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Research Article

Influence of Spatiotemporal Difference and Input of Higher Education on Regional Economy

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Scientific expenditure and distribution of higher education drive the sustainable and stable development of regional economy. Currently, China faces an imbalance in the allocation of higher education resources. To solve the problem, it is necessary to study the spatiotemporal difference of higher education development. Therefore, this paper explores how higher education varies in time and space and measures how the spatiotemporal difference and input of higher education affects regional economy. Firstly, the authors divided the influence of spatiotemporal difference and input of higher education on regional economy into four aspects. Next, the spatiotemporal differences of higher education were examined in detail. Based on the four aspects, an equilibrium model was established for regional economic development, and the law of evolution to equilibrium was analyzed. Experimental results verify the effectiveness of the established model.

1. Introduction

Education is the foundation of national development [1, 2]. If the input scale and allocation structure of higher education are unreasonable, the economic growth will be inevitably dragged down [3–6]. In contrast, scientific expenditure and allocation of higher education drive the sustainable and stable development of regional economy [7–10]. On the allocation of higher education resources, a new perspective is to analyze the causes for the spatiotemporal difference and evaluate the development quality of higher education, following the principles of education, economics, geography, and statistics. The relevant results are constructive for solving the imbalanced allocation of higher education resources in China.

The spatiotemporal difference of higher education is usually analyzed through literature review, comparative analysis, regression analysis, statistical analysis, and projection tracking [11–16]. Rokicki et al. [17] explored the causes for imbalanced spatiotemporal distribution of higher education resources on two scales (time and space) and in three dimensions (scale, faculty, and fund investment) and obtained the global and local autocorrelations of the distributions for multiple influencing factors: regional difference in population density, regional difference in economic development, and regional difference in fund investment.

In recent years, the development capacity of higher education has increased significantly in China, especially in developed regions like the Yangtze River Delta, the Pearl River Delta, and Shandong Peninsula [18–22]. Wilck [23] held that the spatiotemporal development features of higher education in the above regions influence regional economic growth in four aspects, namely, enterprise agglomeration, capital investment, talent training and introduction, and technological innovation and update, and experimentally verified the positive or negative spatial spillover mechanism and effect of the four aspects that promote or suppress regional economic growth. Gupta [24] established a regional production function affected by the core elements of higher education expenditure and empirically tested the mutual influence between higher education input/expenditure and sustainable economic growth. Mendoza et al. [25] constructed the long-term equilibrium equation between higher education and regional economic development and corrected the errors of the damaged equilibrium relationship

between the relevant variables with the residual term with one phase lag, referring to the results of empirical analysis. Considering both efficiency and fairness, Brusakova et al. [26] investigated the spatiotemporal development features of basic education in economic development zones of the Yangtze River Delta and the internal logic of macro-economic development, proposed the paths for basic education input to influence macro-economic growth, examined the influence of income distribution structure on macro-economic growth, and suggested policymakers to reasonably expand expenditure scale, optimize expenditure structure, and improve expenditure management mechanism. Abraukhova et al. [27] constructed a cointegration model between higher education expenditure and gross domestic product (GDP), set up spatial lag model and spatial error model based on GeoDa, and verified the positive correlation between higher education expenditure and GDP.

The following is a brief summation of existing research results. In terms of research scope, the existing studies mainly focus on the allocation of higher education resources like faculty and fund. Few scholars have compared the changes of resources in different dimensions. In terms of research scale, most of the previous research tackled the evolution of basic education and economic development on provincial and national level but rarely discussed the evolution of these factors on the level of smaller regions. In terms of research method, the traditional index analysis approach is too subjective, ignores the spatial perspective, and works poorly on high-dimensional data.

Therefore, this paper decides to analyze the spatiotemporal difference of higher education and explore the influence of the spatiotemporal difference and input of higher education on regional economy. Section 2 divides the influence of spatiotemporal difference and input of higher education on regional economy into four aspects and describes the action mechanism of each aspect on regional economy. Section 3 analyzes the spatiotemporal differences of higher education. Section 4 constructs an equilibrium model for regional economic growth based on the four action mechanisms and analyzes the law of evolution to equilibrium. The proposed model was proved effective through experiments.

2. Preliminaries

This paper aims to disclose the spatiotemporal difference of higher education and reveal the action mechanism of the spatiotemporal difference and input of higher education on regional economy. For this purpose, it is necessary to build an equilibrium model about the action mechanism, under the following hypotheses.

Firstly, the spatiotemporal development features of higher education were hypothesized. Giving full consideration to the spatiotemporal difference of regional higher education development and its unbalanced influence on regional economy, it is assumed that the spatiotemporal difference of higher education development affects the regional economy through four mechanisms:

(1) Social investment coupling mechanism: the influence of spatiotemporal development of higher education on regional investment level through this mechanism is denoted as H_{SI}, which characterizes the degree of interaction between spatiotemporal development of higher education on regional investment level.

(2) Human capital coupling mechanism: the influence of spatiotemporal development of higher education on regional human capital quality and labor force through this mechanism is denoted as H_E, which characterizes how much spatiotemporal development of higher education improves regional labor efficiency and labor force.

(3) Technology progress coupling mechanism: the influence of spatiotemporal development of higher education on regional technology update through this mechanism is denoted as H_C, which characterizes the promoting effect of spatiotemporal development of higher education on regional innovation and update.

(4) Industrial agglomeration coupling mechanism: the influence of spatiotemporal development of higher education on regional industrial agglomeration is denoted as H_Q, which characterizes how much spatiotemporal development and agglomeration of enterprises is affected by spatiotemporal development of higher education.

