Research Article

Studying the Coupling and Coordination of Regional Economic and University Development Levels Based on a Deep Learning Model

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Universities are not only an important foundation of China’s education but also have an important role in promoting the development of the local economy. The interaction between local universities and regional economic development is very significant, and the two promote each other and develop symbiotically. This paper designs a coupled coordination model based on autoencoder (AE) for the development level of regional economy and higher education institutions, and this paper analyses the mutual needs between local universities and regional economy in terms of talent demand, technology research, and material base puts forward the potential advantages of symbiosis, points out the weaknesses and shortcomings in the current symbiotic development, provides a basis for the symbiotic development of the two, and provokes thoughts to promote the symbiosis and win-win situation between the two.

1. Introduction

Local universities and higher education institutions directly under the Ministry of Education are both educational institutions that train talents for the society and also have the responsibilities of conducting scientific research, providing social services and realising cultural heritage and innovation, which are essentially providing services for the society [1]. In addition to providing social services to the local community, local universities also contribute to the development of the regional economy. The development of the regional economy also provides a broader development space for the further expansion of local universities [2]. At present, there are still problems of missing mechanism in the process of good interaction development between many local colleges and universities and regional economic development. In this current situation, it is significant to discuss how local universities can seek the key point for the symbiotic development of the two based on the actual local conditions [3]. Local universities refer to general higher education institutions that are affiliated to provinces, autonomous regions, municipalities directly under the central government, and special zones in Hong Kong and Macao and are mainly supported by local finances and allocated funds by local administrative departments [4, 5]. In this management system, the main body of local universities’ operation and investment is mainly the local government departments. The meaning of regional economy is actually a geographical concept, which refers to the comprehensive economic development of the region [6]. Symbiosis theory mainly refers to the existence of different kinds of things that live together due to the existence of some kind of real-life connection. Symbiosis theory began as a biological theory, but when viewed from the perspective of the social sciences, the concept of symbiosis theory becomes a social form in which different types of material objects cooperate amicably with each other and thus achieve a mutually beneficial development [7]. Local universities and regional economy form
an interdependent and cogrowing relationship due to their natural geographical location [8].

Talent is always the most dynamic and valuable element in economic development. For the regional economy to achieve further development, it must have a stable source of supply of comprehensive and high-quality talents [9]. Although there are many sources of talent, they are mainly local universities. In addition to the advantages of geographical location, local universities have the advantage of talent training that is targeted to meet the actual needs of local talent [10]. At the same time, in order to achieve economic transformation and promote the upgrading and adjustment of industrial structure, the demand for comprehensive talents with excellent vocational skills is constantly increasing [11].

One of the key points of the role of local universities in promoting regional economic construction is that they can provide technical support for local industrial restructuring and enterprise project development [12]. Enterprises provide a platform to support the transformation of knowledge achievements of universities, and universities provide a technical basis for the development of enterprises. This is also a key node for local universities to establish ties with local enterprises [13]. Universities differ according to their actual situation, with undergraduate institutions focusing on technical support and higher education institutions focusing on service support. Cases abound where universities at home and abroad have established close cooperation with local enterprises to effectively promote progress in research, achieve technological innovation, and contribute to regional economic development, such as the Industrial Liaison Office at Cambridge University [14]. On the one hand, these institutions find markets for the research achievements of university teachers and researchers; on the other hand, they introduce the topics and business dynamics of enterprises to university teachers and researchers, playing the role of “matchmaking.” At present, many higher vocational institutions in China, such as Changzhou Information Vocational Technology College, have built a key laboratory for intelligent technology of high-end manufacturing equipment on campus [15].

2. Analysis of Universities for Regional Economic Development

Local universities are not only a source of talent as well as a technical basis for regional economic construction but they are also able to provide industrial creation for local economic construction. By combining new technologies with practical social practice capabilities with practical conditions, universities can serve as technical support for new high-tech enterprises and promote the development of local high-tech industries, thus promoting industrial restructuring and driving regional economic growth. By establishing cooperation with local enterprises, local universities realise the organic combination of production, learning, and research, while the government provides support and a platform for independent innovation and employment for students [16]. By establishing science and technology parks, the government has involved local universities and local enterprises in the research and development of various new technologies and the transformation of their achievements, forming a complete chain of cooperation among industry, university, and research, promoting the development of high-tech industries and facilitating the process of industrial upgrading and restructuring.

For local universities to gain further development, they need not only sufficient financial support but also the support of various social resources. Among them, the support from the local government is very important. The key to local government investment is whether it can play a role in promoting local economic development [17].

A solid material foundation is the key to the sustainable development of universities, while another basis for the development of local universities is to meet the changing needs of regional economic development. Both of these are external manifestations of local economic development. It is important to constantly bring into play the advantages of policies to meet the financial support needed for the development of universities and to improve their research strength [18].

