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Does Industrial Diversification Increase the Resilience of Economic Growth?

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Abstract: With the rapid development of the global economy and the increasingly complex internal and external environment, economic resilience plays a crucial role in the stable development of the region. Using the panel data of 273 prefecture-level cities in my country from 2003 to 2019 as samples, and by constructing an empirical model of the relationship between industrial diversification, related diversification, irrelevant diversification and economic resilience, the study found that the relationship between industrial diversification and economic resilience was showing a significant inverted U relationship, a lower level of industrial diversification improves the resilience of economic growth, but a higher level of diversification inhibits the enhancement of economic resilience. In the further threshold effect test, it is found that there is a double threshold effect on the level of economic development between industrial diversification and irrelevant diversification and economic resilience. The policy implication of the conclusions of this paper is that the government should make the optimal choice between industrial diversity, economic efficiency and growth stability to enhance the regional economic resilience.

Keywords: Industrial diversification, Economic resilience, Threshold effect.

1. Introduction

The subprime mortgage crisis in the United States broke out in 2007 and spread to other countries around the world, triggering a global financial crisis. As a result of the global recession, China's GDP growth rate dropped from 14.23% in 2007 to 9.4% in 2009, while the registered urban unemployment rate reached 4.3% in 2009, which had a great negative impact on China's economic stability and social development. The global spread of COVID-19, which began in late 2019, has also greatly affected economic growth and brought about many structural problems. As the world's second largest economy, China is also facing short-term production and school suspensions, supply chain disruptions, small business closures, underemployment and unemployment [1-2]. At this time, the stability or resilience of an economy in the face of sudden external shocks is very important, and how to improve economic resilience has become a widely concerned issue.

The word "resilience" has been creeping into national policy in recent years. In the chapter on urbanization development in the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of 2035 Vision Goals adopted by the Fourth Session of the 13th National People's Congress in 2021, it is pointed out that in order to comprehensively improve the quality of cities, it is necessary to develop industries and build resilient cities within the affordable range of natural and physical resources. It can be seen from the policy that although the epidemic has affected the stable operation of China's economy and society to some extent, "resilience" is the necessary support force to maintain the orderly development and growth of China's economy. Since the outbreak of COVID-19, China's major cities have been able to turn the crisis around again and again, resume production and schools, ensure people's livelihood and stabilize economic development, thanks to their economic resilience. In this paper, from the perspective of how to enhance the economic resilience of each city, thinking in different levels of economic development, and put forward more targeted development ideas and suggestions.

Economic resilience can be understood as the "safety belt" and "buffer belt" of regional development. In the face of sudden external shocks, strong economic resilience can alleviate the impact, resist the uncertainty of the growth environment, and enable the economy to recover quickly from the trough and reach a new economic steady state. This paper attempts to discuss economic resilience from the perspective of industrial diversity. Generally speaking, diversity is a necessary prerequisite for stability, but diversity also comes at the cost of structural redundancy and system inefficiency, so decision-makers should make the optimal choice between diversity, efficiency and stability.

2. Literature Review

As for whether a diversified industrial structure helps to enhance regional economic resilience, the results of relevant studies at home and abroad are different due to the differences in the samples selected and the samples themselves.

First of all, the role of industrial diversification in diversifying risks in the face of regional shocks is generally recognized. At present, domestic and foreign studies generally show that the crisis will only impact some industries in the region, and with the coordination and help of other unaffected industries in diversified industrial clusters, the region will be able to get out of danger and recover as soon as possible, which reflects the good economic resilience of the region[3-4] . Based on the relevant theories of economic geography, Xu and Deng (2020) [5]analyzed the direct effect of industrial diversification on economic resilience. Therefore, as an important factor affecting economic resilience, industrial diversification provides an important reference direction for the government to formulate industrial structure planning and adjust regional industrial structure[6]. Zhang and Yang (2016)[7] used the data of 30 provinces in China from 2000 to 2014 to study the relationship between industrial diversification and regional economic development. The need to provide them with multiple types of labor, capital, and production environments can create too much pressure to ensure high-quality production efficiency, which can inhibit the development of economic resilience.

Secondly, after the industrial diversification is divided into related diversification and irrelevant diversification, their action mechanisms are also different, but their role as "economic stabilizers" is still prominent. Sun and Chai (2012)[8] analyzed the data of prefecture-level cities from 2003 to 2009 and concluded that with the occurrence of external shocks, related diversification deepened the connection of related industries and increased the probability of direct and indirect shocks to the industrial chain, which would gradually reduce the stabilizing effect of related diversification on the economy from positive to negative. That is, the whole presents the characteristics of inverted U shape. Taking the 2008 economic crisis as the research background and using the data of 264 prefecture-level cities in China from 2004 to 2018, this paper studies the relationship between industrial diversity, unrelated diversification and economic resilience, and the results show that there is an inverted U-shaped relationship[9].

In recent years, due to the impact of COVID-19, changes in the world market, international political instability and a series of factors, how to maintain rapid and high-quality development of China's economy in the midst of turbulence and impact has become a key issue. However, few studies have clearly studied the relationship between industrial diversification and economic resilience based on economic development. And find the industrial diversification level corresponding to the optimal economic resilience of hundreds of cities with different levels of economic development in China.

Through the analysis of the relevant literature on industrial diversification and economic resilience, it can be seen that the current research on economic resilience is still in its infancy, the theoretical system is not perfect, and the conclusions obtained with different influencing factors are different. However, relevant research provides a variety of directions for explaining regional economic resilience. It makes a beneficial exploration for the follow-up in-depth research in this field. Based on the theoretical and empirical research of domestic and foreign scholars, this paper uses the panel data of 273 prefecture-level cities in China from 2003 to 2019 to study the relationship between industrial diversification and economic resilience from the perspective of improving economic resilience, and takes the economic development level as the threshold variable to analyze the relationship between industrial diversification and economic resilience of cities of different sizes.

