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Research on the Influence of Industrial Upgrading on Independent Innovation Ability in China

—Based on Inter-Provincial Panel Data

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Abstract

According to the different levels of economic development in China's provinces, this paper uses principal component analysis to establish a comprehensive index system for evaluating the level of economic development, and then uses cluster analysis to classify 31 provinces in China into economically developed regions, economically relatively developed regions, and economically underdeveloped regions. Next, based on the results of regional division, this paper uses the fixed panel data model to empirically analyze the impact of national and regional industrial upgrading on independent innovation capability, and the model is tested for robustness by systematic generalized moment estimation. The results show that: Industrial upgrading can effectively promote the improvement of national and regional independent innovation capabilities. On the whole, the industrial upgrading transferred to the tertiary industry can effectively promote the improvement of independent innovation capability; moreover, in both economically developed regions and economically underdeveloped regions, the process of industrial upgrading to the secondary and tertiary industries can effectively promote the improvement of regional independent innovation capabilities. Finally, according to the results of empirical analysis, the paper puts forward policy enlightenment of industrial upgrading and suggestions on improving independent innovation ability.

Keywords

Industrial Upgrading, Independent Innovation, Principal Component Analysis, Cluster Analysis, Panel Data Model

1. Introduction

With the deepening of economic globalization, affected by the global financial crisis and competition in the international market, countries around the world have been improving the international competitiveness of their industries through scientific and technological innovation and industrial restructuring. Following the development trend of the world, China has also started to implement the industrial upgrading strategy. With the continuous development of China's industrial upgrading process, the economic effect of industrial upgrading on independent innovation has gradually emerged, and the relationship between industrial upgrading and independent innovation has attracted more researchers' attention.

In order to realize the sustainable and healthy development of economy, and also to achieve the goal of optimizing the allocation of resources of the whole society, the implementation of industrial upgrading strategy is the only way out in front of our country. However, to implement the strategy of industrial upgrading, we must change the original economic development model, implement the strategy of innovation-driven development, abandon the traditional factor-driven development model, and enhance the competitiveness of China's industry in the world with scientific and technological innovation. The key to the strategic transformation of China's economic development is to improve the ability of independent innovation.

How to improve the ability of independent innovation in the process of industrial upgrading and realize the simultaneous development of industrial upgrading and independent innovation is an urgent theoretical and practical problem that needs to be studied. However, the existing literature focuses more on the promotion of independent innovation to industrial upgrading, and from the investment structure [1], foreign investment [2], industrial agglomeration [3], financial development [4], global value chain [5], research on technological progress paths and technology choices [6]. Most recent studies have ignored the impact of industrial upgrading on independent innovation ability. Although some scholars have paid attention to this issue, for example, Fenghua Wu and Ruiming Liu [7] believe that industrial upgrading can drive independent innovation at the three levels of enterprises, regions and countries through micro-demand pull effect, medium-based regional synergy effect and macro-international trade effect. Weiqing Li, Xian-zhong Nie [8] conducted an empirical analysis of the impact of industrial upgrading on independent innovation capability, using the inter-provincial panel data from 1998 to 2012. The results show that industrial upgrading has a significant positive spillover effect on China's overall independent innovation, and the more obvious the spillover effect is, the stronger China's independent innovation capability is, while the independent innovation effect on the eastern, central and western regions is quite different. Haixia Wang and Xin Wang [9] explored the relationship between industrial upgrading, human capital and independent innovation based on China's provincial panel data from 2002 to 2015. The results show that the process of upgrading to the secondary and tertiary industries can effectively promote the improvement of human capital, and thus promote the improvement of independent innovation.

To sum up, industrial upgrading mainly promotes independent innovation from micro, medium and macro mechanisms, and the impact of industrial upgrading on independent innovation ability varies greatly in different regions and economic development degrees. Therefore, in order to explore the impact of different regional industrial upgrading on the capacity of independent innovation, it is necessary to divide the region. However, in the current research, there are certain limitations in only dividing the area according to geographical location to analyze the impact of industrial upgrading in various regions on the ability of independent innovation. Therefore, the innovation of this paper lies in: according to the actual situation of the economic development of various provinces and cities in China, the principal component analysis method is used to establish the comprehensive evaluation index system of economic development, and then the cluster analysis method is used to classify the provinces and cities in China. Based on this, this paper explores the influence mechanism and empirical effect of industrial upgrading on independent innovation in China and various regions.

2. Influence Mechanism of Industrial Upgrading on Independent Innovation Ability

Generally speaking, the mechanism of industrial upgrading to promote independent innovation can be divided into two steps: the first step is the optimization and upgrading of traditional industrial structure; the second step is to promote independent innovation in the process of industrial structure optimization and upgrading. First of all, industrial upgrading will inevitably lead to deepening the division of labor and specialization degree. Both domestic and foreign markets are continuously expanding under the promotion of deepening division of labor and increasing specialization, thus producing more new products in the secondary industry and new services in the tertiary industry. The emergence of new products further promotes the internal upgrading of the secondary industry; The emergence of new services has further promoted the internal upgrading of the tertiary industry. Secondly, in the process of continuous optimization and upgrading of industrial structure, industrial upgrading has a driving role in improving the ability of independent innovation. Its mechanism of action is roughly divided into three aspects: micro, meso and macro. The micro-effect is mainly reflected in demand. The meso-effect is mainly reflected in the geographical synergy, and the macroscopic role is mainly reflected in international trade.

