other enterprises or industries. In the study of the effect of regional innovation capacity on total factor productivity, the theory of knowledge and technology spillover can be applied to explain how the improvement of regional innovation capacity can, through the overflow effect of both knowledge and technology, improve the labor quality of production personnel, promote inter-industry technological exchanges and cooperation, and then promote the enhancement of total factor productivity.

On the other hand, the enhancement of regional innovation capacity promotes the generation and diffusion of new knowledge and technologies. These new knowledge and technologies first generate spillover effects within the enterprise, enhancing the labor quality of production personnel and thus improving productivity. At the same time, knowledge and technology will also flow, diffuse and intermingle among industries, trades and regions, realizing that the innovation of one industry influences, enhances or even subverts the production mode of another industry, thus promoting the enhancement of total factor productivity in the whole region; the improvement of the regional innovation capacity will help enterprises to adopt more advanced and efficient production technology and equipment, thus improving production equipment, simplifying the production process, and eliminating outdated production technology. Improvement of production equipment, streamlining of production processes, and elimination of outdated production technologies. These measures can reduce energy consumption, improve resource utilization efficiency, reduce dependence on traditional energy sources and raw materials, and promote production efficiency, thereby increasing total factor productivity.

Synthesizing the above analysis, this paper formulates research hypothesis I: Strong regional innovation capacity has a contributing effect on total factor productivity improvement.

3.2 Indirect Impact Mechanisms and Research Hypotheses

3.2.1 Analysis of the Mediating Effect of Human Capital Level

The level of human capital refers to the level of knowledge and skills possessed by the labor force itself, and it is an essential measure of the caliber of workers, economic capacity, and social advancement of a region.

Generally speaking, the main influencing mechanisms include knowledge accumulation and technological innovation, optimal allocation of resources, institutional and policy responses, and the improvement of regional innovation capacity. The theory of human capital states that a labor force with a high level of human capital has a stronger ability to acquire knowledge and information and to transform technological innovations. An increase in the level of human capital means an increase in the knowledge and skills of the workforce, which helps to identify new technological opportunities and promote technological innovation. Technological innovation is a key factor in raising total factor

productivity, as new technologies often lead to more efficient resource utilization and greatly increase production efficiency. The theory of optimal allocation of resources emphasizes the maximization of benefits through rational allocation of resources under the conditions of limited resources. A workforce with a high level of human capital can plan and manage production activities more scientifically and optimize resource allocation. Institutional economics argues that institutions are important factors affecting economic development, and that an increase in the level of human capital helps the labor force to better understand and respond to institutional policies. As the level of human capital rises, the labor force's ability to know and understand the policy system increases, enabling it to adapt more quickly to policy changes and adjust its production behavior. Higher levels of human capital also help to enhance the region's innovation capacity. A labor force with a high standard of human capital can promote technological research and development, technological invention and technological diffusion, thus boosting the innovation capacity of the region as a whole. In turn, an improvement in the region's innovation capacity can further contribute to the growth of total factor productivity.

Synthesizing the above analysis, this paper formulates the research hypothesis II: The level of human capital plays a mediating role in the impact of regional innovation capacity on total factor productivity.

3.2.2 Analysis of the Mediating Effect of the Level of Urbanization

The level of urbanization refers to the degree of urbanization achieved in a region, which reflects the process and degree of agglomeration of the region's population, economy, society and other aspects towards cities.

The theory of diffusion of innovation points out that innovative activities will diffuse within a certain spatial scope, leading to the economic development and social progress of neighboring areas. The theory of diffusion of innovation points out that innovative activities will diffuse within a certain spatial scope, driving the economic development and social progress of the surrounding areas. Urbanization, as an important manifestation of economical advancement, is often closely associated with the diffusion of innovative activities; an increase in the level of urbanization implies the refinement of urban infrastructures, the enhancement of the industrial architecture and the expansion of the population scale, which are all favourable to the improvement of the efficiency of resource utilization, the lowering of energy consumption and the reduction of environmental pollution. In addition, the increased level of urbanization has contributed to the enhancement of the urban innovation landscape, which has provided better conditions for the development and application of innovative technologies, thus driving total factor productivity growth. The increase in regional innovation capacity promotes the increase in the level of urbanization, which in turn further promotes the growth of total factor productivity. This mediating effect explains why, in some regions, an increase in regional innovative capacity can contribute more effectively to total factor productivity growth.

