Measuring the Contribution of Postdoctoral Human Capital to Regional Economic Growth: Evidence from Jiangsu Province, China

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ABSTRACT

Human capital is a critical driver of innovation and economic growth. As an important component of high-level talent, postdoctoral researchers play an increasingly significant role in scientific innovation, technology transfer, and industrial upgrading. However, existing studies have mainly focused on postdoctoral training systems and policy design, while limited attention has been paid to the economic contribution of postdoctoral human capital. Drawing upon human capital theory and economic growth theory, this study investigates the contribution of postdoctoral human capital to regional economic growth in Jiangsu Province, China. An extended Cobb–Douglas production function incorporating physical capital, labor input, and postdoctoral human capital is developed. Furthermore, an entropy-weighting method is employed to construct a comprehensive index of postdoctoral human capital. The empirical results indicate that postdoctoral human capital has a significant positive effect on regional economic growth. Specifically, a 1% increase in postdoctoral human capital is associated with a 0.039% increase in regional GDP. The average contribution rate of postdoctoral human capital to economic growth reached 9.88% during the period 2017–2019, exceeding the contribution of ordinary labor input. These findings suggest that postdoctoral researchers not only serve as key actors in knowledge creation but also constitute an important source of sustainable regional development.

Keywords:
Postdoctoral Human Capital; Regional Economic Growth; Human Capital Contribution; Economic Growth Accounting; Jiangsu Province

1. Introduction

1.1 Research Background

Talent is widely recognized as the primary resource for socioeconomic development, while innovation serves as the fundamental driving force for sustainable growth. In the era of the knowledge economy, scientific and technological innovation has become a key indicator of national and regional competitiveness. Among various innovation factors, high-level innovative talents represent the most active and critical contributors to scientific and technological advancement. In recent years, China has continuously emphasized the strategic importance of talent development. The Report to the 20th National Congress of the Communist Party of China highlighted the need to implement the strategy of strengthening the nation through talent and accelerate the establishment of world-class centers for talent and innovation. Building a strong national strategic talent force has become an important component of China's modernization agenda.

As an essential component of China's high-level talent development system, the postdoctoral system has played a significant role in cultivating young scientific researchers, promoting technological innovation, and supporting socioeconomic development since its establishment in 1985. After more than three decades of development, China has established a relatively comprehensive postdoctoral training and management system. By the end of 2020, China had established 3,318 postdoctoral research stations in universities and research institutes and 3,850 postdoctoral workstations in enterprises and public organizations. More than 250,000 postdoctoral researchers had been recruited nationwide, producing a large number of scientific leaders and innovation-oriented professionals. Practical experience has demonstrated that postdoctoral researchers have become an indispensable force in China's innovation system, making important contributions to major national research projects, key technological breakthroughs, and the commercialization of scientific achievements.

With the implementation of the innovation-driven development strategy, competition for high-level talent has become increasingly intense across regions. Owing to their advanced educational background, strong research capabilities, and high innovation potential, postdoctoral researchers have gradually become a core component of regional innovation systems. Particularly in the context of the rapid development of strategic emerging industries and high-technology sectors, postdoctoral talent plays a vital role in enhancing regional innovation capacity, promoting industrial upgrading, and facilitating high-quality economic growth. Consequently, how to strengthen postdoctoral training, improve the utilization efficiency of postdoctoral talent, and maximize its contribution to economic development has become an important concern

for policymakers and academic researchers.

Jiangsu Province is one of China's most economically developed, educationally advanced, and innovation-oriented regions. It was also among the earliest provinces to establish postdoctoral programs. In recent years, the provincial government has attached great importance to the development of postdoctoral education and has introduced a series of policies aimed at improving the quality and effectiveness of postdoctoral training. By the end of 2020, Jiangsu had established 1,396 postdoctoral platforms, trained more than 23,000 postdoctoral researchers, and hosted nearly 8,000 postdoctoral fellows. Both the number of postdoctoral platforms and the scale of postdoctoral training have consistently ranked among the highest in China. As a result, postdoctoral researchers have become an important source of scientific innovation and industrial development in Jiangsu Province.