2.1. Micro-Impact Mechanism of Industrial Upgrading on Independent Innovation Capability

First of all, the optimization and upgrading of the industrial structure will inevitably lead to the rationalization and high-level of the industrial structure, thus promoting the continuous expansion and segmentation of the domestic and foreign markets. The continuous expansion and subdivision of the domestic and international markets will certainly cause demand expansion. The expansion of demand has enabled more companies to see the market and business opportunities, thus attracting more companies to enter the market. More companies entering the market will inevitably lead to more intense market competition. The highly competitive market forces companies to continually innovate to increase their competitiveness, thereby attracting more consumers and occupying a larger market share. Second, the continuous expansion and segmentation of the market and the increase in demand will result in higher consumer demand for products and services. The expansion of demand leads to intensified labor mobility and stricter requirements for the quality of labor, which raises the level of human capital and provides essential talent resources for independent innovation and research and development. Therefore, from the perspective of the micro-impact mechanism, the demand pull effect can drive independent innovation (Figure 1).

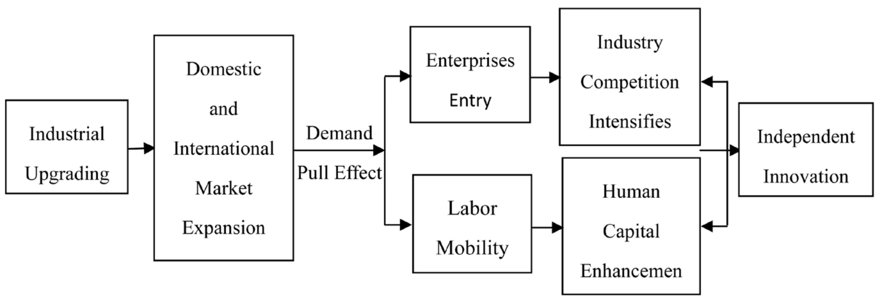

Figure 1. Micro-impact mechanism.

2.2. Meso-Impact Mechanism of Industrial Upgrading on Independent Innovation Capability

In the process of optimizing and upgrading the industrial structure, due to the different development models between regions and the degree of government support, there are also differences in the industrial transformation and development of various regions. Under the encouragement of regional GDP targets, governments in various regions have continuously improved the independent innovation capabilities of various regions in the competition by introducing advanced technologies, learning scientific management models and developing strategic emerging industries. At the same time, in order to transform the traditional industries better in various regions and develop high-tech industries, regional governments will also carry out regional cooperation. By exerting the comparative advantages of each region, we will form a spatial agglomeration effect, break through the technical bottlenecks in the process of industrial upgrading, reduce the risk problems in the process of regional independent innovation, save the cost of scientific research in the region, and improve the return on capital for scientific research and development. Therefore, from the perspective of the meso-impact mechanism of action, the optimization and upgrading of the industrial structure has led to the coexistence of cooperation and competition in various regions, thus forming a regional synergy effect, which in turn promotes independent innovation in various regions (Figure 2).

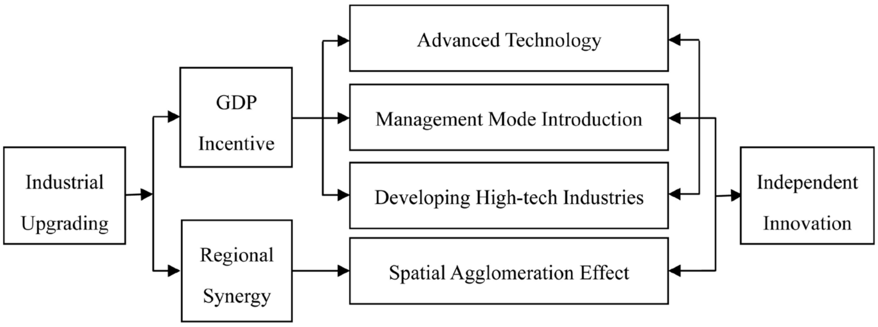

Figure 2. Meso-impact mechanism.

2.3. Macro-Impact Mechanism of Industrial Upgrading on Independent Innovation Capability

In the process of industrial structure optimization and transformation and upgrading in China, government departments will certainly formulate and implement some policies on industrial structure optimization, transformation and upgrading. Governments in various regions will vigorously support strategic emerging industries such as information technology and biotechnology, energy conservation, environmental protection, new energy and new materials and so on. Regional governments will formulate a series of policies to improve the policy system with industrial policy as the core, to encourage independent innovation to research and develop key technologies and core technologies in key fields, and actively create a policy environment for collaborative innovation to form a long-term mechanism for collaborative innovation.

At the same time, industrial transformation and upgrading will promote import and export trade. China integrates relevant products and services into the international market through export, making China's relevant industries become the intermediate link in the global industrial chain. In the process of participating in global production, China can learn advanced technology and scientific experience independently through OFDI technology reverse spillover effect and dry middle school, and constantly improve China's independent innovation ability through absorption, digestion and innovation. In addition, industrial upgrading has raised international trade barriers to a certain extent. In order to enhance the competitiveness of domestic products, it is necessary to constantly carry out independent innovation to improve domestic terms of trade so as to break down technical barriers. Therefore, from the perspective of macro mechanism, international trade effect can promote national independent innovation (Figure 3).

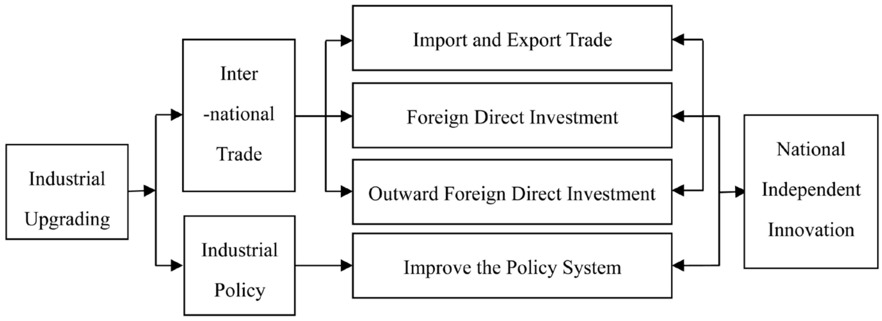

Figure 3. Macro-impact mechanism.