Due to the vast territory, the level of economic development and the industrial structure of different regions of the country vary greatly, and the focus of economic development varies greatly at different times in the same region, which makes the level of demand for talents as well as the type and quantity of talents different [19]. At the same time, the country is currently in a critical period of industrial restructuring, and local universities are therefore adjusting their development strategies to serve society. With the upgrading and optimisation of the regional industrial structure, the direction of talent training in local universities will also be adjusted, and the main body will match the regional talent structure adjustment. For example, during the current rapid development of e-commerce, especially during the epidemic, community e-commerce, live-streaming with goods and other e-commerce models provide business opportunities for local economic development, and the demand for related e-commerce talents has suddenly increased [20].

3. A Model of Regional Economic Growth and University Coupling

3.1. Coupled Coordination Models. With the help of physical capacity coupling based on the orderly combination degree of the two subsystems, so as to obtain the coupling model as $C_n = (u_1, u_2, \ldots, u_m)$ $\prod (u_i + u_j)/n$, where the coupling degree value $C \in [0, 1]$. Thirdly, according to the specific coupling situation, we can judge that when $C = 0$, the coupling degree between regional economy and university factors is extremely small, and economic growth and universities are in a state of mutual incoherence. When $C \in (0, 0.3]$, the regional economy is in a state of low uneven coupling with universities. When $C \in (0.3, 0.5]$, the coupling is in the collapsing phase.
3.2. Coupled Simulation Index Analysis. The analysis of the cubic function model and coupling indices of university indicators and economic indicators in each province of China can determine that the three current indicators of industrial emissions of waste water, industrial solid waste, and industrial emissions of exhaust gases in China are generally on a decreasing trend. Firstly, the coupling index of typical university indicators is relatively good, in which the overall decrease of industrial waste water emissions can be explained by the increasing emphasis on environmental protection in the growth of GDP per capita in China, and it is also related to the increasingly strict requirements of environmental protection laws in China. Secondly, emissions are still a serious problem in China, with vehicle emissions and industrial production emissions remaining high in recent years, and the coupling between this indicator and universities is extremely low. Thirdly, the problem of seasonal universities is still very prominent, and the problem of pollution in our winter climate universities is serious, which also has a very general relationship with economic development.

4. Denoising Automatic Coder

4.1. AE. AE is a three-layer unsupervised neural network [12], which is divided into two parts: the encoding network and the decoding network, as shown in Figure 1.

Given an unlabeled sample set \( \{x^m\}_{m=1}^M \) of mechanical health conditions, the coding network transforms each training sample \( x^m \) into a coding vector \( h^m \) by means of a coding function \( f_\theta \):

\[
h^m = f_\theta(\mathbf{x}^m) = s_f(Wx^m + b). \tag{1}
\]

Then, the encoding vector \( h^m \) is inversely transformed into a reconstructed representation \( \mathbf{x}'^m \) of \( x^m \) by the decoding function \( g_\theta \), such as (2) and (3).

\[
\mathbf{x}'^m = g_{\theta_1}(h^m) = s_g(Wh^m + d), \tag{2}
\]

\[
L(x, \mathbf{x}) = \frac{1}{M} \sum_{m=1}^{M} \| x - \mathbf{x} \|^2. \tag{3}
\]

The variation in working conditions due to complex tasks lead to fluctuations in the properties of the samples under the same health conditions, so the autoencoder needs to be given certain constraints so that it learns a robust feature representation. The DAE solves this problem by reconstructing sample data containing noise to solve this problem [13].

Firstly, random noise is added to the sample \( x^m \) according to \( q_D \) the distribution [14] to make it a noisy sample \( x'_m \), such as

\[
x'_m \sim q_D(x'_m | x^m). \tag{4}
\]

where \( q_D \) is the binomial random hidden noise.

The DAE is then trained by optimising the following objective function such as

\[
\arg\min_{\theta, \theta_1} L(x^m, g_\theta(f_\theta(x'_m))). \tag{5}
\]

4.2. Pretraining and Fine-Tuning of Deep Neural Networks. The core of the deep neural networks, hereinafter referred to as (DNN) pretraining algorithm is the unsupervised stacking of multiple DAE layers to form a DNN hidden layer structure, as shown in Figure 2 [14–16]. Firstly, sample \( x^m \) is used to train DAE1, and \( x'^m \) is encoded as (6) and (7).

\[
h^m = f_{\theta_1}(x^m), \tag{6}
\]

\[
h_N = f_{\theta_N}(h_{N-1}). \tag{7}
\]

Pretraining connects multiple DAEs to each other to form a DNN hidden layer structure to achieve layer-by-layer extraction of fault information [17]. After pretraining, the output layer with classification function is added in order to monitor the economic health of the diagnosed area, and the DNN parameters are fine-tuned using the BP algorithm. The output of the DNN is represented as

\[
y^m = f_{\theta_{N+1}}(h^m_N), \tag{8}
\]

where \( \theta_{N+1} \) is the parameter of the output layer. The health condition type of \( x^m \) is set to \( d^m \) and the DNN fine-tunes by minimising \( \phi_{\text{DNN}}(\Theta) \) such as

\[
\phi_{\text{DNN}}(\Theta) = \frac{1}{M} \sum_{m} L(y^m, d^m), \tag{9}
\]

where \( \Theta \) is the set of parameters of the DNN and \( \Theta = \{\theta_1, \theta_2, L, \theta_{N+1}\} \).