3. Concept Definition and Theoretical Mechanism Analysis

Industrial diversification mainly refers to the industrial structure in which there are various types of enterprises in a certain region. Frenken subdivides industry diversification into related and unrelated diversification. Related diversification refers to the agglomeration of industries with high economic and technological correlation, substitution and complementarity within a certain range, which is mainly reflected by Jacobs externality: by promoting the effective exchange of knowledge and technology among various types of industries in a region, accelerating the birth of new technologies to improve the innovation ability in a region, and actively breeding emerging economies to cope with external shocks. Unrelated diversification mainly refers to the agglomeration of industries with low or no economic and technological correlation within a certain range, which is more reflected in the portfolio effect.

Resilience first appeared in physics, and then was applied to ecological systems and gradually introduced into spatial economics in economic systems. Based on the research of scholars, Martin explained economic resilience from four perspectives of resistance, recovery, renewal and repositioning, and gave a relatively complete definition of regional economic resilience[10]: Economic resilience is reflected in the ability of a region to resist external shocks, the length of time it is affected by shocks, and the ability to recover its own economy from the shocks, transfer the shocks, reach a stable state and develop a new economy.

Similar to ecological resilience, regional economic resilience emphasizes the ability to stabilize in a diversified and highly heterogeneous economic environment. Therefore, industrial diversification is an important factor affecting economic resilience. Its diversified industrial structure brings diversified investment portfolio, knowledge and technology, demand elasticity, export orientation, labor and capital to the region, which can effectively disperse the impact risk. We will protect the stable development of the market economy and society and give play to its role as a "stabilizer". However, if a region pursues excessive industrial diversification, its impact on regional economic resilience will be different. Reference scholars[9,11] studied the correlation mechanism between diversification and external shocks, and analyzed the performance of regional high industrial diversification in the face of risk shocks. According to the CES utility function, the utility level formula of the region is obtained:

$$U_{n,t}=\left[\sum_{\alpha\in I}\omega(\alpha)^{\frac{1}{\sigma}}q(\alpha)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}(\sigma>1) \quad (1)$$

In Formula (1), $U_{n,t}$ represents the utility level of region n, α represents the industry type; I represents the sum of all industry types owned by region n; $\omega(\alpha)$ represents the impact parameter of external crisis; $q(\alpha)$ represents the proportion of α industry in the market of region n; σ is the elasticity of industrial substitution, which is greater than 1.

Next, we will consider economic activity and exposure to external shocks between specific regions. Assuming that in year t, the transaction volume between industry j in region c and region n is $x_{c,j,n,t}$, and the marginal cost of industry in region c is $1/k_{c,t}$, the formula of the total trade volume between the two regions can be expressed as:

$$x_{c,j,n,t}=\frac{\omega_{c,j,n,t}Y_{n,t}}{P_{n,t}^{1-\sigma}}\left(\frac{\sigma}{(1-\sigma)k_{c,t}}\right)^{1-\sigma} \quad (2)$$

Where, $Y_{n,t}$ is the overall expenditure level of region n in year t, and P is the price index. The specific formula is expressed as equation (3).

$$P_{n,t} = \left(\sum_c \sum_j \omega_{c,j,n,t} p_{c,j,n,t}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{3}$$

When external shocks occur, it is assumed that the impact parameter of the region on the industry expectation is $\omega_{c,j,n,t}$: when a certain industry in the region is impacted, its related industries will be affected one after another, and the transmission of risks through the industrial chain will accelerate the transmission of risks and the enhancement of the effect; From the perspective of information correlation, information spillover will have a significant impact on regional industrial clusters and will have a deeper impact on the production efficiency, production cost and corresponding production decisions of relevant enterprises. In this paper, the expected parameters of the industry when the crisis occurs are expressed as follows:

$$\tilde{\omega}_{c,j,n,t} = \left(\omega_{c,j,n,t_0}\right)^{\alpha} \prod_{i \in \Omega_{c,j,t-1}} \left(\omega_{c,i,n,t-1} \tilde{\omega}_{c,i,n,t}^{j}\right)^{\frac{1}{2}(1-\alpha)\beta_{i,j,t-1}} \left(0 < (1-\alpha)\beta_{i,j,t-1} < \alpha < 1\right) \tag{4}$$

In Formula (4), is the impact parameter of industry j during the previous period of impact, $\Omega_{c,j,t-1}$ represents the industry set related to industry j in region c, $\omega_{c,i,n,t-1}$ represents the parameter value of industry i related to industry j in region c during the impact in year t-1, $\tilde{\omega}_{c,i,n,t}^{j}$ represents the expected impact parameter value of industry i related to industry j in region c during the impact in year t. $\beta_{i,j,t-1}$ is the influence degree coefficient of related industry i on industry j in t-1, which is proportional to the correlation degree of the two industries and is a constant term. According to formula (4), industry j in region c will dynamic reasonable expected impact parameters of industry of terrain cost according to the trade situation of industry i associated with it in t-1 year and parameters before and after the impact.

According to Equation (4), the direct effect of the impact parameter of relevant industry i in year t−1 on the parameters of industry j in year t is (DE) :

$$DE = \frac{\partial \ln \tilde{\omega}_{c,k,n,t}^{j}}{\partial \ln \omega_{c,i,n,t-1}} = \frac{1}{2}(1-\alpha)\beta_{i,k,t-1}, k \in \Omega_i \tag{5}$$

The indirect effect is (IE) :

$$IE = \sum_{k \in \Omega_j \cap \Omega_i} \frac{\partial \ln \tilde{\omega}_{c,j,n,t}}{\partial \ln \tilde{\omega}_{c,k,n,t}^{j}} \frac{\partial \ln \tilde{\omega}_{c,k,n,t}^{j}}{\partial \ln \tilde{\omega}_{c,i,n,t-1}} = \frac{1}{4}(1-\alpha)^2 \sum_{k \in \Omega_j \cap \Omega_i} \beta_{i,k,t-1}\beta_{k,j,t-1} \tag{6}$$