In fact, due to the different economic development conditions in different regions, the impact of industrial structure on independent innovation is quite different. In general, for regions with relatively slow economic development, the dominant industry in this region is generally the secondary industry, so the secondary industry enterprises are the main innovation industries. However, when the economy develops to a certain extent, the role of enterprise innovation in the secondary industry in the overall independent innovation will gradually weaken. Some of the more innovative industries in the tertiary industry, such as computer services and software, information transmission, scientific research, and technical services, play an increasingly important role in independent innovation, and their innovation efforts far exceed the secondary industry. Therefore, the path of industrial upgrading depends on the actual development of each region. This paper will carry out regional division according to the economic development level of various provinces in China to explore the impact of industrial upgrading in different regions on independent innovation capability.

3. The Division of Provinces and Regions Based on the Level of Economic Development

According to the concept of economic development, it includes not only economic growth, but also economic benefits, resources, people's lives and other aspects. Therefore, the establishment of the index system needs to consider all the factors that affect the economic development comprehensively.

3.1. Initial Establishment of the Indicator System

In order to comprehensively reflect the situation of China's economic development, and based on the scientific, representative and comprehensive principles of selected indicators, the initial indicator system selected in this paper is as follows (**Table 1**).

Table 1. Initial indicator system for regional economic development.

Level indicators	The secondary indicators	Measurement methods
The level of regional economic development	Per capita regional GDP Per capita fiscal revenue	Gross Regional Product/Population Financial income/population

Continued

Regional economic benefits	Labor productivity	Regional GDP/regional employees
People's living standards	Per capita disposable income of urban residents Per capita disposable income of rural residents	Per capita disposable income of urban residents Per capita disposable income of rural residents
Regional traffic and communication	Operating line network length Total public transport passenger traffic Telephone penetration rate Number of Internet users	Operating line network length Total public transport passenger traffic Telephone penetration rate Number of Internet users
Regional funding factors	Per capita fixed asset investment Per capita fiscal expenditure	Fixed asset investment/regional population Financial expenditure/population of the region
Regional resource endowment status	Per capita water resources	Total water resources/regional population
Regional openness	The total value of export commodities as a percentage of GDP	The total value of export commodities as a percentage of GDP
Regional health conditions	Number of health institutions Government health expenditure	Number of health institutions Government health expenditure

Data source: China Statistical Yearbook.

3.2. Establishment of Indicator System Based on Principal Component Analysis

In order to enhance the scientific and rationality of the indicator system, this paper uses the data of relevant indicators of China's provinces and cities in 2012-2016, and then takes the average value, and uses SPSS software to do the principal component analysis of the primary selection indicators, and then eliminate the unimportant indicators.

1) Extraction of principal components

We use software to perform principal component analysis on the data, to calculate the variance contribution rate and the cumulative contribution rate. The results are as follows (Table 2).

Table 2. Principal component analysis results.

Ingredient	Initial eigenvalue			Extracting the sum of squared loads		
	Total	Percentage of variance	Cumulative%	Total	Percentage of variance	Cumulative%
1	5.669	37.790	37.790	5.669	37.790	37.790
2	4.753	31.685	69.476	4.753	31.685	69.476
3	1.806	12.042	81.517	1.806	12.042	81.517
4	1.148	7.650	89.168	1.148	7.650	89.168
5	0.465	3.101	92.269			
6	0.343	2.284	94.553			
7	0.227	1.516	96.069			
8	0.180	1.202	97.271			
9	0.162	1.081	98.352			
10	0.099	0.660	99.011			

Continued

11	0.061	0.410	99.421
12	0.036	0.240	99.661
13	0.032	0.212	99.874
14	0.013	0.084	99.957
15	0.006	0.043	100.000

Method: Principal Component Analysis.

According to the principal component analysis method, the components with eigenvalues greater than 1 are extracted. It can be seen from Table 2 that the cumulative variance of the first four components has reached 89.168%, so the extraction of the four principal components can better explain the inclusion of the original variables information. From the cumulative variance value, the weight of principal component 1 = 37.790/89.168 = 0.4238, the weight of principal component 2 = 31.685/89.168 = 0.3553, the weight of principal component 3 = 12.04/89.168 = 0.1351, the weight of principal component 4 = 7.650/89.168 = 0.0858.

2) Principal component comprehensive index score

The rotation component matrix is established for the first four eigenvalues, and the rotation component score coefficient matrix is obtained. The results are shown in the following Table 3.

Table 3. Component score coefficient matrix.

Variable	Ingredient			
	1	2	3	4
Per capita GDP	0.164	0.045	0.135	0.034
Labor productivity	0.037	0.053	0.451	0.284
Urban per capita disposable income	0.160	0.063	−0.078	−0.057
Rural disposable income	0.158	0.066	0.010	−0.040
Per capita fiscal revenue	0.167	0.005	−0.013	−0.091
Per capita fiscal expenditure	0.085	−0.135	−0.143	0.419
Per capita water resources	−0.008	−0.099	−0.225	0.667
Per capita fixed asset investment	0.058	−0.041	0.443	0.224
Exports as a share of GDP	0.121	0.092	−0.175	0.114
Internet access	0.007	0.197	−0.051	0.162
Telephone penetration rate	0.154	0.031	−0.120	−0.092
Number of health institutions	−0.084	0.156	0.036	0.124
Local financial health expenditure	−0.017	0.203	−0.057	0.109
Highway mileage	−0.115	0.134	0.003	0.131
Total passenger traffic	−0.016	0.188	−0.074	0.122

Method: Principal Component Analysis.