Synthesizing the above analysis, this paper formulates research hypothesis III: the level of urbanization plays a mediating role in the impact of regional innovation capacity on total factor productivity.
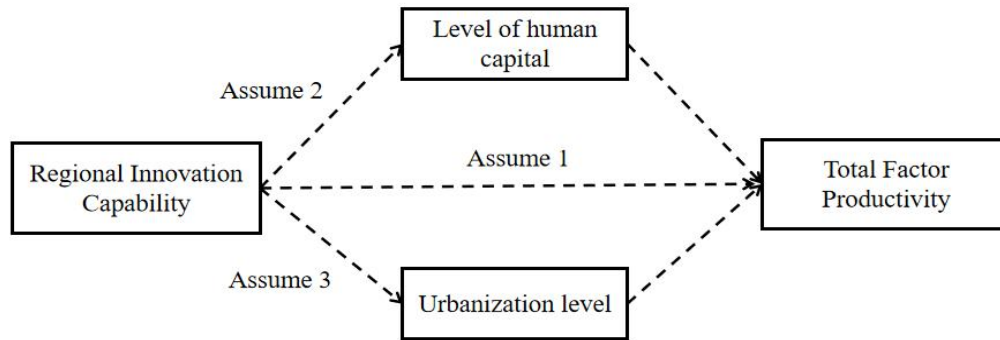
Figure 1. Theoretical Framework Diagram

4. Research Design

4.1 Model Development

4.1.1 Statistical Regression Model

The benchmark regression model is a fundamental statistical analysis tool that quantifies the influence of independent variables on dependent variables through mathematical modeling. This model reveals the intrinsic relationships between variables, aiding researchers in understanding the underlying patterns in data. By utilizing the benchmark regression model, we can assess the model's accuracy and provide robust empirical support and evidence for scientific research, policy-making, or corporate decisions.

$$\text{TFP}_{it} = \alpha_0 + \alpha_1 Innov_{it} + \alpha_n x_{it} + \lambda_i + \varepsilon_{it} \tag{1}$$

These include, is the explanatory variable, representing the total factor productivity of region in period

t, $Innov_{it}$ is the core explanatory variable, indicating regional innovation capability, represents the control variables in the model, including four types of variables: industrial structure, degree of openness, level of transportation infrastructure, and level of social consumption. In addition, represents the intercept term, represents the unobservable individual fixed effects, and is the random error term.

4.1.2 Mediation Effect Model

The mediation effect model is a statistical framework designed to explore how one or more variables can indirectly influence another variable through one or more mediators. This model aids researchers in comprehensively understanding the mechanisms through which independent variables affect dependent variables, thereby facilitating the formulation of more effective interventions. In-depth study of the ways in which the level of regional innovation affects green total factor productivity, the author sidesteps potential endogeneity bias associated with stepwise regression methods prevalent in traditional mediation effect models. Following moderating influence testing approach proposed by Jiang et al. (2022), the study first examines the direct impact of regional innovation levels on green

27

total factor production capability, followed by an analysis of the weight of regional innovation levels on the mediating variables. By employing this two-step method for mechanism testing, difficulties in distinguishing between indirect effects and potentially unexplainable direct effects are effectively mitigated. On the basis of Model (1), the author constructs the following mediation effect analysis mould:

$$mediation_{it} = \beta_0 + \beta_1 Innov_{it} + \beta_n x_{it} + \lambda_i + \varepsilon_{it} \tag{2}$$

Among them, representing mediating variables, that is, Human capital level and the level of urbanization, β_1 is the parameter to be estimated, β_n is the parameter vector to be evaluated, and other variables are the same as in equation (1). under the new testing standards, when conducting a mediation effect test, if the regression coefficient α_1 in mould (1) is extremely important and the ratio in mould (2) is also significant, then It has a mediating effect.