The formula of total elasticity (TE) can be obtained from formula (5) and (6) as follows:

$$\begin{aligned} TE &= \frac{\partial \ln \tilde{\omega}_{\text{c,j,n,t}}}{\partial \ln \omega_{\text{c,i,n,t-1}}} \\ &= \frac{1}{2}(1-\alpha)\beta_{i,k,t-1}, k \in \Omega_i + \frac{1}{4}(1-\alpha)^2 \sum_{k \in \Omega_j \cap \Omega_i} \beta_{i,k,t-1}\beta_{k,j,t-1} \\ &= DE + IE \end{aligned} \tag{7}$$

Then, the parameter change rate of industry j in region c when it is expected to be affected by external shocks can be expressed as:

$$\Delta \ln \tilde{\omega}_{c,j,n,t} = -\varphi \left[\frac{1}{2}(1-\alpha) \sum_{i \in \Omega} \beta_{i,j,t-1} + \frac{1}{4}(1-\alpha)^2 \sum_{i \in \Omega_j} \sum_{k \in \Omega_j \cap \Omega_i} \beta_{i,k,t-1}\beta_{k,j,t-1} \right] \tag{8}$$

Where, k represents an industry that is simultaneously associated with industry i and industry j, $\beta_{i,k,t-1}$ represents the influence of industry i on industry k, and $\beta_{k,j,t-1}$ represents the influence of industry k on industry j. Both of the two coefficients are positively correlated with the degree of correlation, indicating that when the region is affected by external shocks, the more related industries there are in the industrial cluster, the higher the degree of correlation will be. The greater the direct and indirect effect the region suffers.

From the theoretical analysis of the effect of industrial diversification on economic resilience, it can be seen that there is a nonlinear relationship between the impact of diversified industrial structure on economic resilience. However, when the growth reaches a high level, the high industrial linkage will lead to a positive growth impact effect, which is not conducive to the development of regional economic resilience.

Industrial diversification affects economic resilience in three main ways: First, industrial diversification promotes complementary exchange and learning among enterprises. Because there is no market competition relationship between the industry and complementary industries, a good market environment effectively controls the phenomenon of agglomeration diseconomy, which helps enterprises in the industry to jointly open up new markets. Second, the diversification of industries and products brought by industrial diversification will effectively promote the connection between upstream and downstream enterprises and expand the industrial chain, but at the same time, the excessively complicated types will increase the production costs of diversified labor and resources [12]. Third, the production cycle of different enterprises in diversified industrial clusters is quite different, which helps to solve the employment problem of labor with different demands, and the interactive flow of labor force will match the appropriate type of labor force for specific positions [13] . As the recovery cycle of various industries varies greatly, a high degree of industrial diversification will increase the post-crisis recovery time of the whole industrial chain and affect the production efficiency.

Related diversification affects economic resilience in three main ways: First, regions with a high degree of correlation promote the innovation capacity of enterprises and effectively reduce production costs through the sharing of resources, knowledge and technology among enterprises, and the generation of new technologies will continue to strengthen the economic exchange activities between industries, thus forming a dynamic virtuous cycle [8]. Second, the knowledge spillover effect generated by the interaction between related industries reduces the cost of innovation for enterprises, and proximity facilitates the integration of knowledge and technology for enterprises [14-15]. Third, inter-industry cooperation improves the overall innovation level of the region, thus indirectly elevating the level of economic development. Meanwhile, the labor force will flow fully in the industrial cluster, reducing the cost of seeking labor force and increasing the employment rate. The analysis of the disadvantages of excessive correlation diversification and industrial diversification shows that the higher the degree of correlation between industries, the wider and deeper the range of industries affected by the impact.

Irrelevant diversification mainly affects economic resilience in the following three ways: First, agglomeration of unrelated industries expands the tradable scope of supply and demand markets and reduces the cost of capital, technology, labor and other aspects among enterprises, which is conducive to the formation of diversified market activities. Second, the diversified agglomeration of unrelated industries increases the types of intermediate goods in the product chain, enriches the demand market and deepens the degree of contact between industries. Third, the rapid growth of inter-industry demand for labor with different types, skills and education levels has solved a large number of employment problems, and labor specialization matching job positions will improve the production efficiency of products [8]. The unrelated diversified industrial structure of a region can help disperse the risk of external shocks by increasing the stability of economic development [16-17], however, accompanied by the high supply-demand correlation between industries generated by market transactions, the overall stability of a region's trading market will be greatly affected when it faces internal and external shocks.

To sum up, through micro-level analysis, industrial diversification, related diversification and unrelated diversification all have dual impacts on economic resilience. Therefore, it is necessary to find the optimal degree of industrial diversification to ensure regional economic development while having the optimal ability to resist shocks and cope with crises. And in a relatively short period of time to adjust the magnitude of the impact, develop a new economy and reach a steady state [5].

From the macro level, due to the large differences in regional scale and economic development level, it is very important for cities with different development scales to adjust the appropriate degree of diversification to enhance their economic resilience. According to Williamson's hypothesis, a region in the early stage of economic development has a poor foundation in all aspects (road traffic, communication equipment, resource opening, talent reserve, etc.), and benefits (technology, talent, capital, etc.) brought by diversified agglomeration will effectively improve regional economic growth and industrial efficiency. When the economic development level of the local area gradually increases, the losses brought by the highly diversified industrial agglomeration will be higher than its benefits, and diversified industries will cause regional overcrowding, such as "urban disease" and other negative effects, that is, when the economic scale of the local area is large, the positive relationship between diversification and economic stability will show a marginal decline and gradually turn to negative relationship [18-19]. Therefore, among the effects of diversification and economic resilience, there exists a threshold effect with regional economic development level as the threshold variable. Therefore, based on the above literature review and theoretical analysis, this paper proposes the following research hypotheses:

Hypothesis: The relationship between the level of industrial diversification and economic resilience is non-linear, and a moderate level of industrial diversification is conducive to improving economic resilience.