Despite the rapid expansion of postdoctoral programs, several challenges remain. On the one hand, local governments have continuously increased financial investment in postdoctoral training, resulting in a substantial expansion of support programs and funding resources. On the other hand, the economic returns generated by such investments remain insufficiently understood. In particular, the extent to which postdoctoral human capital contributes to regional economic growth has not been systematically quantified. Under the dual pressures of fiscal constraints and intensifying talent competition, evaluating the performance of postdoctoral training programs and accurately measuring the economic contribution of postdoctoral talent have become increasingly important for optimizing talent policies and improving the efficiency of public investment.

1.2 Literature Review

The relationship between human capital and economic growth has long attracted scholarly attention. Early studies by Schultz (1961) and Becker (1964) established the foundations of human capital theory, arguing that education, training, and talent development should be regarded as investments that enhance labor productivity and promote economic growth. Building upon this perspective, Lucas (1988) further emphasized that human capital not only improves individual productivity but also generates knowledge spillovers that contribute to broader regional economic development.

In China, existing studies have mainly focused on the relationship between high-level talent agglomeration, technological innovation, and regional economic growth. Most

scholars agree that high-level talent is a key source of regional innovation capacity and that talent concentration facilitates knowledge creation, technological advancement, and industrial upgrading, thereby stimulating economic development. Some studies have also found significant regional and industrial heterogeneity in the economic effects of high-level talent.

Research specifically related to postdoctoral talent can generally be classified into three streams. The first focuses on postdoctoral training models, including training mechanisms, development pathways, and quality evaluation. The second examines the postdoctoral system itself, emphasizing institutional evolution, management structures, and policy design. The third explores policy measures for postdoctoral development, including financial support, platform construction, and internationalization strategies.

Although these studies provide valuable insights into the development of postdoctoral programs, two major gaps remain. First, most existing research focuses on institutional arrangements and training mechanisms, while relatively little attention has been paid to the economic value generated by postdoctoral talent. Second, quantitative studies measuring the contribution of postdoctoral human capital to regional economic growth remain scarce, particularly those based on formal economic growth models. Therefore, a systematic assessment of the contribution of postdoctoral human capital to regional economic growth can not only enrich the literature on the economic value of high-level talent but also provide empirical evidence for optimizing talent development policies.

1.3 Research Objectives

To address the above research gaps, this study takes Jiangsu Province as a case and investigates the contribution of postdoctoral human capital to regional economic growth from the perspective of human capital theory. Specifically, this study aims to:

(1) construct a comprehensive evaluation index system for measuring postdoctoral human capital;

(2) develop an extended Cobb–Douglas production function incorporating postdoctoral human capital as an additional production factor;

(3) estimate the contribution of postdoctoral human capital to regional economic growth; and

(4) provide policy implications for improving postdoctoral training and talent development systems.

Through these efforts, this study seeks to deepen the understanding of the economic value of postdoctoral talent and provide evidence-based recommendations for regional

innovation and talent policies.

2. Research Design

2.1 Theoretical Framework

According to human capital theory, human capital is an important source of economic growth. Compared with ordinary labor, high-level talents possess greater knowledge reserves, stronger innovation capabilities, and higher research and development potential, enabling them to contribute more significantly to economic development. As an important component of high-level innovative talent, postdoctoral researchers serve as a critical bridge between basic research and industrial innovation. Their contribution to regional economic growth can be explained through three primary mechanisms: knowledge creation, technology transfer, and knowledge spillovers.

2.1.1 Knowledge Creation Effect

Postdoctoral researchers are active participants in frontier scientific research and technological innovation. By undertaking national and provincial research projects, conducting original scientific research, and addressing key technological challenges, postdoctoral researchers facilitate the generation of new knowledge and technologies. Such innovation activities contribute directly to technological progress and productivity improvement, thereby promoting economic growth.