4.2 Measurement of Variables

4.2.1 Core Explanatory Variable: Regional Innovation Capability ($Innov$)

Considering the usability and authority of comprehensive numbers, this study applies regional innovation capability ($Innov$) act as core explanatory variant. Available studies has various indicators to measure innovation capability; however, due to the accessibility of patent data, many scholars opt to use it as a measure. This paper follows the method of Li (2007) and employs the number of authorized invention patents as a measure (Li, 2007). To prevent potential instability in the data, logarithmic processing is applied.

4.2.2 Dependent Variable: Total Factor Productivity (TFP)

This study selects total factor productivity as the dependent variable, utilizing the OLS (Ordinary Least Squares) method for estimation. The chosen evaluation indicators for input and output factors are presented in Table 1.

Table 1. System of Evaluation Indicators Total Factor Productivity

Variable Definition	Variable Representation	Variable Characteristics and Computation
Labor input	Lainp	All employees in society

Capital investment	Cainp	This article follows the approach of Zhang Jun (2005) and uses the perpetual disk method for estimation, adjusting the resulting share capital data to use 2005 as the base year, with a depreciation rate set at 10%.
Expected Output	Exoutp	Real GDP

4.2.3 Mediating Variables

① Human Capital Level($Human$): The metric is the logarithm of the full-time equivalents of research and development personnel(in tens of thousands).

② Urbanization Level($Urban$): Assessed by the ratio of urban population.

4.2.4 Control Variables

Reference to previous research, this research options industrial structure, transportation infrastructure level, degree of openness, and social consumption level as control variables.

① Industrial Structure (IS): Measured by the ratio of tertiary sector output to secondary sector output.

② Transportation Infrastructure Level (TI): Measured by the logarithm of the total highway mileageand railways.

③ Degree of Openness ($Open$): Represented by the percentage of total exports and imports trade gross domestic product.

④ Social Consumption Level ($Consumption$): The metrics is the ratio of total regional retail sales of consumer goods to regional GDP.

Table 2. Qualitative Description of Variables

Variable type	Variable name	Variable measurement	Variable symbol
Explained variable	Total factor productivity	Estimate using ordinary least squares method	TFP
Core explanatory variable	Regional innovation capability	Logarithmic value of the number of patents granted for inventions	$Innov$
Mediating variable	Level of human capital	Logarithm of R&D personnel full-time	$Human$

		equivalents	
	Level of urbanization	Ratio of urban population	*Urban*
Control variable	Industrial structure	Ratio of tertiary sector output to secondary sector output.	*IS*
	Transportation infrastructure	The logarithm of the sum of highway and railway mileage.	*TI*
	Level of openness to foreign countries	Total import and export trade/GDP	*Open*
	The level of social consumption	Gross retail sales of consumer goods/GDP	*Consumption*

4.3 Data Sources and Descriptive Statistics

The study selects 30 provinces in China as the research sample from 2012 to 2022. Due to significant data gaps in the Hong Kong, Macau, Taiwan regions, and Tibet, these areas have been precluded from the analysis. The number is sourced from the "China Statistical Yearbook," "National Bureau of Statistics," "China Science and Technology Statistical Yearbook," and various provincial statistical yearbooks. To avoid heteroscedasticity and multicollinearity, logarithmic transformations were suitable for use in the relevant variables. For missing number in certain regions and years, linear interpolation was used for imputation. The descriptive statistics of the variables are presented in Table 3.