The fine-tuned DNN optimises the representation of regional economic health information and provides the ability to monitor and diagnose regional economic health conditions.
4.3. Regional Economic and University Coupling Analysis. Universities are harsh and volatile, so the vast amount of data collected by their monitoring systems contain a wealth of variable fault information about the various components of the regional economy. Traditional intelligent diagnostic methods rely on signal processing and diagnostic experience to extract features from the regional economy signals and use machine learning models for intelligent diagnosis. However, signal processing-based feature extraction methods tend to extract features with a deep understanding of the signal characteristics and are “inadequate” to extract typical features reflecting the health of the regional economy in the face of the massive signals of the regional economy with alternating working conditions, heavily coupled fault information, and unknown and variable patterns. In addition, traditional methods use shallow models to identify regional economic health conditions, resulting in poor monitoring and diagnostic capabilities and generalisation performance [18–20].

This paper combines the characteristics of regional economic big data with the advantages of deep learning and proposes a deep learning-based method for monitoring the health of regional economies. The method achieves the organic combination of unsupervised learning and supervised learning and can simultaneously complete the adaptive extraction of big data fault features and the identification of regional economic health, overcoming the shortcomings of traditional methods in feature extraction and fault identification. The method flow is shown in Figure 3, and the steps can be summarized as follows.

Firstly, the frequency domain signal of the regional economy, i.e., the spectrum, is obtained and the spectrum is used as the training sample; secondly, the number of hidden layers of the DNN, N, is determined and N DAEs are trained layer by layer in an unsupervised manner, i.e., the output of each DAE is used as the input of the next DAE until the training of N DAEs is completed; then, the output layer is added and the DNN parameters are fine-tuned according to the type of health condition of the sample to complete the training of the DNN; finally, the DNN is used to monitor and diagnose the health condition of the regional economy [21–23].

5. Empirical Analysis

5.1. Coupling. The coupling degree of coordinated development of regional economy and universities is in the fly down stage in all provinces, except Jiangsu, Guangdong, Shandong, and Zhejiang, which are in the grinding stage, and the level of coupling is relatively low, which fully indicates that there is still much room for improvement in terms of improving universities in each province. As shown in Figure 4, the coupling degree of each region shows obvious regional differences. Provinces with low coupling degree account for about 55% of the total number of coupling types in the country. Coupling coordination is also uneven in spatial distribution, usually the regional economy in the more economically developed areas in the south has a higher coupling degree with colleges and universities, while the coupling degree between the economy and colleges and universities in relatively economically backward areas is lower [24–26]. Thirdly, provinces with faster economic growth are more sensitive to the influence of colleges and universities, and some provinces, though with faster economic development, also have more serious problems for colleges and universities, even beyond the carrying capacity of natural colleges and universities, and ecological colleges and universities are not yet able to complete full absorption of the problems brought about by the influence of colleges and universities due to economic growth.

5.2. Spatial Pattern Characterisation. There is also a significant correlation between the regional economic development and the coupling degree of universities in the spatial pattern; as shown in Figure 5, each year the regional
coordination is higher compared to the national inland cities, but there is no significant advantageous gathering area, especially the coordination of economy and universities in the central and western regions is the main direction of future research [7]. The state has taken systematic supportive measures to break the unbalanced pattern in the central and western regions, thus the relationship between regional economic indicators and universities is showing a steady increase year by year. In response to the above problems, a coordinated development protection strategy of economy and universities should be adopted to continuously enhance the friction between universities and economy so that the two can develop in a coordinated and sustainable direction and achieve the goal of friendly development of economy and universities.

6. Conclusions

For local universities, only by fully establishing a symbiotic relationship with the regional economy and insisting on mutual benefit and win-win situation can we achieve further development of both. As a talent training base, local universities should strengthen exchanges and cooperation with local enterprises and institutions, deepen the basis of
cooperation, and realise resource sharing. At the same time, the local government should also strengthen the financial and policy support of resources to enhance the awareness of local universities in serving the regional economy, so as to truly achieve sustainable symbiotic development. In the process of development, universities attach too much importance to the circle of land, people, and professions and do not know enough about their social service function and the importance of win-win cooperation with regional economic development. In the process of running the university, the traditional teaching mode is still the main one, and the large and comprehensive construction of disciplines is pursued excessively. The scientific research of many disciplines is detached from the reality, and awards are the focus, ignoring the social foundation, and all scientific research work premised on various fame and profit demands or materialistic demands is lacking in connotation, and discipline construction should be carried out on the premise of serving society, and scientific research innovation should be promoted on the basis of serving local construction.

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

Conflicts of Interest
The authors declare that they have no conflicts of interest regarding this work.

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