Based on the coefficient matrix in Table 3, we can calculate the principal component composite score:

Principal component 1 score:

$$F_1 = 0.164X_1 + 0.037X_2 + 0.160X_3 + 0.158X_4 + 0.167X_5 + 0.085X_6 - 0.008X_7 + 0.058X_8 + 0.121X_9 + 0.007X_{10} + 0.154X_{11} - 0.084X_{12} - 0.017X_{13} - 0.115X_{14} - 0.016X_{15}$$

Principal component 2 score:

$$F_2 = 0.045X_1 + 0.053X_2 + 0.063X_3 + 0.066X_4 + 0.005X_5 - 0.135X_6 - 0.099X_7 - 0.041X_8 + 0.092X_9 + 0.197X_{10} + 0.031X_{11} + 0.156X_{12} + 0.203X_{13} + 0.134X_{14} + 0.188X_{15}$$

Principal component 3 score:

$$F_3 = 0.135X_1 + 0.451X_2 - 0.078X_3 + 0.010X_4 - 0.013X_5 - 0.143X_6 - 0.225X_7 + 0.443X_8 - 0.175X_9 - 0.051X_{10} - 0.120X_{11} + 0.036X_{12} - 0.057X_{13} + 0.003X_{14} - 0.074X_{15}$$

Principal component 4 score:

$$F_4 = 0.034X_1 + 0.284X_2 - 0.057X_3 - 0.040X_4 - 0.091X_5 + 0.419X_6 + 0.667X_7 + 0.224X_8 + 0.114X_9 + 0.162X_{10} - 0.092X_{11} + 0.124X_{12} + 0.109X_{13} + 0.131X_{14} + 0.122X_{15}$$

According to the above formula, the scores of the four principal components in each region from 2012 to 2016 are calculated as shown in Table 4. So far, we have changed the economic development described by the 15 initial indicators into four comprehensive According to the indicator. The four principal components are less than 30% of the original amount, and the amount of information contained therein is 89% of the original information, which simplifies the number of indicators and retains the information of the original indicators.

Table 4. Scores of four comprehensive indicators in each region.

Province	Principal component 1 score	Principal component 2 score	Principal component 3 score	Principal component 4 score	Composit-e scores	Comprehensiv-e ranking
Jiangsu	0.94883	1.29539	0.7767	0.95926	1.0496	1
Guangdong	0.62156	2.52968	−1.72172	0.89181	1.0061	2
Shanghai	2.80749	−0.05106	−1.26832	−0.7634	0.9348	3
Zhejiang	1.3643	1.03252	−0.34202	0.01967	0.9005	4
Tianjin	1.83929	−0.76768	2.46261	0.60941	0.8917	5
Beijing	2.56209	−0.08709	−1.34555	−1.09346	0.7793	6
Shandong	−0.25341	1.48479	0.96109	1.0193	0.6374	7
Inner Mongolia	0.33632	−0.45478	2.46077	0.95432	0.3953	8
Fujian	0.58452	0.09149	0.24134	−0.2089	0.2949	9
Liaoning	0.26031	0.10151	0.5928	−0.01706	0.2250	10
Hebei	−0.69543	0.77014	0.6606	0.30099	0.0940	11

Continued

Hunan	−0.81706	0.84062	0.4758	0.45027	0.0553	12
Hubei	−0.52252	0.46427	0.41173	0.15297	0.0123	13
Sichuan	−1.06004	1.32728	−0.4435	0.46277	0.0021	14
Henan	−1.01587	1.18219	−0.36272	0.13505	−0.0479	15
Chongqing	−0.01347	−0.26526	0.0645	−0.28295	−0.1155	16
Anhui	−0.62552	0.32085	0.2513	−0.03102	−0.1198	17
Ji Lin	−0.13384	−0.57429	0.78617	−0.37921	−0.1871	18
Shaanxi	−0.40875	−0.1075	0.32038	−0.22762	−0.1877	19
Jiangxi	−0.63542	−0.05343	−0.12248	−0.3796	−0.3374	20
Guangxi	−0.68333	−0.10578	0.01774	−0.39877	−0.3590	21
Ningxia	0.03479	−1.36582	0.64546	−0.60696	−0.4354	22
Xinjiang	−0.30506	−0.64544	−0.49392	−0.4913	−0.4675	23
Heilongjiang	−0.56788	−0.39402	−0.44988	−0.86776	−0.5159	24
Hainan	0.024	−1.1868	−0.11917	−1.09822	−0.5218	25
Shanxi	−0.61943	−0.33885	−0.41075	−0.97351	−0.5219	26
Qinghai	−0.12383	−1.55785	0.32733	0.23612	−0.5415	27
Yunnan	−0.92751	−0.1534	−0.78557	−0.70225	−0.6140	28
Guizhou	−0.92494	−0.26487	−0.67756	−0.70193	−0.6379	29
Gansu	−0.9284	−0.68493	−0.74706	−1.11622	−0.8335	30
Tibet	−0.12179	−2.38188	−2.16606	4.14821	−0.8346	31

3.3. Regional Division Based on Cluster Analysis

The initial index number and the possible correlation between indicators will influence the reliability of the clustering analysis results, therefore, this article first principal component analysis was carried out on the initial index. Then according to the results obtained by principal component analysis, Q-type clustering is performed for each province, city and autonomous region, and the distance between the class and the class is calculated by the method of squared deviation. We can get the tree clustering diagram as follows:

According to the results of the above figure (**Figure 4**), there are large differences in the economic development of various regions in China. If 31 regions are divided into three categories according to the economic development of each region, the results are shown in **Table 5**.

Table 5. Results of cluster analysis in various regions of china.