Table 3. Descriptive Statistics of Variables

VarName	Obs	Mean	Sd	Median	Max	Min
Innov	330	8.4297	1.4338	8.4362	11.6534	4.5109
TFP	330	0.6288	0.2659	0.6887	1.2363	0.1212
IS	330	1.2942	0.7082	1.1358	5.2968	0.5493
TI	330	11.7144	0.8524	11.9856	12.9126	9.4368
Open	330	0.2606	0.2745	0.1438	1.4409	0.0076
Consumption	330	0.3825	0.0702	0.3877	0.5384	0.2191
Human	330	2.0735	1.2045	2.2834	4.4979	-0.9144
Urban	330	0.6077	0.1171	0.5934	0.8958	0.3630

5. Empirical Findings and Analysis

5.1 Baseline Regression

After conducting the Hausmann test, this study determines that fixed-effects models are more appropriate. Based on the previous analysis, we first examine the effect of regional innovation capacity

on total factor productivity. As shown in Column (1), no control variables, the correlation coefficient between regional innovation capacity and total factor productivity is 0.105, which passes the significance test at the 1% level. This indicates that an increase in regional innovation capacity can promote the improvement of green total factor productivity. Column (2) introduces the baseline regression results after adding four control variables, illustrating the combined impact of regional innovation capacity and control variables on total factor productivity. The data indicate that, under the influence of control variables, the regression coefficient between regional innovation capacity and total factor productivity decreases; however, it remains significant at the 1% level. This demonstrates that, with or without control variables, regions with strong innovation capacity significantly enhance total factor productivity, thereby validating Hypothesis 1 of this study.

Table 4. Benchmark Regression Results

Variables	(1) Total Factor Productivity	(2) Total Factor Productivity
Innov	0.105***	0.034***
	(0.008)	(0.012)
IS		0.001
		(0.020)
TI		0.015
		(0.022)
Open		0.477***
		(0.071)
Consumption		0.747***
		(0.179)
Cons	-0.259***	-0.249
	(0.072)	(0.218)
Obs	330	330
R^2	0.323	0.475
Year	Yes	Yes
Id	Yes	Yes

Note. * $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$; robust standard errors are reported in parentheses. The same applies to the table below.

5.2 Mediating Effect

Table 5 presents the gains of testing the mediating mechanisms by which regional innovation capability

affects total factor productivity (TFP). The coefficients and significance levels of core variables and mediators indicate that both human capital and urbanization levels directly influence regional blaze new trail capability. Specifically, in mould (2), the regression coefficient of regional innovation capability is significantly positive at the 1% level, suggesting that enhanced regional innovation capability fosters an increase in human capital levels. This highlights the mediating effect of human capital on TFP improvement in regions. The accumulation of per capita human principal is crucial for enhancing the growth rate, efficiency, and technological advancement of total factor productivity in China's provinces. Moreover, the increase in human capital improves labor quality, promotes technological progress and industrial upgrading, and expands market demand and employment, significantly driving TFP growth and overall economic development. Column (2) illustrates the model estimates with urbanization level as a mediating variable; under its influence, regional innovation capability exhibits a mediating effect on TFP. A 1% rise in regional innovation capability brings about a 0.049% boost in regional TFP. The synergistic effects of coordinated urbanization, along with human capital and financial resources, provide essential infrastructure, talent, and technological support for regional development, effectively improving the allocation of production factors and enhancing regional TFP.

Table 5. Results of the Mechanism Test on the Impact of Regional Innovation Capability on Regional Total Factor Productivity

	(1)	(2)
	Human	Urban
Innov	0.732***	0.049***
	(0.019)	(0.003)
I_S	-0.337***	0.010*
	(0.032)	(0.005)
T_I	0.134***	-0.074***
	(0.034)	(0.005)
Open	0.849***	0.048**
	(0.114)	(0.019)
Consumption	0.214	-0.288***
	(0.287)	(0.048)
Cons	-5.541***	1.147***
	(0.350)	(0.059)

N	330	330
R²	0.933	0.796
F	911.55	253.47

6. Research Findings and Policy Implications

6.1 Conclusions of the Study

This paper centers on the national strategy for high-quality development and examines how enhancing regional innovation capability can drive the growth of total factor productivity (TFP). Using provincial panel data from 2012 to 2022, the study employs fixed-effects models and mediation effect models to analyze both the direct impact of regional innovation capability on TFP and its underlying mechanisms. The main conclusions are as follows: First, there is a significant positive correlation between regional innovation capability and TFP. Second, regional innovation capability indirectly promotes an increase in TFP by enhancing the level of human capital. Third, regional innovation capability further strengthens TFP by accelerating the urbanization process.