Suppose the above four mechanisms have a balanced effect on regional economy. It can be inferred that the greater H_{SI}, H_E, H_C, and H_Q, the higher the regional investment level, regional human capital quality and labor force, regional technology progress, and regional industrial agglomeration and the more prominent the influence of spatiotemporal difference and input of higher education on regional economy (Figure 1).

To quantify core influencing factors, the Cobb–Douglas production function is widely adopted to study economic growth. This function was selected to derive the production function of the study areas. Let GO, TL, L, LE, NU, β, and EF be the total output, technology level, capital, labor efficiency, labor force, elastic coefficient of marginal capital output, and effective labor force of the region, respectively. Then, the Cobb–Douglas production function can be established as

$$\mathrm{GO} = \mathrm{TL} \cdot L^{\beta} (\mathrm{EF})^{1-\beta}. \tag{1}$$

The above analysis clarifies the industrial clustering coupling mechanisms, which characterize the degree of influence of spatiotemporal development for higher education on the spatiotemporal development and clustering of enterprises. Considering the spatiotemporal difference of higher education, the Cobb–Douglas production function can be revised into

$$\mathrm{PF} = \left(1 + H_Q\right)\mathrm{TL} \cdot L^{\beta} (\mathrm{EF})^{1-\beta}. \tag{2}$$

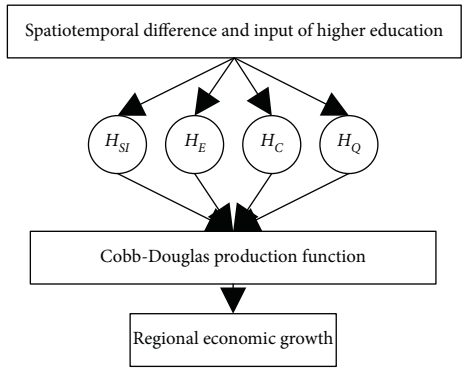

FIGURE 1: Principle for influence of spatiotemporal difference and input of higher education on regional economy.

Formula (2) shows that $\mathrm{TL} \cdot L^{\beta}(\mathrm{EF})^{1-\beta}$ and $H_q \cdot \mathrm{TL} \cdot L^{\beta}(\mathrm{EF})^{1-\beta}$ jointly constrain regional economic growth.

Without considering the spatiotemporal difference of higher education development in the region, this paper characterizes the core influencing factors of economic growth in the form of mainstream economics. Let G, ξ, and ξL be the total resident consumption, capital discount rate, and capital discount in the region, respectively. Then, the variation in regional capital can be described as $L' = \mathrm{GO} - G - \xi L$. Let $H_{SI}L$ be the influence of spatiotemporal development of regional higher education on L via social investment coupling mechanism. Then, the dynamic changes of regional capital can be described by

$$L' = \mathrm{GO} - G - \xi L + H_{SI}L. \tag{3}$$

The variation in regional human capital quality $\mathrm{LE}' = h_E \cdot \mathrm{LE}$ satisfies $\mathrm{LE}' = (1 + G_E)h_E \cdot \mathrm{LE}$; the variation in regional technology progress $\mathrm{TL}' = h_C \cdot \mathrm{TL}$ satisfies $\mathrm{TL}' = (1 + \mathrm{GO})h_C \cdot \mathrm{TL}$; the variation in regional labor force $\mathrm{NU}' = h_A \cdot \mathrm{LE}$ satisfies $\mathrm{NU}' = (1 + G_E)h_A \cdot \mathrm{LE}$, where h_A is the growth rate of regional labor force.

When the regional residents are homogenous in spending, the total consumption in the region directly bears on the social welfare. Let $\mathrm{TE}(G)$ be the total utility of the region; $1/\omega$ be the elastic coefficient for the intertemporal consumption of regional residents; and δ be the discount factor for the intertemporal consumption preference of regional residents. Then, social welfare can be described by the following function:

$$\mathrm{TE}(G) = \int_0^{\infty} \frac{G^{1-\omega}}{1-\omega} e^{-\delta t} \mathrm{d}t. \tag{4}$$

Formula (4) shows that regional social welfare increases with the growing level of resident consumption.

3. Spatiotemporal Difference Analysis

The Gini index is usually obtained by measuring the equality of the distribution of social income. This index can describe the spatiotemporal changes of the clustering and distribution of advanced education population. Let M_C and R be the number of colleges in the region and the number of students receiving higher education in each college, respectively, and ψ be the difference between the number of students and the number of teachers in each college. Then, the Gini coefficient can be expressed as

$$\mathrm{GI} = \frac{\psi}{2R(M_C - 1)}. \tag{5}$$

The Gini coefficient obtained by formula (5) falls in [0, 1]. The GI value is positively correlated with the clustering of higher education population in the region.

To accurately analyze the overall spatiotemporal landscape of higher education regions, the relevant data on the four coupling mechanisms, which are obtained in the preceding subsection, were adopted to replace the assumption of balanced influence. From the objective perspective, the entropy method was selected to initialize the weights of the four mechanisms, and the initial weights were corrected through AHP from the subjective perspective. After normalization, the weighted sum of the data on the four coupling mechanisms was solved, producing the composite score EST of the spatiotemporal development quality of higher education in the region. Let A_{ij} be the normalized value of the j-th influencing factor in the i-th coupling mechanism; B_{ij} be the weight of the j-th factor in the i-th mechanism; and Y_iB_i be the weight of the i-th mechanism in the composite score. Then, the composite score EST can be described as

$$\mathrm{EST} = \sum_{i=1}^{4} B_I \left(\sum_{j=1}^{11} B_{ij} A_{ij} \right). \tag{6}$$

Let EST_{AV} and φ be the mean and standard deviation of the composite scores of N regions, respectively, and M be the number of data samples of the four mechanisms. Then, the spatial distribution of EST can be characterized by the variation coefficient χ:

$$\chi = \frac{\varphi}{\mathrm{EST}_{AV}} = \frac{1}{\mathrm{EST}_{AV}} \times \left[\frac{\sqrt{\sum_{\mathrm{EST}=1}^{M} (\mathrm{EST}_i - \mathrm{EST}_{AV})^2}}{M - 1} \right]. \tag{7}$$

Formula (7) shows that the χ value is positively correlated with the dispersion of composite score in space and the spatiotemporal difference of higher education development.