2.1.2 Technology Transfer Effect

Compared with ordinary researchers, postdoctoral training places greater emphasis on collaboration among universities, research institutes, and enterprises. Many postdoctoral projects are conducted through enterprise-based research platforms and postdoctoral workstations. As a result, research outcomes can be more rapidly transformed into practical applications, accelerating the commercialization of scientific achievements and generating economic value.

2.1.3 Knowledge Spillover Effect

Postdoctoral researchers also generate significant knowledge spillover effects through academic collaboration, technological exchange, and talent mobility. By interacting with universities, research institutes, and enterprises, postdoctoral researchers facilitate the diffusion of knowledge and innovation resources across organizations, thereby enhancing the overall innovation capability of a region.

Based on the above analysis, postdoctoral human capital contributes to economic growth not only through direct innovation outputs but also through indirect channels

such as technological progress, industrial upgrading, and knowledge diffusion.

2.2 Measurement of Postdoctoral Human Capital

2.2.1 Evaluation Indicator System

Postdoctoral human capital is a multidimensional concept that cannot be adequately measured using a single indicator. Therefore, this study constructs a comprehensive evaluation system consisting of both input and output dimensions.

The input dimension reflects the resources devoted to postdoctoral training and development. Four indicators are selected: the number of postdoctoral platforms, the number of postdoctoral researchers in station, the annual number of newly recruited postdoctoral researchers, and provincial financial support for postdoctoral programs.

The output dimension reflects the performance and outcomes of postdoctoral training. Due to the limited availability of data on publications and patent applications at the provincial level, the number of postdoctoral researchers completing their programs is used as the primary output indicator.

Table 1. Evaluation Indicators of Postdoctoral Human Capital

Dimension	Indicator	Unit
Input	Number of postdoctoral platforms	Units
Input	Number of postdoctoral researchers in station	Persons
Input	Annual recruitment of postdoctoral researchers	Persons
Input	Provincial financial investment	10,000 RMB
Output	Number of postdoctoral researchers completing programs	Persons

2.2.2 Measurement Models

To evaluate the contribution of postdoctoral human capital to economic growth, this study employs two complementary methods: the entropy weight method and an extended Cobb–Douglas production function.

(1) Extended Cobb–Douglas Production Function

The traditional Cobb–Douglas (C–D) production function can be expressed as:

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \qquad (1)$$

where:

- Y_t denotes regional economic output (GDP);
- $A_t$represents total factor productivity;
- K_t^{α}denotes physical capital input;

- L_t^{β} denotes labor input;
- K_t^{α} represent the output elasticities of capital and labor, respectively.

To capture the economic contribution of postdoctoral human capital, this study introduces an additional production factor, namely postdoctoral human capital (B), resulting in the following extended production function:

$$Y_t = A_t(N)K_t^{\alpha}L_t^{\beta}B_t^{\gamma} \quad (2)$$

where:

- B denotes postdoctoral human capital;
- γ represents the output elasticity of postdoctoral human capital.

Taking the natural logarithm of both sides yields the linearized form:

$$lnY_t = lnA_t + \alpha lnK_t + \beta lnH_t + \gamma lnB_t \quad (3)$$

The estimated coefficien reflects the elasticity of GDP with respect to postdoctoral human capital. A positive value of indicates that postdoctoral human capital contributes positively to economic growth.

$$y = \lambda + \alpha k + \beta h + \gamma b \quad (4)$$

Based on growth accounting theory, the contribution rate of postdoctoral human capital can be estimated using:

$$E_M = \frac{\gamma b}{y} \quad (5)$$

where:

- y、k、h、b denotes the contribution rate of postdoctoral human capital;
- α、β、γ denotes the growth rate of postdoctoral human capital;
- E_M denotes the GDP growth rate.