4. Empirical Research Design

4.1. Model construction

Based on the above theories and research assumptions, this paper examines the relationship between industrial diversification, related diversification and unrelated diversification, and builds the following regression model:

$$res_{i,t} = C + \beta_1 tv_{i,t-1} + \beta_2 tv_{i,t}{}^2 + \beta_3 res_{i,t-1} + \beta_4 X_{i,t} + \varepsilon_{i,t} \quad (9)$$

After dividing industrial diversification into related diversification and unrelated diversification, the benchmark model is as follows:

$$res_{i,t} = C + \beta_1 rv_{i,t-1} + \beta_2 rv_{i,t}{}^2 + \beta_3 res_{i,t-1} + \beta_4 X_{i,t} + \varepsilon_{i,t} \quad (10)$$

$$res_{i,t} = C + \beta_1 uv_{i,t-1} + \beta_2 uv_{i,t}{}^2 + \beta_3 res_{i,t-1} + \beta_4 X_{i,t} + \varepsilon_{i,t} \quad (11)$$

Among them, the explained variable res represents the economic resilience of a region, tv is industrial diversification, rv is industry-related diversification, uv is industry-unrelated diversification, X is other influencing factors affecting economic resilience. It includes the level of economic development (lnpgdp) and its lag term, the level of opening up (lnfdi), the degree of government intervention (lnfisc), scientific and technological innovation (lnrd), industrial upgrading (lnthisec) and the level of education (lnedu). C is the constant term, i is the region, t is time, and ε_{it} is the random error term. Due to the time lag of economic resilience and to reduce the endogeneity problem caused by the possible omission of variables in the model, a one-period lag of the explained variable is introduced into the model.

4.2. Indicator measurement

4.2.1. Measurement of economic resilience

In this paper, the method of measuring economic resilience refers to the common practice of scholars to establish an index index [20], and after obtaining the GDP data of each city and each year, the real GDP growth rate over the years is measured respectively. Since the outbreak of the financial crisis in 2008, the economy of various regions was impacted by the crisis. Therefore, this paper takes the real GDP growth rate of each city in 2008 as the benchmark data to obtain the difference between the real GDP growth rate of each city over the years and the GDP growth rate of the city in 2008, and uses the difference to reflect the resilience of regional economy. The specific calculation formula is as follows:

$$res_{it} = \frac{rate_{it} - \min rate_{it}}{\max rate_{it} - \min rate_{it}} \quad (12)$$

Where, $rate_{it}$ is the difference between the GDP growth rate of each city over the years and 2008, $\min rate_{it}$ is the minimum value of the difference, and $\max rate_{it}$ is the maximum value of the difference.

At the same time, referring to the method of measuring economic resilience proposed by Martin, the economic resilience is measured by comparing the GDP growth rate of each city and its provincial area.

$$res_{it} = \frac{y_{it} - Y_{it}}{\left|Y_{it}\right|} \quad (13)$$

Where y_{it} is the GDP growth rate of each region in year t, and Y_{it} is the GDP growth rate of the province where the region is located in year t. When the value is greater than 0, it indicates that the impact of the shock on the economy of the region is less than the average level of the province where it is located, and the economic resilience is high.

4.2.2. Measurement of industrial diversification

In order to ensure the consistency and accuracy of the measurement of industrial diversification, this paper selects the industrial division standard in the regional statistical yearbook issued by the National Bureau of Statistics of China. Since 2003, China's industrial division standard has been unified, increasing from the original 15 subcategories to 19 subcategories. The specific division is shown in Table 1.

Table 1. Industry category and division of national economy

Industry category	Specific industry
Primary industry	(1) Agriculture, forestry, animal husbandry and fishery
Secondary industry	Mining (2) Manufacturing (3) Electricity, heat, gas and production and supply (4) Construction
Tertiary industry	(1) Wholesale and retail trade (2) Transportation, warehousing and postal services (3) Hotels and restaurants (4) Information transmission, computer services and software (5) Finance (6) Real estate (7) Leasing and business services (8) Scientific research, technical services and geological survey (9) Management of water conservancy, environment and public facilities (10) Residential services, repairs and other services (11) Education (12) Health and social work (13) Culture, education and recreation (14) Public administration, social security and social organization

The first measurement index of industrial diversification, industry-related diversification and industry-unrelated diversification was proposed by Frenken and other scholars. The entropy index was established to represent the degree of industrial diversification. The specific formula is shown as follows:

$$TV = \sum_{i=1}^{N} P_i \ln(1/P_i) \tag{14}$$

Where, TV is the degree of industrial diversification represented by entropy; P_{i} is the employment proportion of each industry; N ranges from 1 to 19; Table is 19 industries owned by each region. The size of entropy is positively correlated with the degree of industrial diversification, and the higher the value, the higher the degree of diversification.

The formula of industrial diversification is decomposed as follows:

$$\begin{aligned} TV &= \sum_{i=1}^{N} P_i \ln(1/P_i) \\ &= \sum_{g=1}^{G} \sum i \in S_g P_i \ln(1/P_i) \\ &= \sum_{g=1}^{G} \left[\sum i \in S_g P_g \frac{P_i}{P_g} \left(\ln \frac{P_g}{P_i} + \ln \frac{1}{P_g} \right) \right] \\ &= \sum_{g=1}^{G} \left(\sum i \in S_g P_g \frac{P_i}{P_g} \ln \frac{P_g}{P_i} \right) + \sum_{g=1}^{G} \sum i \in S_g P_{\mathrm{i}} \ln \frac{1}{P_g} \\ &= RV + UV \end{aligned} \tag{15}$$

It can be derived from the above formula:

$$RV = \sum_{g=1}^{G} \left(\sum i \in S_g P_g \frac{P_i}{P_g} \ln \frac{P_g}{P_i} \right) \tag{16}$$

$$\begin{aligned} UV &= \sum_{g=1}^{G} \sum i \in S_g P_{\mathrm{i}} \ln \frac{1}{P_g} \\ &= TV - RV \end{aligned} \tag{17}$$

Where G is the number of industries divided into categories and N is the number of subdivided industries divided into categories. The sum of the employment proportion of each subsector is the major sector S_{g} (g=1,2... ,G) the proportion of employment $P_g = \sum i \in S_g P_i$. The Jacobs externality is used to measure the degree of diversification within industries with high economic, technological or knowledge correlation for related diversification(RV), and the degree of diversification among industries with low or no correlation for unrelated diversification(UV).