4. Equilibrium Model and Law Analysis

4.1. Modeling. Under the aforementioned hypotheses, three objectives were defined for the equilibrium model for the influence of the spatiotemporal difference and input of higher education on regional economic growth: the maximization of resident salary, enterprise profit, and social welfare in the region. Let $l = L/\mathrm{EF}$ and $g = G/\mathrm{EF}$ be the unit effective labor capital and consumption, respectively. Suppose $\delta' = \delta - (1 - \omega)(1 + H_E)(h_E + h_A)$, and $\xi' = \xi - H_i + (1 + H_E)(h_E + h_A)$. Then, the decision function for regional socioeconomic development can be described as

$$\begin{aligned} \mathrm{Max}(g) &= \int_0^{\infty} \frac{g^{1-\delta}}{1-\omega} e^{-\delta' t} \mathrm{d}t \\ \text{s.t.} \quad l' &= \left(1 + H_Q\right)\mathrm{TL} \cdot l^{\beta} - g - \xi' l. \end{aligned} \tag{8}$$

Let μ be the Hamiltonian operator. Then, the Hamiltonian equation for decision making of regional economic growth can be given by

$$\mathrm{TL}(g) = \frac{g^{1-\omega}}{1-\omega} e^{-\delta' t} + \mu\left[\left(1 + H_A\right)\mathrm{TL} \cdot l^{\beta} - g - \xi' l\right]. \tag{9}$$

Suppose the partial derivative of TL to g is 0. Then, we have

$$\frac{\partial \mathrm{TL}}{\partial g} = g^{-\omega} e^{-\delta' t} - \mu = 0. \tag{10}$$

The partial derivative of TL to l can be expressed as

$$\frac{\partial \mathrm{TL}}{\partial l} = -\mu' = \mu\left[\beta\left(1 + H_A\right)\mathrm{TL} \cdot l^{\beta-1} - \xi'\right]. \tag{11}$$

The cross-sectional condition for decision making of regional economic growth can be given by

$$\lim_{t \longrightarrow \infty} \mu(t) l(t) = 0. \tag{12}$$

The Euler equation for effective labor consumption can be established as

$$\frac{g'}{g} = \frac{\beta\left(1 + H_A\right)\mathrm{TL} \cdot l^{\beta-1} - \xi' - \delta'}{\omega}. \tag{13}$$

If equilibrium is achieved through optimal decision making, the unit effective labor capital can be expressed as

$$\hat{l} = \left[\frac{\beta\left(1 + H_A\right)\mathrm{TL}}{\xi' + \delta'}\right]^{(1/1-\beta)}. \tag{14}$$

In addition, the regional output can be expressed as

$$\bar{a} = \frac{\beta^{(\beta/1-\beta)}\left[\left(1 + H_A\right)\mathrm{TL}\right]^{(1/1-\beta)}}{\left[\xi + \delta - H_{SI} + \omega\left(1 + H_E\right)\left(h_E + h_A\right)\right]^{(\beta/1-\beta)}}. \tag{15}$$

4.2. Equilibrium Law Analysis. Formula (15) indicates that the balanced development of regional economy is jointly affected by three groups of factors: (1) the asymmetric effect of the four coupling mechanisms H_{SI}, H_E, H_C, and H_Q; (2) the effect of three growth rate factors h_E, h_A, and h_C; and (3) the effect of correlation coefficients of economic structure, capital discount, and consumption β, ξ, δ, and ω.

Figure 2 shows how industrial agglomeration coupling mechanism affects regional economic growth. The equilibrium effect of the spatiotemporal difference of higher education development on regional economic growth was equivalent to the effect of H_Q on $\bar{a}$. Formula (15) shows that $\bar{a}$ is a power function of H_Q. Then, we have

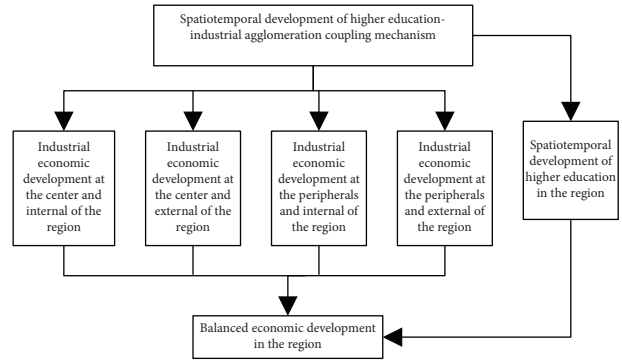

Figure 2: Principle of how industrial agglomeration coupling mechanism affects regional economic growth.

$$\frac{d\hat{b}}{dH_Q} = \beta^{(\beta/1-\beta)} \frac{\mathrm{TL}}{1-\beta}\left[\frac{\left(1 + H_Q\right)\mathrm{TL}}{\xi + \delta - H_{SI} + \omega\left(1 + H_E\right)\left(h_E + h_A\right)}\right]^{(\beta/1-\beta)}. \tag{16}$$