(2) Entropy Weight Method

To avoid subjective weighting bias, the entropy weight method is adopted to construct a composite index of postdoctoral human capital.

The procedure consists of the following steps:

Step 1: Data Matrix Construction

Assume that there are (m) observations and (n) evaluation indicators. The original data matrix is expressed as:

$$X = \{x_{ij}\}_{mn} \quad (6)$$

Step 2: Data Standardization

To eliminate dimensional differences among indicators, all data are standardized before further analysis.

Step 3: Calculation of Indicator Proportions

The proportion of indicator (j) in observation (i) is calculated as:

$$P_{ij} = \frac{X_{ij}^{'}}{\sum m \quad y'}, 1 \le j \le n \qquad (7)$$

whereP_{ij}represents the standardized value.

Step 4: Entropy Calculation

The entropy value of indicator (j) is calculated as:

$$E_j = -k \sum_{.} P_{ij}\, lnP_{ij}, 1 \le i \le m, 0 \le E_j \le 1 \qquad (8)$$

where:

$$k = (\ln m)^{-1}$$

Step 5: Utility Value Calculation

The utility value of indicator (j) is calculated as:

$$g_j = 1 - E_j \qquad (9)$$

A smaller entropy value indicates that the indicator contains more useful information and should receive a higher weight.

Step 6: Weight Determination

The weight of each indicator is calculated as:

$$W_j = \frac{g_j}{\sum_{j=1}^{n} g_j}, 0 \le g_j \le 1, W_1 + W_2 + \cdots W_j = 1 \qquad (10)$$

Step 7: Composite Index Calculation

The comprehensive score of postdoctoral human capital is calculated as:

$$U = \sum_{j=1}^{n} W_j\, X_{ij}' \qquad (11)$$

where$g_j$denotes the composite score of postdoctoral human capital in year (i).

The resulting index is used as the proxy variable for postdoctoral human capital in the empirical analysis.

2.3 Data Sources and Variable Description

This study focuses on Jiangsu Province, one of the most economically developed and innovation-intensive regions in China. The study period covers 2016–2019, during which relatively complete data on postdoctoral training and economic development are available.

The data are collected from multiple official sources, including:

- *China Statistical Yearbook*;
- *Jiangsu Statistical Yearbook*;
- *China Postdoctoral Development Report*;
- Statistical reports issued by the Department of Human Resources and Social Security of Jiangsu Province.

The main variables used in this study are defined as follows:

GDP (Y): Gross Domestic Product of Jiangsu Province, representing regional economic output.

Capital Input (K): Total fixed asset investment, representing physical capital input.

Labor Input (L): Total employed population in Jiangsu Province.

Postdoctoral Human Capital (B): Composite index calculated using the entropy weight method.

By integrating the entropy-based human capital index with the extended Cobb–Douglas production function, this study estimates the contribution of postdoctoral human capital to regional economic growth and evaluates its economic significance.

3. Empirical Results and Discussion

3.1 Measurement Results of Postdoctoral Human Capital

Based on the evaluation indicator system presented in Table 1, the entropy weight method was employed to calculate the composite index of postdoctoral human capital in Jiangsu Province during the period 2016–2019. The calculation results are reported in Table 2.

Table 2. Composite Scores of Postdoctoral Human Capital in Jiangsu Province

Year / Indicators	2016	2017	2018	2019
X1	1204	1219	1338	1416
X2	5960	6066	7021	8137
X3	1807	1705	1971	2390
X	3100	4225	3100	7900
X	1109	1122	1088	1247

As shown in Table 2, the overall level of postdoctoral human capital in Jiangsu Province exhibited an upward trend during the study period. The composite score increased from 0.1842 in 2016 to 0.3423 in 2019, representing an increase of approximately 85.8%. This indicates that Jiangsu Province achieved substantial progress in the development of postdoctoral programs and the accumulation of high-level human capital.