4.2.3. Control variables

After referring to relevant literature on economic resilience and theoretical analysis, the following six common control variables that have a greater impact on economic resilience are added to the model in this paper. The specific description of each variable is as follows:

① Economic development level (lnpgdp), as the basic factor of regional development, affects regional infrastructure construction, financial development degree and social development status, and is an important factor affecting economic resilience. This paper refers to the common practice of scholars, that is, the per capita real GDP is used to measure. In order to reduce the result volatility caused by excessive data value, the GDP per capita is taken as the result. ②Level of openness to the outside world (lnfdi). The higher the degree of opening to the outside world, the closer the connection between the region and the external market, the easier it is to be affected by external economic changes compared with the closed economy, and the higher the ability of the region to absorb the risks brought by external shocks. In this paper, the proportion of foreign direct investment in GDP is expressed. ③The degree of government intervention (lnfisc). As the region faces shocks, governments, as key decision-makers in the region, need to help their industries, companies and other economies weather the crisis. In this paper, the proportion of the government's fiscal expenditure to the regional GDP is expressed. ④As the embodiment of regional innovation ability, scientific and technological innovation (lnrd) can help economies to carry out structural adjustment, structural upgrading and help them enter a new stage of development, and is an important factor affecting regional economic resilience. This article uses the proportion of budget science and technology expenditure to gdp to measure. ⑤Industrial upgrading (lnthisec) is the process of transferring the whole industry to the tertiary industry. As the society enters the information age, the industry needs to be upgraded to the information-based dominant structure with the proportion of traditional industries gradually decreasing. Therefore, this paper uses the proportion of the output value of the tertiary industry in the output value of the secondary industry to measure the degree of industrial structure upgrading. ⑥ Education level (lnedu). Higher education talents are the source driving force for regional development. High-quality talents with higher technology and knowledge can help enterprises carry out innovative and entrepreneurial activities to improve their market competitiveness, and they are a powerful source of resilience for enterprises in the face of shocks. This paper considers using the number of students in colleges and universities per 10,000 people.

4.2.4. Data description

The data in this paper are derived from China Statistical Yearbook, China Regional Statistical Yearbook and China Statistical Yearbook of Science and Technology from 2003 to 2020, as well as Guotai 'an CSMAR database and Development Research Center of The State Council Information Network. In the empirical analysis, DMSP/OLS and VIIRS/DNB image light data from 2003 to 2019 released free of charge by NOAA will be used for robustness test.

For the data of source collation, 273 prefecture-level cities were selected after the abnormal samples such as large regional changes, serious data missing and less years of establishment were deleted. Data with fewer missing values will be replaced by linear interpolation using Stata16.0 software. The processing of night light data is based on the practice of scholars [21]. The mask extraction and projection of China's municipal regional map and night light data map over the years are carried out in Arcgis10.8 software, and the complete light data is finally obtained according to the district-level statistics.

5. Empirical Analysis

5.1. Baseline regression analysis

In order to ensure the rationality of the model setting, the multicollinearity between variables was tested before empirical regression. Firstly, the correlation between variables is tested: the correlation coefficient between variables is all less than 0.6, so it is judged that there is no multicollinearity between variables.In this paper, variance inflation factor VIF analysis was conducted for each variable, and the results showed that the VIF values of all explanatory variables were far less than 10.

In summary, from the correlation analysis and square VIF analysis results of variables, it can be seen that there is no multicollinearity among variables, so the next regression analysis of the data can be carried out.

As for the selection of regression model, firstly, LM test is used to select between the mixed regression model and the random effect model. The test results show that the concomitant probability is 0, so the random effect model is selected because the null hypothesis is rejected. Secondly, the Hausman test is conducted on the selection of the random effect model and the fixed effect model, and the concomitant probability is 0.

The regression results of square terms added in turn are shown in Table 2. From column (1) to (3) in the table, it can be seen that overall diversification, correlated diversification and unrelated diversification have positive promoting effects on economic resilience from 2003 to 2019. Except for the correlation diversification, the rest are significant at the 5% level. For the insignificance of relevant diversification, the possible reason is that in regional industrial groups, when an industry is impacted, it has a high degree of influence on the industrial chain where the industry is located and the positive promoting effect of relevant diversification cannot be reflected. Since diversification pays more attention to the connection between different industries, when an industry is affected, other industries are not susceptible to it. Instead, they will help the enterprise to quickly cope with internal and external shocks through knowledge and technology transfer and exchange. In general, diversification has the effect of "buffer" and "stabilizer" on regional economy, which contributes to the improvement of regional economic resilience.

When the squared terms of the three types of diversification are added, there is an inverted U-shaped relationship between the three types of diversification and regional economic resilience, and all of them are significant at the level of 10% at least. By enhancing the types of regional industries, industrial diversification can meet the daily life and work needs of residents in a region in many aspects and at many levels. Meanwhile, diversified industrial structure helps a region to improve its innovation ability and accelerate economic development [22]. When the degree of industrial diversification exceeds the affordability of a region, Too many types of industries will increase the demand for resources, multiple types of labor, and more capital in a region, which will backfire and weaken regional economic resilience. Related diversification enhances the economic resilience of enterprises, industries and regions by increasing the exchange and learning of knowledge and technology between industries that are closely connected in the unified industrial chain, and generating new technologies and knowledge through mutual and frequent exchanges to help industries achieve higher productivity. When the degree of related diversification is high, the disadvantages of the huge related industrial chain will be highlighted. Unrelated diversification builds a more diversified industrial unit by strengthening the communication of industries with low or no connection, in which enterprises reduce the cost of finding supply and demand enterprises, and also save time cost for the allocation of labor, capital, technology and other resources, which is conducive to promoting the cooperation among different types of enterprises. Similarly, when the development of this industrial unit is too large, the scope of risk spread will be wider when accidents occur, and too high degree of unrelated diversification will also hinder the resilient growth of regional economy.