Economically developed regions	Tianjin, Zhejiang, Shanghai, Jiangsu, Guangdong, Beijing, Shandong
Economicallyrelatively developed regions	Liaoning, Fujian, Inner Mongolia, Jilin, Shaanxi, Anhui, Chongqing, Hebei, Hunan, Hubei, Sichuan, Henan
Economically underdeveloped regions	Shanxi, Hainan, Heilongjiang, Qinghai, Ningxia, Xinjiang, Guizhou, Yunnan, Jiangxi, Guangxi, Tibet, Gansu

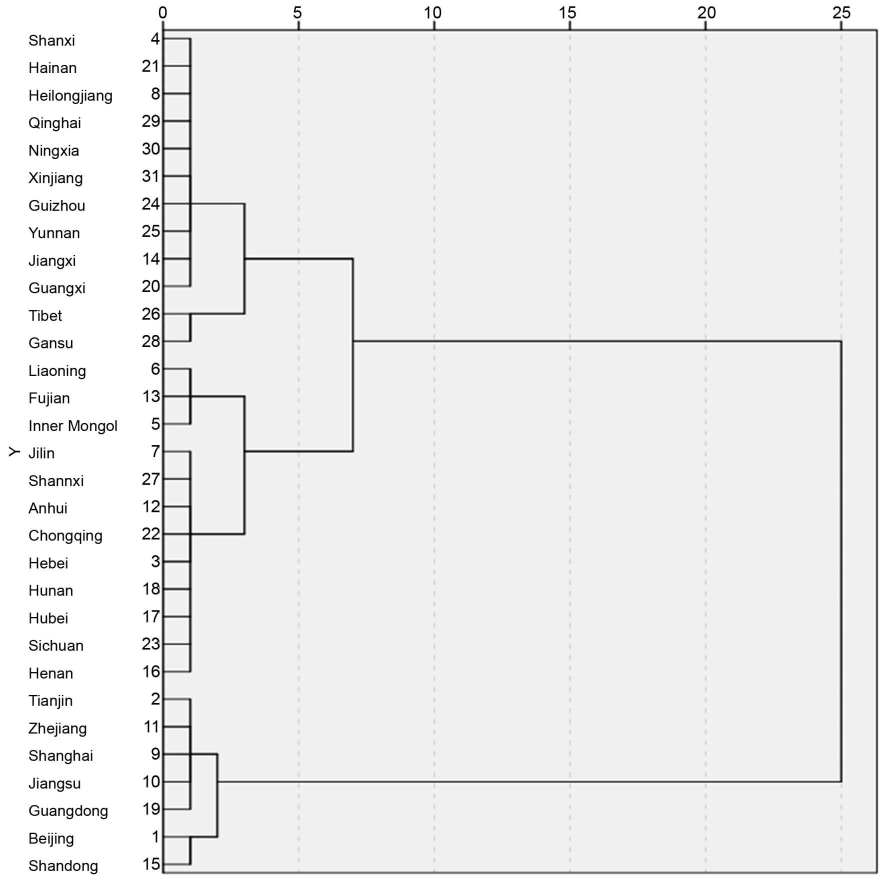

Figure 4. Cluster tree diagram of each region. Method: Cluster Analysis.

From the above results combined with the combined distance in the cluster map, we can know that the economic development of Jiangsu, Guangdong, Shanghai, Zhejiang, Tianjin, Beijing, and Shandong is relatively rapid. They are the top seven scores calculated by the weight distribution of the four principal components, which are the most developed regions in China; The economic development of Liaoning, Fujian, Inner Mongolia and other 12 provinces and cities can be classified into the same category, and it is an area with relatively developed economic development; The economic development of 12 provinces and cities such as Shanxi, Hainan and Heilongjiang can be classified into the same category and belong to underdeveloped areas with economic development; In summary, 31 provinces and cities in China can be roughly divided into three categories: economically developed regions, economically relatively developed regions, and economically underdeveloped regions.

4. Analysis of the Impact of Industrial Upgrading on Independent Innovation Capability

4.1. Indicator Selection and Model Establishment

1) Variable Determination and Measurement Methods

This paper mainly focuses on the impact of industrial upgrading on independent innovation ability. However, since the independent innovation ability of each region is also affected by factors such as regional education level, regional openness, foreign investment level and R&D expenditure, this paper introduces these variables into the model as control variables. The specific variable indicators and measurement methods are as follows:

a) Explained variable. This paper will select two variables to measure the independent innovation ability of each province in China. They are: the number of domestic patent applications accepted and the number of domestic patent applications authorized, both of which can measure the overall level of independent innovation in a region. In this paper, logarithmic processing is carried out for these two variables, that is, the number of domestic patent applications accepted is measured by lnpatent, and the number of domestic patent applications authorized is measured by lnpatentapply.

b) Explanatory variables. The most intuitive manifestation of industrial upgrading is the proportion of secondary and tertiary industries. Therefore, this paper selects the proportion of regional secondary gross domestic product and tertiary industrial gross domestic product in regional gross domestic product as explanatory variables. The proportion of the GDP of the secondary industry is expressed by ind, and the proportion of the GDP of the tertiary industry is expressed by ser.

c) Control variables. In this paper, four variables are selected as control variables. They are: i) Higher education level. Higher education can provide a steady stream of innovative talents for the independent innovation of a region and reflect the basic ability of independent innovation of a region. Higher education level (edu) is usually measured by the number of students in higher education schools/regional total population. ii) The degree of regional openness. The degree of openness will affect a region's independent innovation ability through foreign technology spillover, foreign technology import and transfer. The influence of the degree of openness on the independent innovation ability of a region is relatively complex. The greater the degree of openness, the higher the competitive pressure of the domestic market will be. It is also possible to compete in the fierce competition to improve the survival and development competitiveness of enterprises through continuous independent innovation, to stand firm in the domestic and foreign markets, and then to drive the improvement of regional independent innovation ability. Typically, openness is measured by Regional import and export volume/regional GDP. iii) Foreign investment level. Foreign direct investment can bring advanced technology and management experience to the region, so as to improve the local independent innovation ability. Generally, foreign investment level (fdi) is measured by Regional foreign direct investment/regional GDP. iv) R&D spending. The investment of regional research and development funds provides impetus for the region's independent innovation, thus promoting the improvement of the region's independent innovation ability. Typically, R&D spending (rd) is measured by "Regional R&D expenditure/regional GDP" (**Table 6**).