6.2 Policy Implications

a. Governments should attach great importance to the centrality of human capital in the enhancement of regional innovation capacity. Human capital is the foundation and key driver of regional innovation activities. To this end, the Government should increase its investment in education and training, especially for the cultivation of high-level human capital, and through deepening the reform of the education system, build a more flexible and efficient education system to cultivate high-quality human resources with innovative thinking and practical skills. At the same time, incentive policies for talents should be formulated and improved, the treatment and development space for talents should be enhanced, and a more attractive career environment and growth space should be provided for high-level scientific and creative talents, so as to attract and retain these valuable human resources. This will not only directly enhance regional innovation capacity, but also indirectly contribute to the sustained growth of total factor productivity through the cumulative effect of human capital.

b. In promoting the urbanization process, the Government should focus on improving the quality of urbanization development and achieving the coordinated development of small towns and large cities. By optimizing the layout of towns and cities and promoting the rational allocation of population, industry and resources, more favourable conditions will be created for the enhancement of human capital and the development of innovative activities. The Government should encourage and support the development of small towns with special characteristics, while strengthening the role of large cities in radiating and driving the surrounding areas, so as to form a new urbanization pattern that is diversified, economical and efficient. Moreover, the government needs to vigorously advance the deep integration of industry, academia, and research institutions, accelerate the commercialization and application of scientific and technological achievements, and optimize the allocation and utilization

efficiency of innovation resources. These efforts will further boost regional innovation capabilities and provide robust support for the increase in total factor productivity.

c. The government should broaden the channels for attracting capital at home and abroad, and encourage enterprises to increase investment in independent research and development to improve innovation efficiency. Attracting the inflow of high-quality domestic and foreign capital through the formulation of more favorable capital attraction policies to provide adequate financial support for regional innovation activities. At the same time, the government can strengthen its guidance and support for corporate independent R&D activities and enhance corporate independent innovation capabilities by offering policy measures such as R&D subsidies and tax incentives. Moreover, the government needs to establish a robust intellectual property protection system to safeguard the legitimate rights and interests of innovators, thereby motivating enterprises to innovate and providing a continuous driving force for the sustained growth of total factor productivity.

References

Cao, Y., & Qin, Y. X. (2012). Empirical Analysis of the Changes in Regional Innovation Capability Disparities in China. *China Population, Resources and Environment*, *22*(03), 164-169.

Chang, J. K. (2012). An Analysis of the Contribution of Investment, Consumption, and Exports to China's Economic Growth from the Perspective of Keynesian Economic Theory. *Business Times*, (13), 4-5.

Gai, Q. E., Zhu, X., Cheng, M. W. et al. (2015). Factor Market Distortion, Monopoly Power, and Total Factor Productivity. *Economic Research*, *50*(05), 61-75.

Gao, Y. J., & Wu, H. C. (2015). Research on the Impact of Innovation Subjects and Their Interactions on Regional Innovation Capability. *Science Research Management*, *36*(10), 51-57.

Gong, G., & Hu, G. L. (2013). Resource Allocation Efficiency and Total Factor Productivity in China's Manufacturing Industry. *Economic Research*, *48*(04), 4-15+29.

He, X. Y., & Shen, K. R. (2018). Modern Economic System, Total Factor Productivity, and High-Quality Development. *Shanghai Economic Research*, (06), 25-34.

Jiang, T. (2022). Mediating and Moderating Effects in Empirical Studies of Causal Inference. *China Industrial Economy*, (05), 100-120.

Li, X. B. (2007). Empirical Analysis of the Changes in Regional Innovation Capability in China: Based on the Perspective of Innovation Systems. *Management World*, (12), 18-30+171.