Table 2. Regression results among variables

	(1)	(2)	(3)	(4)	(5)	(6)
L.tv	0.0640** (0.0291)			0.125*** (0.0024)		
tvsq				-0.0212** (0.0136)		
L.rv		0.0705 (0.1105)			0.143** (0.0269)	
rvsq					-0.0588* (0.0677)	
L.uv			0.0803** (0.0384)			0.131*** (0.0045)
uvsq						-0.0310* (0.0982)
L.res	0.401*** (0.0000)	0.402*** (0.0000)	0.402*** (0.0000)	0.401*** (0.0000)	0.402*** (0.0000)	0.402*** (0.0000)
lnpgdp	0.158*** (0.0007)	0.156*** (0.0006)	0.158*** (0.0006)	0.153*** (0.0012)	0.154*** (0.0008)	0.155*** (0.0008)
L.lnpgdp	-0.286*** (0.0000)	-0.289*** (0.0000)	-0.285*** (0.0000)	-0.285*** (0.0000)	-0.287*** (0.0000)	-0.284*** (0.0000)
lnfdi	0.00614* (0.0617)	0.00661** (0.0449)	0.00614* (0.0609)	0.00613* (0.0621)	0.00645* (0.0503)	0.00624* (0.0563)
lnfisc	0.0816*** (0.0015)	0.0788*** (0.0023)	0.0834*** (0.0013)	0.0792*** (0.0021)	0.0792*** (0.0022)	0.0814*** (0.0017)
lnrd	-0.0110** (0.0231)	-0.0113** (0.0215)	-0.0115** (0.0172)	-0.0111** (0.0223)	-0.0114** (0.0208)	-0.0115** (0.0172)
lnthisec	-0.0707*** (0.0000)	-0.0703*** (0.0001)	-0.0687*** (0.0001)	-0.0708*** (0.0000)	-0.0695*** (0.0001)	-0.0694*** (0.0001)
lnedu	0.0114** (0.0306)	0.0113** (0.0339)	0.0115** (0.0315)	0.0105** (0.0488)	0.0110** (0.0401)	0.0110** (0.0408)
Intercept term	1.653*** (0.0000)	1.763*** (0.0000)	1.683*** (0.0000)	1.654*** (0.0000)	1.758*** (0.0000)	1.688*** (0.0000)
Control time	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	4368	4368	4368	4368	4368	4368
Within R^2	0.7597	0.7594	0.7596	0.7600	0.7597	0.7597

Note: () inside is p value; ***, ** and * respectively represent significant at 1%, 5% and 10% levels.

5.2. Endogeneity test

According to the relevant theoretical analysis of industrial diversification and economic resilience, industrial diversification within a reasonable range can promote the growth of regional economic resilience; At the same time, the growth of economic resilience will also promote the beneficial changes of industrial diversification within a reasonable range. Therefore, the endogeneity problem between explained variables and core explanatory variables will lead to biased estimation results. In addition, there may be some errors in the original data statistics, data processing and measurement methods of the core explanatory variables, which may lead to the distortion of regression results. In view of the possible endogeneity problems, this paper will use the instrumental variable method to try to solve the problem.

After finding a suitable instrumental variable, its validity for the suspected endogenous variable needs to be determined. The core explanatory variables (l.tv, l.rv, l.uv) were taken as the explained variables of the regression, and the instrumental variables and the control variables in the benchmark regression model were taken as explanatory variables for regression. The results show that the coefficients of the three instrumental variables are 0.940, 0.939 and 0.921 respectively, which are all above 0.9, indicating that the instrumental variables are highly correlated with the suspected endogenous variables, and all the instrumental variables are significant at the 1% significance level, indicating that the instrumental variables selected in this paper are strong instrumental variables and valid, so the endogeneity test can be carried out: First, the residuals of the regression results of the suspected endogenous variables and instrumental variables in the previous section are extracted, and then the three residuals are added into the original model as new explanatory variables for fixed effect regression, and the endogeneity of the core explanatory variables is determined by observing whether the results of each residual are significant. The regression results show that the coefficients of the corresponding residuals of industrial diversification and related diversification are all significant at the 1% significance level, which confirms the endogeneity of industrial diversification and related diversification. However, the corresponding residual results of irrelevant diversification are not significant, indicating that there is no endogeneity of irrelevant diversification. Finally, the endogenous variables of industrial diversification and related diversification are added to the original model and fixed effect regression is carried out to obtain more accurate and reliable empirical results.

Table 3. Regression results of instrumental variable method

	(1)	(2)
L.tv	0.0591 (0.2099)	
tvsq	-0.0244*** (0.0044)	
L.rv		0.0192 (0.8068)
rvsq		-0.0699** (0.0370)
L.res	0.394*** (0.0000)	0.394*** (0.0000)
lnpgdp	0.136*** (0.0038)	0.136*** (0.0028)
L.lnpgdp	-0.283*** (0.0000)	-0.287*** (0.0000)
lnfdi	0.00792** (0.0226)	0.00832** (0.0175)
lnfisc	0.0754*** (0.0079)	0.0738*** (0.0089)
lnrd	-0.00851* (0.0965)	-0.00865* (0.0942)
lnthisec	-0.0723*** (0.0000)	-0.0722*** (0.0000)
lnedu	0.00674 (0.1886)	0.00761 (0.1441)
Intercept term	0.339*** (0.0021)	0.432*** (0.0000)
Control time	Yes	Yes
Sample size	4095	4095
Within R2	0.7592	0.7600

Note: () inside is p value; ***, ** and * respectively represent significant at 1%, 5% and 10% levels.

The regression results are shown in Table 3. It can be seen from the results in the table that the coefficient of the square term of industrial diversification is −0.0244, which is 0.0032 accurate compared with the original coefficient (−0.0212), and the significance level is increased from 5% to 1%. The coefficient of the square term of related diversification is −0.0699, which is accurate to 0.0376 compared with the original result (−0.0588), and the significance level is increased from 10% to 5%. In general, the original regression results of industrial diversification and related diversification are overestimated.

5.3. Robustness test

5.3.1. Change the measurement method of core variables

The second measure of economic resilience (Formula (13)) was used for robustness test, and the OLS method was used for regression of the model. The results are shown in Table 4.