Table 6. Variables and measurement methods.

Variable	Measurement method
Domestic patent application acceptance number (patent)	Logarithmic processing (lnpatent)
Domestic patent application authorization number (patentapply)	Logarithmic processing (lnpatentapply)
Second industry GDP ratio (ind)	Secondary industry GDP/regional GDP
Tertiary industry GDP ratio (ser)	Tertiary industry gross production value/regional GDP
Higher education level (edu)	Number of students in higher education schools/regional total population
Openness (open)	Regional import and export volume/regional GDP
Foreign investment level (fdi)	Regional foreign direct investment/regional GDP
R&D spending (rd)	Regional R&D expenditure/regional GDP

Data source: China Statistical Yearbook and China Science and Technology Statistical Yearbook.

2) Model Establishment

Based on the determination of relevant variables, this paper uses the panel data model to study the impact of industrial upgrading and related control variables on independent innovation capabilities. To further determine whether to select a fixed effect or a random effect panel data model, we have established the basic test model as follows:

$$\text{patent}_{it} = \alpha_0 + \alpha_1 \times \text{ind}_{it} + \alpha_2 \times \text{ser}_{it} + \sum_j \alpha_j \times \text{control} + v_i + \mu_{it}$$

Among them: patent represents the explanatory variable, consisting of two variables, measuring the independent innovation ability of the region, that is, the number of domestic patent applications (patent) and the number of domestic patent applications (patentapply); ind is the proportion of the secondary industry; *ser* is the proportion of the tertiary industry; control is a series of control variables; v is the amount that does not change with time under the fixed effect; There is no such variable under random effect. μ is the residual item. The subscripts i and t respectively represent the i-th province and the t-th year.

4.2. Empirical Analysis Based on Provincial Panel Data

To explore China's industrial upgrading of the impact of the independent innovation and driving effects, this paper selected the 2007-2016 panel data of 31 provinces in China, using the panel data model to investigate the overall and economically developed areas of China, the economy more developed regions and underdeveloped regions in three regional industrial upgrade effects on independent innovation ability promotion. We use Stata13 to estimate the results, and use the system generalized moment estimation method (GMM) to test the robustness of the results. All the data in this paper are from the "China Statistical Yearbook" and the "China Science and Technology Statistical Yearbook".

1) Results and Analysis of National Panel Data Model Regression

This paper firstly conducted regression of fixed effect and random effect for 31 provinces in China from 2007 to 2016, and the regression results were shown in Table 7. For the fixed-effect model, the coefficients of the proportion of secondary industry (ind) and the proportion of tertiary industry (ser) respectively are 3.554, 5.689 and 4.120, 6.181, which are all positive coefficients, and are significant when the significance level is 1%. For the random-effect model, the coefficients of the proportion of the secondary industry (ind) and the proportion of the tertiary industry (ser) are both positive, and significant at the significance level of 1%. It shows that the development of secondary and tertiary industries can effectively promote the increase of patent acceptance and authorization in China, and further shows that industrial upgrading can effectively promote the improvement of independent innovation ability. In order to more accurately and effectively analyze the impact of China's industrial upgrading on independent innovation and its driving effect, Hausman test is carried out on the fixed effect model and the random effect model, and the test results support the fixed effect model.

Table 7. National panel data model regression results.

Model	FE (Fixed Effect)		RE (Random Effect)	
Variable	lnpatent	lnpatentapply	lnpatent	lnpatentapply
ind	3.554*** (3.91)	4.120*** (4.03)	4.4805*** (3.91)	4.885*** (4.49)
ser	5.689*** (5.22)	6.181*** (5.63)	6.355*** (5.22)	6.758*** (5.84)
edu	210.008*** (13.64)	184.057*** (13.71)	195.913*** (13.64)	172.557*** (12.58)
open	−0.607** (−3.99)	−0.709*** (−2.81)	−0.893*** (−3.99)	−0.948*** (−4.36)
fdi	−0.129** (−1.41)	−0.041 (−0.75)	−0.087 (−1.41)	−0.008 (−0.13)
rd	0.742*** (5.21)	0.818*** (6.85)	0.566*** (5.21)	0.660*** (6.27)
_cons	1.143 (1.13)	0.471 (0.59)	1.030 (1.13)	0.383 (0.44)
R2	0.7832	0.7922	0.7804	0.7901
F	164.37	173.51		

Note: The values in parentheses are the t-test values, *, **, *** respectively indicate the test by the significance level of 10%, 5%, and 1%.

According to the regression results of the fixed effect model of the above table, for the explanatory variables, the coefficients of the proportion of the secondary and tertiary industries are all positive, and both are significant at the level of significance of 1%. It shows that due to the three effects of demand pull effect, regional synergy effect and international trade effect, industrial upgrading can effectively promote the development of independent innovation. In addition, the coefficient of the proportion of the tertiary industry is greater than the coefficient of the proportion of the second industry, indicating that in terms of the current development of China, the industrial upgrading transferred to the tertiary industry can more effectively promote the improvement of China's independent innovation capability. The possible reason is that some industries with higher levels of innovation such as computer services and software industry, information transmission, scientific research, and technical service industries in the tertiary industry play an increasingly important role in independent innovation, and their innovation efforts far exceed Second industry enterprises.

For the control variables, a) the coefficient of higher education level is positive, and both are significant at the level of significance of 1%, indicating that the improvement of the higher education level can effectively promote the ability of independent innovation; b) the coefficient of openness is negative, Moreover, both of them are significant at the level of significance of 5%, indicating that with the deepening of reform and opening up, China's ability to cope with domestic and foreign market competition still needs to be improved. Therefore, to a certain extent, the degree of openness limits China's independent innovation; c) The coefficients of foreign investment are both negative, and are basically significant at the 10% significance level. The possible reasons are: on the one hand, although foreign investment can bring advanced technology and experience to China, due to the relatively weak independent absorption capacity of Chinese enterprises, advanced technology is still in the hands of foreign enterprises, which inhibits the improvement of independent innovation of Chinese enterprises. On the other hand, China no longer relies on the technology spillover brought by foreign direct investment to enhance the independent innovation ability of enterprises. d) The coefficients of R&D spending are all positive, and both of them are significant at the significance level of 1%, indicating that R&D spending has a positive spillover effect on the improvement of independent innovation and can effectively promote China's independent innovation.