Li, Y. H., Shi, L. Y., & Li, Y. (2020). Measurement and Comparison of Total Factor Productivity Growth in China's Manufacturing Industry. *Economic Issues*, (03), 83-91.

Liu, B. L., Wu, P., & Liu, Y. H. (2010). Transportation Infrastructure and Total Factor Productivity Growth in China: A Spatial Panel Econometric Analysis Based on Provincial Data. *China Industrial Economy*, (03), 54-64.

Liu, Y. W., Ouyang, Y., & Cai, H. Y. (2021). Measurement and Temporal-Spatial Evolution Characteristics of Green Total Factor Productivity in Chinese Agriculture. *Quantitative Economics.Research on Technological Economics*, *38*(05), 39-56.

Liu, Z. B., & Ling, Y. H. (2020). Structural Transformation, Total Factor Productivity, and High-Quality Development. *Management World*, *36*(07), 15-29.

Lu, L. W., Song, D. Y., & Huang, C. (2017). Measurement of Urban Green Total Factor Productivity in the Yangtze River Economic Belt: A Case Study of 108 Cities in the Yangtze River Economic Belt. *Urban Problems*, (01), 61-67.

Mao, Q. L., & Sheng, B. (2012). Economic Openness, Regional Market Integration, and Total Factor Productivity. *Economics (Quarterly)*, 11(01), 181-210.

Qiu, Z. X., & Zhou, Y. H. (2021). The Development of the Digital Economy and Regional Total Factor Productivity: An Analysis Based on National-Level Big Data Comprehensive Experimental Zones. *Financial Research*, *47*(07), 4-17.

Ran, G. H., Xu, K., & Lu, Z. Y. (2013). The Impact of Financial Development and FDI on Regional Innovation Capability. *Science Research Management*, *34*(07), 45-52.

Wang, J., & Jia, C. R. (2009). Spatial Econometric Analysis of Regional Innovation Capability and Its Influencing Factors in China. *China Science and Technology Forum*, (12), 73-78.

Wei, S. H., Wu, G. S., & Lü, X. L. (2010). Factors Influencing Regional Innovation Capability: A Review of Regional Disparities in Innovation Capability in China. *China Soft Science*, (09), 76-85.

Wei, S. H., Zhuo, J. J., & He, Y. (2011). Spatial Distribution and Trends of Regional Innovation Capability. *Science Research Management*, *32*(04), 152-160.

Wen, J., Yan, Z. J., & Cheng, Y. (2019). The Digital Economy and the Enhancement of Regional Innovation Capability. *Exploration of Economic Issues*, (11), 112-124.

Wu, C. Q., & Song, Z. Y. (2018). Measurement of Agricultural Green Total Factor Productivity and Its Influencing Factors in the Yangtze River Economic Belt. *Science and Technology Progress and Countermeasures*, *35*(17), 35-41.

Xu, H. L., Qi, P., & Zhu, S. J. (2006). Trade Openness, Human Capital, and Total Factor Productivity: An Empirical Analysis Based on Interprovincial Panel Data in China. *World Economy*, (12), 3-10+96.

Yang, H. M., & Jiang, L. (2021). Digital Economy, Spatial Effects, and Total Factor Productivity. *Statistical Research*, *38*(04), 3-15.

Yang, R. D., Li, Y., & Meng, S. S. (2023). Digital Development of Enterprises, Total Factor Productivity, and Industry Chain Spillover Effects. *Economic Research*, *58*(11), 44-61.

Yu, Y. S., & Wei, P. (2021). Research on the Measurement of Urban Green Total Factor Productivity in China. *Ecological Economy*, *37*(03), 43-52.

Zhang, L. J. (2006). A Systematic Study on Regional Innovation Environment and Innovation Capability: Empirical Evidence Based on Interprovincial Data. *Finance and Trade Research*, (05), 1-9.

Zhao, C. Y., Wang, W. C., & Li, X. S. (2021). How Digital Transformation Affects Enterprise Total Factor Productivity. *Finance and Trade Economics*, *42*(07), 114-129.