If $[\xi + \delta - H_{SI} + \omega(1 + H_E)(h_E + h_A)]^{\beta/1-\beta} > 0$, the partial derivative of $\bar{a}$ to H_Q is greater than zero, that is, $\bar{a}$ increases with H_Q. Then, the marginal variation of $\bar{a}$ with H_Q can be described by

$$MC_Q = \beta^{(\alpha/1-\alpha)} \frac{\mathrm{TL}}{1-\beta}\left[\frac{\left(1 + H_Q\right)\mathrm{TL}}{\xi + \delta - H_{SI} + \omega\left(1 + H_E\right)\left(h_E + h_A\right)}\right]^{(\beta/1-\beta)}. \tag{17}$$

Formula (17) confirms that $\bar{a}$ is a power function of H_Q. However, under the combined effect of factors like β, ξ, δ, ω, H_{SI}, H_E, h_E, and h_A, the spatiotemporal difference of higher education development can only promote the balanced development of regional economy via industrial agglomeration coupling mechanism under very special conditions.

Figure 3 shows how social investment coupling mechanism affects regional economic growth. The derivative of $\bar{a}$ to H_{SI} can be expressed as

$$\frac{\mathrm{d}\bar{a}}{\mathrm{d}H_{SI}} = \frac{\beta^{(1/1-\beta)}}{1-\beta}\left[\frac{\left(1 + H_Q\right)\mathrm{TL}}{\xi + \delta - H_{SI} + \omega\left(1 + H_E\right)\left(h_E + h_A\right)}\right]^{(1/1-\beta)}. \tag{18}$$

If $[\xi + \delta - H_{SI} + \omega(1 + H_E)(h_E + h_A)]^{1/1-\beta} > 0$, the partial derivative of $\bar{a}$ to H_{SI} is greater than zero, that is, $\bar{a}$ increases with H_{SI}. Then, the marginal variation of $\bar{a}$ with H_{SI} can be described by

$$MC_{SI} = \frac{\beta^{(\beta/1-\beta)}}{1-\beta}\left[\frac{\left(1 + H_Q\right)\mathrm{TL}}{\xi + \delta - H_{SI} + \omega\left(1 + H_E\right)\left(h_E + h_A\right)}\right]^{(1/1-\beta)}. \tag{19}$$

Formula (19) shows that the spatiotemporal development of higher education can bring changes to the regional capital level via the social investment coupling mechanism. But H_{SI} can only effectively promote the balanced development of regional economy, under the collaboration between factors like β, ξ, δ, ω, H_Q, H_E, h_E, and h_A.

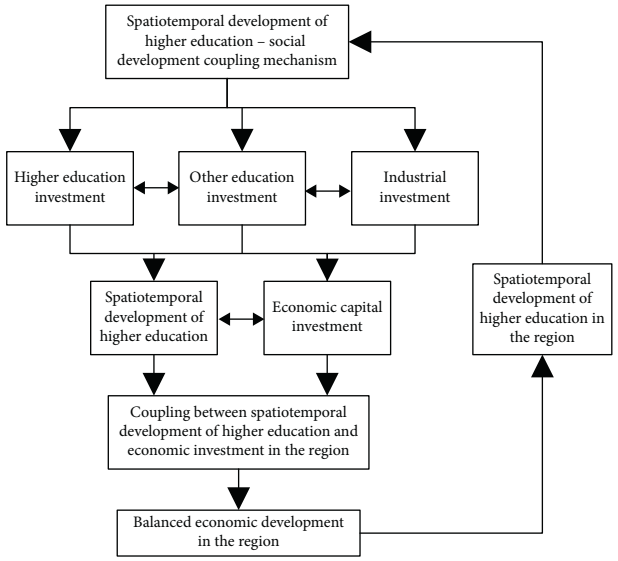

Figure 3: Principle of how social investment coupling mechanism affects regional economic growth.

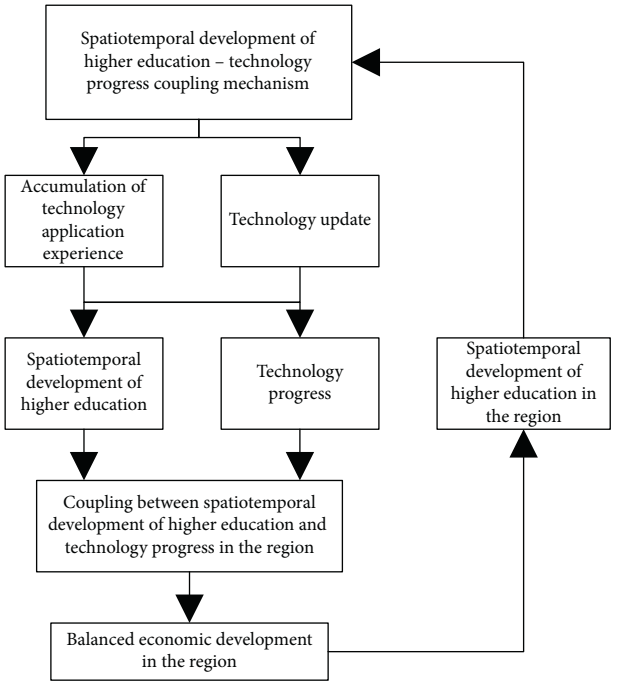

Figure 4: Principle of how technology progress coupling mechanism affects regional economic growth.