2) Regression Results and Analysis of Panel Data Models in Three Major Regions

According to the results of the regional division in Chapter 4, the fixed-effect model and the random-effect model regression are respectively used in the inter-provincial panel data of the three regions from 2007 to 2016, and the Hausman test is performed on the estimation results. The test results of the three regions all supported fixed effect. Regression results of fixed effects are shown in **Table 8**.

Table 8. Panel data regression results of the three major regions.

Variable	Economically developed regions		Economically relatively developed regions		Economically underdeveloped regions	
	lnpatent	lnpatent apply	lnpatent	lnpatent apply	lnpatent	lnpatent apply
ind	2.045*** (2.52)	1.436*** (4.31)	1.788*** (3.53)	1.579** (2.32)	3.261** (2.26)	4.641*** (3.70)

Continued

ser	2.175*** (5.60)	4.390*** (5.63)	.854*** (2.64)	.133* (2.10)	2.854** (1.99)	2.968*** (2.98)
edu	3.728** (0.15)	13.818* (5.49)	230.992*** (11.27)	235.320*** (11.19)	314.137*** (11.60)	258.854*** (11.08)
open	−0.476* (−1.61)	−0.640* (−1.91)	−1.108** (−2.04)	−1.250** (−2.25)	−1.338 (−1.32)	−1.534* (−1.76)
fdi	−0.409* (−1.42)	−0.645* (−1.97)	0.911* (1.96)	0.856* (1.79)	0.156** (2.21)	0.052 (0.85)
Rd	0.693*** (3.47)	0.768*** (6.85)	1.206*** (8.26)	1.258*** (8.39)	0.117* (2.25)	0.128 (0.32)
_cons	10.116** (2.47)	7.300 (1.57)	3.05*** (3.61)	2.712*** (3.13)	1.598 (1.16)	1.191 (1.00)
R2	0.8308	0.8166	0.9108	0.9077	0.7917	0.7917
F	46.65	42.29	173.69	167.17	64.63	64.63

Note: The values in parentheses are the t-test values, *, **, *** respectively indicate the test by the significance level of 10%, 5%, and 1%.

According to the regression results of the three regions in the above table, the coefficients of the proportion of the secondary industry (ind) and the proportion of the tertiary industry (ser) of the three regions are all positive, and are basically significant at the significance level of 1% and 5%. It shows that the industrial upgrading process of transferring to the secondary and tertiary industries can effectively promote the improvement of regional independent innovation ability in both developed and underdeveloped regions.

Further observation shows that among the regression results of the three regions, the coefficient of the proportion of the tertiary industry in economically developed regions is higher than that of the secondary industry, while the coefficient of the proportion of the tertiary industry in economically relatively developed regions and underdeveloped regions is lower than that of the secondary industry. It shows that in economically developed regions, the upgrading of the primary industry to the secondary industry has been completed, and the process of industrial upgrading has transitioned to the transition to the tertiary industry. Therefore, the tertiary industry plays a strong role in stimulating regional independent innovation. However, in economically relatively developed and underdeveloped regions, industrial upgrading is still in the process of transferring to the secondary industry, and the transfer to the tertiary industry is slow. So the secondary industry plays a strong role in stimulating regional independent innovation, while the independent innovation of the tertiary industry is weaker.

The reason for the difference in the influence of industrial upgrading on independent innovation between different regions can be found from the difference in the influence of control variables on the explained variables: a) although the coefficients of openness of the three regions are all negative, the overall significance of the underdeveloped regions is lower than that of the developed and the relatively developed regions. The possible reason is that the degree of openness of the underdeveloped regions is lower, and its openness does not play a strong role in independent innovation. b) the coefficient of the foreign investment level is negative in the whole country and the economically developed regions, but positive in the economically relatively developed regions and underdeveloped regions. The possible reasons are as follows: economically developed regions have good economic development and strong independent research and development capabilities, and no longer rely on technology spillovers brought about by foreign direct investment to enhance their independent innovation capabilities. In economically relatively developed regions and economically underdeveloped regions, the economic development is generally low and the independent research and development capabilities are weak. It is still necessary to learn and introduce foreign technology and experience to enhance the region's independent innovation capability.

3) Results and Analysis of System Generalized Moment Estimation Regression

In order to test the robustness of the panel data model regression results, we use the system generalized moment estimation (GMM) two-step method for estimation and sargan over-identification test for verification. The specific results are shown in **Table 9**.

Table 9. System generalized moment estimation regression results.

Variable	lnpatent	lnpatentapply
lnpatent(−1)	1.047*** (6.24)	
Lnpatentapply(−1)		0.824** (1.77)
ind	1.025*** (3.11)	1.256* (1.17)
ser	1.609*** (4.08)	1.780** (2.16)
edu	11.588** (6.20)	34.887*** (5.24)
open	−0.015 (−0.01)	−0.134 (−0.13)
fdi	−0.0.070 (−0.14)	−0.063 (−0.09)
rd	0.154** (2.24)	0.137** (2.11)
_cons	−0.564 (−0.1)	0.074 (0.01)
AR(1)	0.0134	0.0833
AR(2)	0.3964	0.3463
sargan	1.0000	1.0000

Note: The values in parentheses are the t-test values, *, **, *** respectively indicate the test by the significance level of 10%, 5%, and 1%.