A closer examination of the entropy weights reveals that provincial financial investment accounted for the largest proportion of the overall score, with a weight of 0.5966, followed by the number of postdoctoral platforms, with a weight of 0.3524. In contrast, indicators related to postdoctoral recruitment and training outcomes received relatively lower weights. These findings suggest that government financial support and platform

construction have played dominant roles in the development of postdoctoral programs in Jiangsu Province.

The continuous increase in the composite score also reflects the expanding scale of postdoctoral training, the improvement of research infrastructure, and the enhancement of innovation capacity. As a result, postdoctoral human capital has become an increasingly important strategic resource for regional innovation and economic development.

3.2 Estimation of the Extended Production Function

To examine the impact of postdoctoral human capital on regional economic growth, the extended Cobb–Douglas production function was estimated using data from Jiangsu Province between 2016 and 2019.

The variables included in the model are presented in Table 3.

Table 3. GDP, Capital Input, Labor Input, and Postdoctoral Human Capital in Jiangsu Province

indicator / **year**	X1	X2	X3	X4	X5	**Contribution**
weight	0.3524	0	0.0511	0.5966	0	1
2016	0.1896	0.2500	0.2496	0.1754	0.2500	0.1842
2017	0.1899	0.2500	0.2052	0.2678	0.2500	0.2372
2018	0.3876	0.2500	0.2580	0.1451	0.2500	0.2363
2019	0.2330	0.2500	0.2872	0.4116	0.2500	0.3423

Using the logarithmic form of the extended production function and applying ordinary least squares (OLS) regression, the estimated model can be expressed as:

$$lnY_t = -81.5253 + 1.5282lnK_t + 9.013lnL_t + 0.0391lnB_t \quad (12)$$

The estimated coefficients indicate that all three production factors exert positive effects on economic output.

The elasticity coefficient of physical capital is 1.5282, suggesting that a 1% increase in capital investment leads to a 1.5282% increase in GDP, holding other factors constant. The elasticity coefficient of labor input is 9.0130, indicating that labor remains an important contributor to economic growth.

More importantly, the elasticity coefficient of postdoctoral human capital is 0.0391. This result implies that a 1% increase in postdoctoral human capital is associated with a 0.039% increase in regional GDP.

Although the elasticity coefficient of postdoctoral human capital is lower than those of capital and labor, its positive sign confirms that postdoctoral human capital contributes significantly to economic growth. This finding supports the argument that high-level talent serves as an important production factor in the knowledge economy.

3.3 Contribution of Postdoctoral Human Capital to Economic Growth

Based on the estimated elasticity coefficient and the growth accounting framework, the contribution rates of postdoctoral human capital to regional economic growth were calculated. The results are presented in Table 4.

Table 4. Contribution of Postdoctoral Human Capital to GDP Growth in Jiangsu Province

Year	GDP	Capital K	Labor L	Postdoctor Capital B
2016	76086.17	49370.85	4756.2	0.1842
2017	85900.90	53000.21	4757.8	0.2372
2018	92000.00	55915.22	4750.9	0.2363
2019	99631.52	58766.90	4745.2	0.3423

The results indicate that postdoctoral human capital made a positive contribution to regional economic growth during most of the study period. The contribution rate reached 8.72% in 2017 and increased significantly to 21.13% in 2019. Although a slight decline was observed in 2018, mainly due to the temporary slowdown in the growth of postdoctoral human capital, the overall contribution remained positive.

The average contribution rate of postdoctoral human capital during 2017–2019 was 9.88%, demonstrating that postdoctoral researchers have become an important source of regional economic growth in Jiangsu Province.

By comparison, physical capital remained the dominant driving force of economic growth, with an average contribution rate of approximately 99.78%. This finding reflects the continued importance of investment-led growth in Jiangsu Province. However, the contribution of postdoctoral human capital consistently exceeded that of labor input, highlighting the increasing significance of high-level talent in a knowledge-based economy.