As shown in the table, the inverted U-shaped relationship between industrial diversification and related diversification and economic resilience is significant at the 1% significance level, while the sign of the second term independent of diversification is negative but not significant. On the whole, the robustness of the empirical analysis results is proved, which further verifies the research hypothesis of this paper.

5.3.2. Change the measurement data of core variables

The night light data used in this paper mainly reflects the use of night light in various countries and regions, including regional street lights, commercial lights, household lights of rural residents, street lights, etc. Xu et al. (2015) [23]proved the positive correlation between lighting data and regional economic development status. Therefore, based on scholars, this paper used regional night lighting data as an alternative data of regional GDP to measure economic resilience.

Table 4. Robustness Test -- Change the measurement method of economic resilience

	(1)	(2)	(3)
L.tv	0.249*** (0.0006)		
tvsq	-0.0635*** (0.0003)		
L.rv		0.354*** (0.0016)	
rvsq		-0.242*** (0.0001)	
L.uv			0.205** (0.0410)
uvsq			-0.0616 (0.1392)
L.res	0.238*** (0.0000)	0.237*** (0.0000)	0.237*** (0.0000)
lnpgdp	0.476*** (0.0000)	0.476*** (0.0000)	0.476*** (0.0000)
L.lnpgdp	-0.483*** (0.0000)	-0.488*** (0.0000)	-0.482*** (0.0000)
lnfdi	0.0102** (0.0209)	0.00879** (0.0495)	0.0110** (0.0126)
lnfisc	-0.0294* (0.0574)	-0.0197 (0.2076)	-0.0316** (0.0372)
lnrd	0.00951 (0.1484)	0.00809 (0.2155)	0.0112* (0.0887)
lnthisec	0.00702 (0.6006)	0.000848 (0.9483)	-0.00356 (0.8010)
lnedu	-0.000568 (0.9228)	0.000906 (0.8761)	-0.00289 (0.6186)
Intercept term	-0.170 (0.2354)	0.000991 (0.9934)	-0.101 (0.4467)
Sample size	4368	4368	4368
Ad-R2	0.1078	0.1087	0.1062

Note: () inside is p value; ***, ** and * respectively represent significant at 1%, 5% and 10% levels.

Table 5. Robustness test - Replace economic resilience measurement data

	(1)	(2)	(3)
tvsq	-0.0231*** (0.0007)		
rvsq		-0.0981*** (0.0007)	
uvsq			-0.0208 (0.2679)
L.res	-0.238*** (0.0000)	-0.238*** (0.0000)	-0.238*** (0.0000)
lnpgdp	-0.119*** (0.0000)	-0.115*** (0.0000)	-0.114*** (0.0000)
L.lnpgdp	-0.0218 (0.3372)	-0.0189 (0.4052)	-0.0228 (0.3170)
lnfdi	-0.00153 (0.6730)	-0.00222 (0.5414)	-0.00185 (0.6087)
lnfisc	0.123*** (0.0000)	0.129*** (0.0000)	0.124*** (0.0000)
lnrd	0.00307 (0.5299)	0.00278 (0.5766)	0.00391 (0.4155)
lnthisec	-0.0853*** (0.0000)	-0.0828*** (0.0000)	-0.0878*** (0.0000)
lnedu	-0.0149* (0.0606)	-0.0141* (0.0744)	-0.0143* (0.0713)
Intercept term	2.244*** (0.0000)	2.165*** (0.0000)	2.127*** (0.0000)
Control time	Yes	Yes	Yes
Sample size	4352	4352	4352
Within R^2	0.3492	0.3495	0.3481

Note: () inside is p value; ***, ** and * respectively represent significant at 1%, 5% and 10% levels.

In the robustness test analysis of night light data, the results are shown in Table 5. From the regression results in columns

(1) - (3), it can be seen that when the squared terms of the three types of diversification are added successively, there is an inverted U-shaped relationship between the three types and regional economic resilience, which is consistent with the benchmark regression results. Among them, the coefficient of industrial diversification decreased from -0.0212 to -0.0231 with a small change, the coefficient of related diversification decreased from -0.0588 to -0.0981 with a relatively large change, while the coefficient of unrelated diversification increased from -0.0310 to -0.0208. At the same time, the results of industrial diversification and related diversification are both significant at the level of 1%, but the results of unrelated diversification are not significantly negative. On the whole, the results verify the inverted U-shaped relationship between diversification and economic resilience, indicating the robustness and credibility of the regression results in this paper.

6. Expansion Analysis: Threshold Effect Test Based on The Difference of Economic Development Level

As the number of sample regions reaches 273, the large heterogeneity between regions will lead to certain errors in the research results. To examine the relationship between diversification and economic resilience in regions with different levels of economic development. Referring to the fixed effect panel threshold model regression method of Wang (2015) and Hansen (1999)[24-25], this paper firstly takes industrial diversification, related diversification and unrelated diversification as the core explanatory variables, and takes economic development level (lnpgdp) as the threshold variable to test the single threshold, double threshold and triple threshold model of the model respectively. The results of P value, F statistic and critical values of 1%, 5% and 10% are obtained by repeated sampling 1000 times by the Bootstrap method. The results show that the P values of the single threshold model and the double threshold model of the threshold model of industrial diversification, unrelated diversification and economic resilience are both 0 and significant at the significance level of 1%, while the P values of the three threshold model are all around 0.9 and insignificant, indicating that the threshold models of industrial diversification and unrelated diversification have double thresholds. Since the three threshold p-values of related diversification are all greater than 0.1 and not significant, it is determined that there is no obvious threshold effect.

Table 6. Threshold estimation and confidence interval

	Threshold model	Threshold name	Estimated value	95% confidence interval
Industrial diversification	Single threshold	Th-1	1.2949	[1.2294, 1.2996]
	Double threshold	Th-21	1.3428	[1.3345, 1.3876]
		Th-22	0.7881	[0.7679, 0.7934]
Independent diversification	Single threshold	Th-1	1.2949	[1.2914, 1.2996]
	Double threshold	Th-21	1.2949	[1.2914, 1.2996]
		Th-22	0.6138	[0.6029, 0.6186]

After determining the respective types of threshold models, the double-threshold model regression analysis is conducted on industrial diversification and unrelated diversification respectively. The estimated threshold values and 95% confidence intervals obtained are shown in Table 6. The two threshold estimates of the double threshold of industrial diversification are 0.7881 and 1.3428 respectively, and the two threshold estimates of the double threshold of unrelated diversification are 0.6138 and 1.2949 respectively. At the significance level of 5%, the critical value of LR statistic is 7.35.