Figure 4 shows how technology progress coupling mechanism affects regional economic growth. Similarly, the marginal variation of $\bar{a}$ with H_C can be expressed as

$$MC_C = \frac{h_C \beta^{(\beta/1-\beta)} \left[\left(1 + H_Q\right) TL\right]^{(\beta/1-\beta)} t}{(1-\beta)\left[\xi + \delta - H_{SI} + \omega\left(1 + H_E\right)\left(h_E + h_A\right)\right]^{(\beta/1-\beta)}}. \tag{20}$$

Formula (20) shows that the combination between β, ξ, δ, ω, H_{SI}, H_Q, H_E, h_E, h_A, and h_C determines the value of MC_C. If $[\xi + \delta - H_i + \omega(1 + H_E)\ (h_E + h_m)]^{\beta/1-\beta} > 0$, the partial derivative of $\bar{a}$ to H_C is greater than zero, that is, $\bar{a}$ increases with H_C.

Figure 5 shows the principle of how human capital coupling mechanism affects regional economic growth. The influence of spatiotemporal development of higher education on balanced development of regional economy via H_E covers both the marginal equilibrium effect and the growth effect. The marginal equilibrium effect of H_E on $\bar{a}$ can be described as

$$MC_E = \frac{\mathrm{d}\bar{a}}{\mathrm{d}H_E} = \frac{-\omega\left(h_E + h_A\right)\beta^{(1/1-\beta)}}{1-\beta}\left[\frac{\left(1 + H_Q\right)\mathrm{TL}}{\xi + \delta - H_{SI} + \omega\left(1 + G_E\right)\left(h_E + h_A\right)}\right]^{(-1/1-\beta)}. \tag{21}$$

If $[\xi + \delta - H_{SI} + \omega(1 + H_E)(h_E + h_A)]^{1/1-\beta} > 0$, then the marginal equilibrium effect of H_E on $\bar{a}$ is negative.

To sum up, the spatiotemporal development of higher education exerts an asymmetric effect on the balanced development of regional economy along multiple complex paths via the four coupling mechanisms H_{SI}, H_E, H_C, and H_Q. Figure 6 shows the principle of how the four mechanisms affect regional economic growth. If $MC_Q + MC_{SI} + MC_C + MC_E > 0$, all direct marginal effects can effectively improve the equilibrium of $\bar{a}$. If $\Delta\bar{a}_Q + \Delta\bar{a}_{SI} + \Delta\bar{a}_C + \Delta\bar{a}_E > 0$, direct growth effect can effectively accelerate the balanced growth rate of regional economy. Therefore, when $MC_Q + MC_{SI} + MC_C + MC_E$ and $\Delta\bar{a}_Q + \Delta\bar{a}_{SI} + \Delta\bar{a}_C + \Delta\bar{a}_E$ are both greater than zero, the spatiotemporal development of higher education can effectively boost the level and rate of balanced economic growth in the region (Figure 6).

4.3. Talent Training and Scientific Output Effects. Based on the previously established Cobb–Douglas production function, the regional human capital input was characterized by the number of students in each college. The elastic coefficients of L, NU, and LE are denoted as β, α, and ϕ, respectively; the random disturbance whose value <1 is denoted as ε. Then, the regional economic output GO measured by GDP can also be expressed as

$$\mathrm{GO} = \mathrm{TL} \cdot L^{\beta} \cdot \mathrm{NU}^{\alpha} \cdot \mathrm{LE}^{\phi} \cdot \varepsilon. \tag{22}$$

The model can be linearized as

$$\ln \mathrm{GO} = \ln \mathrm{TL} + \beta \ln L + \alpha \ln \mathrm{NU} + \phi \ln \mathrm{LE} + \varepsilon. \tag{23}$$

Complexity, autocorrelation, and variability are the defining features of the spatiotemporal development of

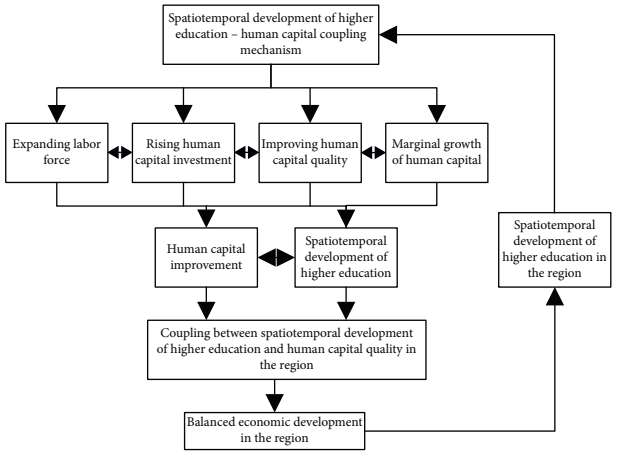

Figure 5: Principle of how human capital coupling mechanism affects regional economic growth.