3.4 Discussion

The empirical findings provide strong evidence that postdoctoral human capital contributes positively to regional economic growth. This conclusion is consistent with

the predictions of human capital theory and endogenous growth theory.

First, postdoctoral researchers generate innovation-driven growth. As highly educated and research-oriented professionals, they actively participate in scientific research, technological development, and knowledge creation. Their activities contribute to technological progress, which serves as a key engine of long-term economic growth.

Second, postdoctoral human capital facilitates technology transfer and commercialization. In Jiangsu Province, a large number of postdoctoral projects are conducted through enterprise-based workstations and industry–university collaboration platforms. This institutional arrangement enables research outcomes to be transformed into practical applications more efficiently, thereby creating economic value.

Third, postdoctoral researchers generate substantial knowledge spillovers. Through research collaboration, talent mobility, and academic exchange, the knowledge and skills accumulated by postdoctoral researchers can spread across organizations and industries, enhancing regional innovation capacity and productivity.

An interesting finding is that although the output elasticity of postdoctoral human capital is relatively small compared with those of physical capital and labor, its contribution rate exceeds that of labor input throughout most of the study period. This result suggests that high-level talent possesses stronger marginal productivity and greater innovation potential than ordinary labor.

Furthermore, the contribution of postdoctoral human capital appears to exhibit cumulative effects. As postdoctoral training systems continue to improve and innovation resources become increasingly concentrated, the economic impact of postdoctoral researchers is expected to grow over time.

Overall, the empirical evidence demonstrates that postdoctoral human capital is not only a key source of scientific innovation but also an increasingly important driver of regional economic development. These findings provide empirical support for policies aimed at strengthening postdoctoral programs and investing in high-level human capital.

4. Conclusions and Implications

4.1 Conclusions

As innovation-driven development becomes increasingly important in the knowledge economy, high-level human capital has emerged as a critical determinant of regional competitiveness and sustainable economic growth. As an important component of China's high-level talent development system, postdoctoral researchers play a vital role

in scientific innovation, technology transfer, and industrial upgrading. However, empirical evidence regarding the economic contribution of postdoctoral human capital remains relatively limited.

To address this research gap, this study constructed a comprehensive evaluation index of postdoctoral human capital using the entropy weight method and incorporated postdoctoral human capital into an extended Cobb–Douglas production function. Taking Jiangsu Province as the research case, the study empirically examined the contribution of postdoctoral human capital to regional economic growth during the period 2016–2019.

Several important conclusions can be drawn from the empirical analysis.

First, postdoctoral human capital has a significant positive effect on regional economic growth. The estimated elasticity coefficient of postdoctoral human capital is 0.0391, indicating that a 1% increase in postdoctoral human capital leads to an approximately 0.039% increase in regional GDP. This finding confirms that postdoctoral researchers constitute an important production factor in the knowledge economy and contribute directly to economic development.

Second, postdoctoral human capital has become an important source of economic growth in Jiangsu Province. The growth accounting results show that the average contribution rate of postdoctoral human capital to regional economic growth reached 9.88% during the study period. Although physical capital remains the dominant driving force of economic growth, the contribution of postdoctoral human capital consistently exceeded that of ordinary labor input, highlighting the increasing importance of high-level talent in regional development.

Third, postdoctoral human capital promotes economic growth through multiple channels. In addition to generating direct innovation outputs, postdoctoral researchers contribute to technological advancement, facilitate the commercialization of research achievements, and create knowledge spillover effects. These mechanisms collectively enhance regional innovation capacity and support long-term economic development.

Fourth, the economic effects of postdoctoral human capital exhibit strong cumulative characteristics. As the scale of postdoctoral programs expands and innovation resources become increasingly concentrated, the contribution of postdoctoral researchers is expected to continue growing. This suggests that investment in postdoctoral training should be viewed as a long-term strategic investment rather than a short-term expenditure.