At the same time, Stata16.0 gives the regression results of the threshold effect, as shown in Table 7. Columns (1) and (2) show the regression results of industrial diversification (lntv) and unrelated diversification (lnuv) as the core explanatory variables, respectively. In the threshold regression results of industrial diversification and economic resilience, when lnpgdp≤0.7881, the influence coefficient of industrial diversification on economic resilience is 0.146, which is significant at the significance level of 1%. When 0.7881 < lnpgdp≤1.3428, the coefficient is 0.0159, but it fails the significance test. When lnpgdp > 1.3428, the coefficient is negative and 0.133, and the result is significant at the significance level of 5%. In the threshold regression results of unrelated diversification and economic resilience, when lnpgdp≤0.6138, the influence coefficient of unrelated diversification on regional economic resilience is 0.498, which is significant at the significance level of 1%. When 0.6138 < lnpgdp≤1.2949, the coefficient is 0.498 and significant at the 1% significance level. When lnpgdp > 1.2949, the coefficient is 0.498, and the result is significant at the level of 1%.

In conclusion, from the perspective of diversification and economic resilience, the effects of the two kinds of diversification on economic resilience gradually changed from a higher positive promotion to a negative inhibition. From the perspective of threshold of economic development level, when the economic development level of a region is low, promoting the two kinds of diversification among various industries is a beneficial measure to promote the growth of economic resilience. However, when the economic development level of the local region reaches 1.3428 and 1.2949 thresholds respectively, increasing the degree of diversification will inhibit the growth of economic resilience. The possible reason is that when the regional economic development level is at a low level, the situation of capital, manpower, technology, infrastructure and other aspects is poor, diversified industrial structure will bring more diversified technology and human resources, and its innovation ability will have a large space to improve, and the promotion effect on economic resilience is greater than the inhibition effect. If a region focuses on the professional development of a certain industry, when the industry suffers from external shocks, the regional economy will collapse and cannot be supported by other industries. When the regional economic development level is at a relatively high level, the diversified industrial structure in the region reaches saturation value and continues to pursue industrial diversification, it will increase the regional production pressure and reduce production efficiency, resulting in a large outflow of talents and resources and resulting in regional hollowing out. At this time, the improvement of industrial diversification will obviously inhibit the improvement of regional economic resilience.

Table 7. Estimated results of threshold model

	(1)	(2)
L.res	0.532*** (0.0000)	0.570*** (0.0000)
lnfdi	0.0142*** (0.0000)	0.0138*** (0.0001)
lnfisc	-0.101*** (0.0000)	-0.106*** (0.0000)
lnrd	-0.0140*** (0.0002)	-0.0206*** (0.0000)
lnthisec	-0.105*** (0.0000)	-0.115*** (0.0000)
lnedu	-0.00689 (0.2708)	-0.0142** (0.0257)
lntv(lnpgdp≤0.7881)	0.146*** (0.0083)	
lntv(0.7881<lnpgdp≤1.3428)	0.0159 (0.7729)	
lntv(lnpgdp>1.3428)	-0.133** (0.0146)	
lnuv(lnpgdp≤0.6138)		0.498*** (0.0000)
lnuv(0.6138<lnpgdp≤1.2949)		0.223*** (0.0000)
lnuv(lnpgdp>1.2949)		-0.180*** (0.0002)
Intercept term	0.0634 (0.2724)	0.00580 (0.8776)
Sample size	4368	4368
Within R^2	0.6785	0.6663

Note: () inside is p value; ***, ** and * respectively represent significant at 1%, 5% and 10% levels.

7. Conclusions and Suggestions

This paper constructs a benchmark model of industrial diversification, related diversification, related diversification and economic resilience, and uses the research samples of 273 regions in China from 2003 to 2019 to explore the relationship between regional industrial diversification and economic resilience. The results show that there is a significant inverted U-shaped relationship between industrial diversification, related diversification and unrelated diversification and regional economic resilience. In the analysis of the threshold effect with the level of economic development as the threshold variable, the conclusion shows that there is a double threshold effect among industrial diversification, unrelated diversification and economic resilience. Therefore, this paper puts forward the following policy suggestions based on the research conclusions:

First of all, from the perspective of policy makers, China should take the development of a more resilient economy as a long-term strategic point of policy making. Secondly, from the regional perspective, we should make full use of the role of industrial diversification in risk dispersion, and provide a good environment for the healthy development of regional industrial diversification by creating a fair and just market cooperation atmosphere, reducing the impact of adverse competition, improving the basic production conditions for industrial development, and dynamically adjusting the support for small and micro enterprises. Actively cultivate diversified industrial structure and encourage knowledge and technology exchange between industries to enhance regional innovation ability, accelerate the birth of new economy and enhance regional economic resilience. At the same time, the government should play its macro-control role to actively guide the adjustment of regional industrial diversification structure, rationally plan the industrial division pattern of each part of the region, and actively promote the process of market integration. Finally, from the perspective of regional economic development, for regions with low levels of economic development, in order to give full play to the role of industrial diversification in promoting their economic resilience, the government should build a smooth information exchange platform for their diversified industries, and provide enterprises with more knowledge, information and technology to reduce their production costs. Combined with its own advantages in resources, industries and other aspects, it can identify the development positioning and actively communicate with other industries to participate in the industrial chain of other regions, driving economic development and transferring the impact risk. For regions with high levels of economic development, focusing the policy on developing advantageous industries rather than developing diversified industrial structures can not only reduce the pressure of regional development, but also reduce the impact of the crisis, and reduce the time for the recovery of industries and the development of a new stable state after the crisis, thus effectively improving the resilience of the economy.

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