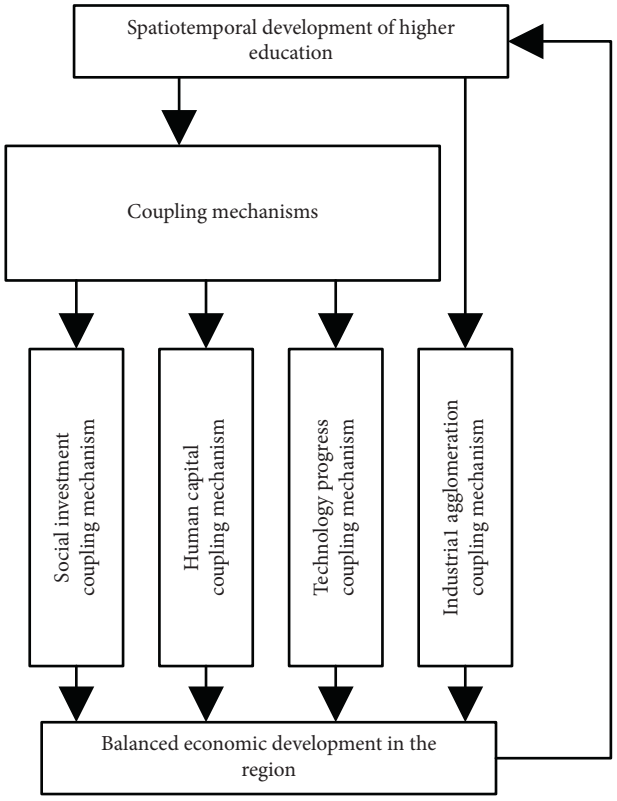

Figure 6: Principle of how the four mechanisms affect regional economic growth.

higher education. It is highly probable for different regions to differ in the balanced development of economy. The previous sections confirm that the spatiotemporal development of higher education positively affects regional economic growth via the four coupling mechanisms. Here, the geographic weighted regression model is selected to perform spatial linear regression of the correlations between the spatiotemporal difference and input of higher education and regional economic growth. Let b_i be the i-th observation; (o_i, p_i) be the coordinates of the i-th coupling mechanism; σ_0 be the regression constant; τ_j be the value of the j-th regression parameter; and σ_i be a random error. Then, we have

$$\mathrm{GO}_i = \sigma_0(o_i, p_i) + \sum_{j=1}^{11} \tau_l(o_i, p_i) A_{ij} + \sigma_i. \tag{24}$$

Let ρ_0 be the regional technology level in the current year. Then, $\rho_0 \cdot e^{h_C t}$ can characterize the degree of technology progress in the region. Then, the regional economic output GO can be expressed as

$$\mathrm{GO} = \rho_0 \cdot e^{h_C t} \cdot L^{\beta} \cdot \mathrm{NU}^{\alpha}. \tag{25}$$

Let h_L be the growth rate of regional fixed asset investment. Then, the production function driven by the scientific output of higher education can be linearized as

$$h_C = h_L - \beta \cdot h_A - \alpha \cdot t. \tag{26}$$

Let S_{hC} be the contribution rate of regional technology progress. Then, the total contribution of technology progress can be calculated by

$$S_{h_C} = \frac{h_C}{h_L} \times 100\%. \tag{27}$$

The correlation coefficient v between the capacity index TU of technology update of higher education and the total change of regional economy ΔGO can be calculated by

$$v = \frac{\sum_{i=1}^{M} \left(\mathrm{TU}_i - \overline{\mathrm{TU}}\right)\left(\Delta\mathrm{GO}_i - \overline{\Delta\mathrm{GO}}\right)}{\sqrt{\sum_{i=1}^{M} \left(\mathrm{TU}_i - \overline{\mathrm{TU}}\right)^2 \times \sum_{i=1}^{M} \left(\Delta\mathrm{GO}_i - \overline{\Delta\mathrm{GO}}\right)^2}}. \tag{28}$$

The contribution TUC_i of the technology update of the higher education in the i-th region on regional economic output can be calculated by

$$\mathrm{TUC}_i = S_{h_C} \times v. \tag{29}$$

Assuming that labor force and resident salary are fixed, v and w can be determined through regression:

$$\frac{\ln \mathrm{GO}}{\mathrm{NU}} = v \cdot \ln \rho_0 + w \cdot \frac{\ln L}{\mathrm{NU}}. \tag{30}$$

5. Experiments and Result Analysis

The data of the core indices were collected from the samples of higher education and economic development in 15 prefectures from 2000 to 2020. The mean entropy method and multiple comparisons were combined to evaluate the spatiotemporal difference in annual development of higher education in each region. Figure 7 shows the spatiotemporal evolution trends of spatiotemporal difference of higher education, input of higher education, and regional economic growth. From 2000 to 2020, the spatiotemporal difference of higher education development slowly declined in the study areas, but the development index remained above 1. This means that the unbalanced distribution of higher education development in the study areas has been significantly improved, but the difference in spatiotemporal development

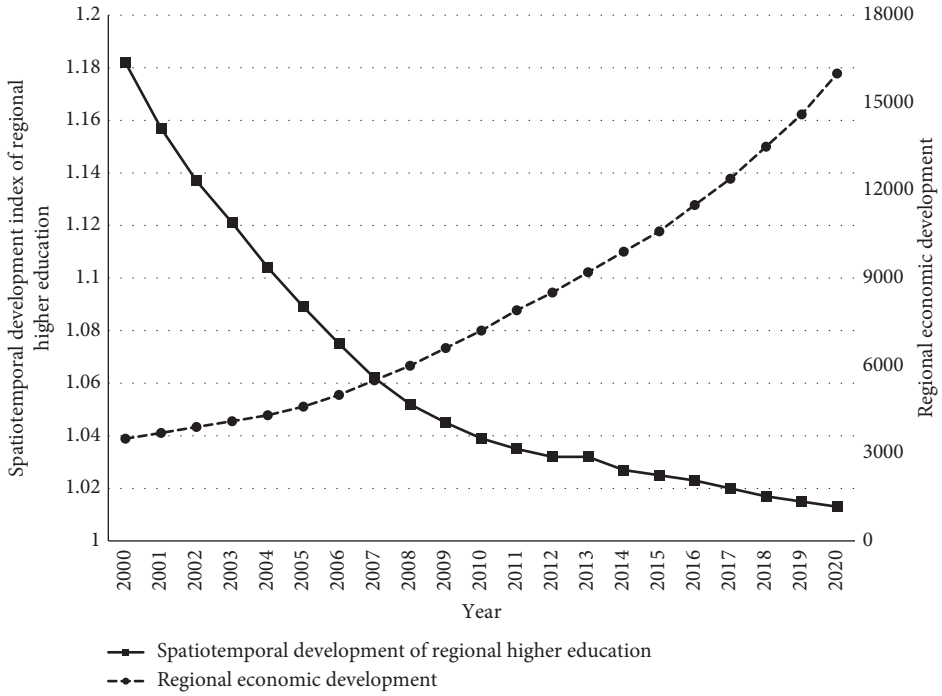

Figure 7: Spatiotemporal evolution trends of spatiotemporal difference of higher education, input of higher education, and regional economic growth.