Overall, the findings demonstrate that postdoctoral human capital not only serves as a critical driver of scientific and technological innovation but also constitutes an important source of regional economic growth and sustainable development.

4.2 Policy Implications

The empirical findings of this study provide several important implications for policymakers seeking to strengthen regional innovation capacity and improve the effectiveness of talent development policies.

4.2.1 Strengthening Financial Support for Postdoctoral Programs

Financial support remains one of the most important factors influencing the development of postdoctoral programs. The entropy-weight analysis indicates that government investment contributes substantially to the accumulation of postdoctoral human capital. Therefore, policymakers should continue to increase financial support for postdoctoral researchers and establish a dynamic funding mechanism linked to regional economic development and innovation priorities.

In particular, targeted support should be provided for postdoctoral research in strategic emerging industries, such as artificial intelligence, advanced manufacturing, biotechnology, and new energy technologies. Such investments can improve the quality of postdoctoral training while enhancing its contribution to regional economic growth.

4.2.2 Promoting Industry-Oriented Postdoctoral Training

The economic value of postdoctoral human capital depends not only on research quality but also on its relevance to industrial development. Consequently, postdoctoral training programs should be more closely aligned with the needs of regional industries and innovation ecosystems.

Governments and universities should encourage greater collaboration between postdoctoral researchers and enterprises through industry–university–research partnerships. Expanding enterprise-based postdoctoral workstations and innovation platforms can help bridge the gap between scientific research and industrial application, thereby improving the economic returns of postdoctoral investment.

4.2.3 Enhancing Technology Transfer and Commercialization

Technology transfer is an important mechanism through which postdoctoral human capital contributes to economic growth. To maximize this contribution, policymakers should further improve technology transfer systems and strengthen incentives for research commercialization.

Specific measures may include establishing specialized technology transfer offices,

supporting intellectual property protection, providing commercialization grants, and encouraging collaborative innovation projects between universities and enterprises. These initiatives can accelerate the transformation of scientific achievements into marketable products and services.

4.2.4 Creating a Favorable Environment for Talent Development

The long-term contribution of postdoctoral human capital depends on the ability to attract, retain, and develop talented researchers. Therefore, governments should continue improving the institutional environment for postdoctoral researchers by providing competitive compensation, career development opportunities, and research support.

Policies that facilitate career transitions from postdoctoral positions to academic, industrial, or entrepreneurial careers can further enhance the attractiveness of postdoctoral programs and improve talent retention.

4.2.5 Promoting the Internationalization of Postdoctoral Training

In the context of global competition for high-level talent, internationalization has become an important strategy for enhancing the quality of postdoctoral programs. Regional governments and universities should strengthen international collaboration with leading research institutions, support international joint training programs, and attract outstanding overseas researchers to participate in postdoctoral research activities. By integrating global innovation resources and expanding international academic networks, postdoctoral researchers can gain access to advanced knowledge and technologies, thereby increasing their contribution to regional innovation and economic development.

4.3 Limitations and Future Research

Despite its contributions, this study has several limitations.

First, the analysis is based on data from a single province and a relatively short observation period. Although Jiangsu Province is one of China's leading regions in terms of economic development and postdoctoral training, the findings may not fully capture regional heterogeneity across China.

Second, due to data availability constraints, the measurement of postdoctoral human capital relies on a limited number of indicators. Future studies may incorporate additional measures, such as research publications, patent quality, research funding, and international collaboration activities, to provide a more comprehensive assessment of

postdoctoral human capital.

Third, this study focuses primarily on the direct contribution of postdoctoral human capital to economic growth. Future research could further explore the indirect mechanisms through which postdoctoral researchers influence innovation performance, industrial upgrading, and regional competitiveness.

Finally, future studies may employ panel data models, spatial econometric methods, or comparative regional analyses to investigate the long-term and spatial spillover effects of postdoctoral human capital. Such research would provide a deeper understanding of how high-level talent contributes to sustainable economic development in different institutional and regional contexts.

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