According to the generalized moment estimation results of the system, the coefficients of the domestic patent application acceptance number (lnpatent) and the domestic patent application authorization number (lnpatentapply) are positive, and they are significant at 5% of the significance level, indicating that the independent innovation of the explanatory variables has strong persistence, that is, the regions with strong independent innovation in the previous period will continue to show advantages in independent innovation in the next period. Moreover, the coefficients of the secondary industry's proportion (ind) and the tertiary industry's proportion (ser) are positive, and the coefficient of the tertiary industry's proportion is greater than that of the secondary industry, which is consistent with the national panel data regression results. In addition, the explanatory variables are mainly significant at 5% of the significance level, further validating the conclusion that industrial upgrading can effectively promote the ability of independent innovation. For the control variables, a) the coefficients of higher education level are positive, and both are significant at 5% of the significance level, which is basically consistent with the results of the national panel data model; b) the coefficients of openness are both negative. However, the coefficients are not significant, indicating that although the degree of openness limits China's independent innovation to a certain extent, it has little effect; c) the coefficients of foreign investment level are both negative and not significant, indicating that China no longer relies on the technology spillover brought by foreign direct investment to enhance the independent innovation ability of enterprises, or that the technology spillover brought by foreign direct investment has little effect on China's independent innovation. d) the coefficients of R&D spending are both positive, and are significant at the significance level of 5%, which is basically consistent with the results of the national panel data model.

5. Conclusions and Recommendations

In order to explore the impact mechanism and empirical effects of industrial upgrading in China and various regions on independent innovation, this paper takes the inter-provincial panel data of 31 provinces in China from 2007 to 2016 as the research sample, and starts from the aspects of regional economic development level, regional economic benefit, people's living standard, regional transportation and communication, regional financial factors, regional resource endowment status, regional openness and regional medical and health conditions, using principal component analysis to establish a comprehensive index system for evaluating economic development level. And then this paper uses cluster analysis to classify 31 provinces in China into economically developed regions, and economic relatively developed regions and economically underdeveloped regions. Then, based on the results of regional division, this paper uses the fixed panel data model to empirically analyze the impact of national and regional industrial upgrading on independent innovation capability, and the model is tested for robustness by systematic generalized moment estimation (GMM). The results are as follows: 1) Industrial upgrading can effectively promote the improvement of national and regional independent innovation capabilities, and the industrial upgrading to the tertiary industry for the whole country can more effectively promote the improvement of independent innovation capability; 2) Regardless of whether it is in economically developed regions or economically underdeveloped regions, the process of industrial upgrading to the secondary and tertiary industries can effectively promote the improvement of regional independent innovation capabilities. However, due to the differences in regional economic development levels, the impact of industrial upgrading on independent innovation capability also differs. In economically developed regions, the tertiary industry has a stronger pulling effect on regional independent innovation, while in economically relatively developed regions and economically underdeveloped regions, the secondary industry has a stronger role in promoting regional independent innovation. 3) Independent innovation has a strong sustainability, that is, the region with strong independent innovation in the previous period will continue to show its advantages in independent innovation in the next phase. Therefore, based on the results of empirical analysis, this paper puts forward the following suggestions on the path of industrial upgrading and the improvement of independent innovation ability in China and various regions:

1) Promote industrial upgrading with innovation, and then promote the ability of independent innovation. China should strengthen the implementation of the innovation-driven development strategy, implement the innovation-driven industry upgrading strategy, and commit to building an innovative country. Innovating to drive industrial upgrading means that innovation is born in industrial upgrading and economic development. Vigorously develop key technologies and core technologies with independent intellectual property rights, use core technologies to lead the development of modern emerging industries, lead the future development direction of the industry, and then promote the transformation and upgrading of traditional industries, and improve the independent innovation capability in the transformation and upgrading of traditional industries.

2) The local government should select a local industrial upgrading strategy based on the level of local economic development. The empirical analysis of this paper shows that the industrial upgrading process to the secondary and tertiary industries can effectively promote the improvement of regional independent innovation ability in both economically developed regions and economically underdeveloped regions. However, due to the differences in the level of economic development of various regions, the impact of industrial upgrading on independent innovation capacity is also different. In economically developed regions, the tertiary industry has a stronger pulling effect on regional independent innovation, while in economically relatively developed regions and economically underdeveloped regions, the secondary industry has a stronger role in promoting regional independent innovation. Therefore, in the process of implementing in-

dustrial upgrading, we should consider the regional economic development and choose an industrial upgrading path that is more conducive to enhancing local independent innovation capabilities. Specifically, economically developed regions should give priority to the development of tertiary industries and increase the proportion and quality of tertiary industries. The regions needs to focus on developing cutting-edge science and industries such as energy conservation, environmental protection, biomedicine and information technology, so as to better enhance its capacity for independent innovation.. Economically relatively developed regions and economically underdeveloped regions should steadily develop secondary industries, strengthen exchanges and cooperation with economically developed regions, and actively use scientific and technological means and advantageous resources in developed regions to transform traditional industries to better enhance independent innovation capabilities. .

3) China should pay special attention to the independent innovation effect of industrial upgrading, provide superior conditions for vigorously improving China's independent innovation capability, formulate favorable policies, improve corresponding laws, and create a good atmosphere. First, increase investment in scientific and technological research, and accelerate the establishment of a technological innovation system with enterprises as the main body, the market as the guidance and the combination of enterprises, universities and research institutes. Encourage enterprises and various scientific research institutions to develop key and core technologies with independent intellectual property rights; Second, formulate and implement more attractive innovation and entrepreneurship policies, actively utilize domestic and foreign scientific and technological resources, and cultivate top international talents in important fields to enhance independent innovation capabilities. Third, improve the incentive mechanism for independent innovation, and encourage innovation and public entrepreneurship. Strengthen the protection of intellectual property, establish and improve laws and regulations for the protection of intellectual property rights, and improve various policies and laws and regulations related to independent innovation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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