remains significant. The main reasons are the overall development level of higher education in China and the insufficient fairness of government policies. With the elapse of time, regional economic growth exhibited a steady upward trend, which is opposite to the trend of spatiotemporal difference of higher education.

Table 1 presents the Gini coefficients of spatiotemporal development of regional higher education. Combining the data in Table 1 with actual satellite maps of higher education distribution, it can be seen that the distribution of Gini coefficients became less dispersed. First and second tier cities saw a weaker dispersion of the spatiotemporal development of higher education than the central, western, and northeastern regions. From 2000 to 2020, the spatiotemporal development of higher education in all the prefectures changed towards dispersed distribution.

Table 2 provides the composite scores of regional spatiotemporal development of higher education obtained by weighted sum calculation. Judging by the mean values, first and second tier cities had much higher composite scores than the other prefectures, thanks to their good education quality and strong technical innovation ability. With the passage of time, the prefectures supported by the government assistance plan for the central and western regions witnessed a steady rise in their composite scores. Meanwhile, the higher education quality in some prefectures declined with oscillations.

Table 3 presents the variation coefficients of regional spatiotemporal development of higher education in 2000, 2005, 2010, and 2020. The standard deviation of spatiotemporal development of higher education fell in [0.23, 0.26], and the variation coefficients oscillated about 1. This further confirms the significant regional difference in spatiotemporal development of higher education.

Table 4 presents the regression results on the influence of spatiotemporal development of higher education on regional economy. The marginal effect of spatiotemporal development of higher education on regional economy mainly depends on the collaboration between the influencing factors in the four coupling mechanisms. Without considering geographical location of regions, spatiotemporal development of higher education makes more per unit marginal contribution to regional economic development, if the labor input increases, government support enhances, technology progresses, social investment rises, urbanization picks up speed, and industrialization declines. If geographical location is considered, the direct growth effect and marginal effect per unit spatiotemporal development of higher education will increase on regional economy.

To accurately disclose the global spatial autocorrelation of spatiotemporal development of higher education and balanced development of regional economy, this paper selects Moran's I scatterplot, a tool for spatiotemporal autocorrelation analysis, to further describe the regional spatial distribution features of spatiotemporal development of higher education and balanced development of regional economy. Figures 8 and 9 show local Moran's I scatterplots of spatiotemporal development of higher education and balanced development of regional economy, respectively. The prefectures are mainly concentrated in the first quadrant (high-high), second quadrant (low-high), and third quadrant (low-low). Only a few fell in the fourth quadrant (high-low). It can be inferred that in eastern region, the cities with a

Table 1: Gini coefficients of spatiotemporal development of regional higher education.

Prefectures	2000	2005	2010	2020	Mean	Variation
*A*1	0.72	0.66	0.64	0.63	0.70	−0.02
*A*2	0.73	0.63	0.73	0.62	0.71	−0.03
*A*3	0.74	0.74	0.75	0.70	0.74	−0.04
*A*4	0.71	0.72	0.63	0.61	0.70	−0.02
*A*5	0.63	0.65	0.72	0.60	0.68	−0.12
*A*6	0.73	0.63	0.68	0.60	0.67	−0.13
*A*7	0.76	0.71	0.69	0.60	0.71	−0.05
*A*8	0.76	0.70	0.71	0.61	0.70	−0.03
*A*9	0.55	0.72	0.62	0.59	0.65	0.03
*A*10	0.62	0.67	0.65	0.61	0.64	−0.11
*A*11	0.67	0.65	0.67	0.61	0.65	−0.07
*A*12	0.62	0.63	0.64	0.60	0.64	−0.06
*A*13	0.63	0.61	0.63	0.60	0.63	−0.05
*A*14	0.61	0.56	0.61	0.60	0.62	0.02
*A*15	0.65	0.53	0.65	0.55	0.64	−0.12

Table 2: Composite scores of regional spatiotemporal development of higher education.

Prefectures	2000	2005	2010	2020	Mean	Variation
*A*1	0.872	0.953	1.006	0.861	0.923	0.125
*A*2	0.672	0.552	0.607	0.982	0.703	−0.085
*A*3	0.521	0.36	0.513	0.633	0.506	−0.023
*A*4	0.269	0.251	0.359	0.541	0.355	0.115
*A*5	0.276	0.324	0.362	0.392	0.338	0.037
*A*6	0.275	0.265	0.265	0.286	0.273	0.056
*A*7	0.203	0.257	0.251	0.262	0.243	0.121
*A*8	0.135	0.223	0.234	0.251	0.211	0.072
*A*9	0.149	0.194	0.237	0.213	0.198	0.083
*A*10	0.162	0.156	0.232	0.125	0.168	−0.035
*A*11	0.274	0.033	0.175	0.172	0.163	0.041
*A*12	0.058	0.047	0.092	0.061	0.064	−0.017
*A*13	0.073	0.059	0.075	0.039	0.061	0.006
*A*14	0.031	0.031	0.062	0.037	0.040	0.002
*A*15	0.082	0.025	0.035	0.025	0.418	−0.015

Table 3: Variation coefficients of regional spatiotemporal development of higher education.

	2000	2005	2010	2020	Mean
Standard deviation	0.2372	0.2566	0.2637	0.2519	0.2523
Variation coefficient	1.0963	1.0352	0.9837	1.0632	1.0446

high level of spatiotemporal development of higher education or a high level of economic development are often surrounded by similar cities, and the cities with a low level of spatiotemporal development of higher education or a low level of economic development are often surrounded by similar cities. Further comparison shows that the distribution of prefectures across the quadrants changed with the time, but the change trend remained stable: the high-high prefectures improved their development capacity, while the low-low prefectures weakened their development capacity. The observation further verifies the reasonability of the proposed equilibrium development model.

Table 4: Influence of spatiotemporal development of higher education on regional economy.

Variables	Nonspace-fixed effects model	Our model		
		Direct growth effect	Marginal effect	Total effect
Log of spatiotemporal development of higher education	−0.062 (0.025)	0.081 (0.026)	−0.015 (0.057)	0.075 (0.063)
Log of technology progress	−0.043 (0.012)	0.016 (0.009)	−0.023 (0.035)	−0.007 (0.024)
Log of social investment	0.471 (0.015)	0.081 (0.022)	−0.003 (0.042)	0.062 (0.057)
Log of human capital	0.506 (0.115)	0.357 (0.087)	0.089 (0.163)	0.423 (0.184)
Log of labor input	−0.172 (0.037)	−0.135 (0.035)	−0.112 (0.092)	−0.273 (0.088)
Urbanization level	0.009 (0.001)	0.005 (0.002)	−0.012 (0.003)	−0.08 (0.005)
Industrialization level	0.017 (0.003)	0.015 (0.005)	−0.011 (0.002)	0.003 (0.003)
Level of economic openness	0.039 (0.025)	0.025 (0.026)	0.037 (0.061)	0.415 (0.075)
Level of government support	0.172 (0.051)	−0.105 (0.053)	−0.177 (0.092)	0.289 (0.075)

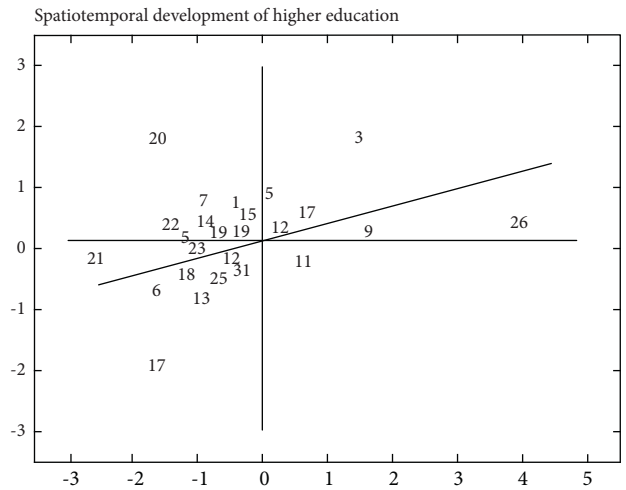

Figure 8: Local Moran's I scatterplot of spatiotemporal development of higher education.

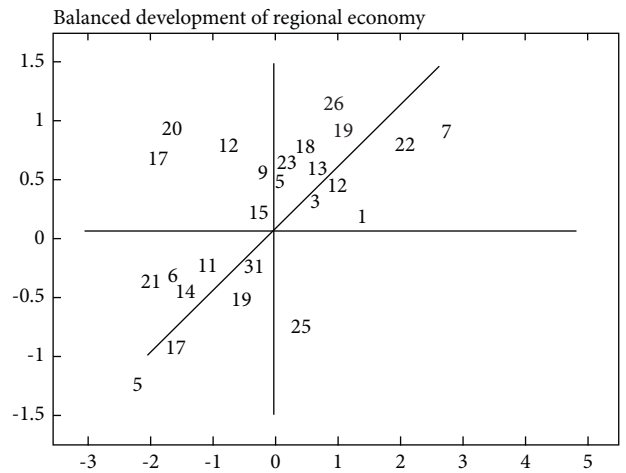

Figure 9: Local Moran's I scatterplot of balanced development of regional economy.

6. Conclusions

This paper explores how the spatiotemporal difference and input of higher education affects regional economy. The influence was divided into four coupling mechanisms: social investment, human capital, technology progress, and industrial agglomeration. Then, the spatiotemporal difference of higher education was analyzed by the Gini coefficient, spatiotemporal pattern, and comprehensive evaluation of spatiotemporal development quality. Finally, an equilibrium development model was constructed for regional economy under the four coupling mechanisms, and the law of evolution to equilibrium was analyzed. Through experiments, the Gini coefficients and composite scores of spatiotemporal development were obtained for the study areas, which confirm the obvious difference between prefectures in spatiotemporal development of higher education. Further, the influence of spatiotemporal development of higher education on regional economy was regressed and prepared into local Moran's I scatter plots. The results verify the reasonability and effectiveness of our model.

Taking prefectures as the basic units and focusing on city clusters in China, this paper attempts to analyze the spatiotemporal features of higher education, discloses the spatiotemporal differentiation of higher education in China from the angle of city clusters, and provides evidence to the regional economic effect of higher education in city clusters. Finally, several countermeasures were provided to optimize the spatial distribution of education and enhance the regional economic effect of higher education under the landscape of city clusters in China.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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