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Research on the Relationship between Human Capital, Technological Innovation and Industrial Upgrading——Based on China's 2001-2016 Experience Data

Chao Yang[1], Gang Xu[2], Qin Li[3]

[1]*School of Management, Chongqing University of Technology, Chongqing, China*

[2]*School of Management, Chongqing University of Technology, Chongqing, China*

[3]*School of Management, Chongqing University of Technology, Chongqing, China*

Abstract: - *As China's economic development enters a new normal, industrial upgrading is an important way for China's economy to maintain sustained growth. Panel data of 29 provinces (municipalities and autonomous regions) in China from 2001 to 2016 were selected, and the panel cointegration test and error correction model were used to examine the relationship between human capital, technological innovation and industrial upgrading in China. The empirical results show that there is a significant positive correlation between China's industrial upgrading and human capital and technological innovation in both the long-term and short-term, but the impact of human capital and technological innovation on China's industrial upgrading in the long run is greater than their short-term influence to China's industry upgrading. Finally, based on the results of empirical tests, this paper gives the corresponding countermeasures.*

Keywords: *Human capital, technological innovation, industrial upgrading*

1. INTRODUCTION

Over the past 40 years of reform and opening-up, China's economy has achieved rapid growth, and its economic aggregate ranks among the top in the world. At present, China's economic development has entered a new normal, and the economic growth rate has shifted from high-speed growth to medium-high-speed growth; the economic structure has undergone comprehensive and profound changes, and it has been continuously optimized and upgraded; economic development has shifted from factor-driven and investment-driven to innovation-driven. In order to maintain sustained economic growth under the normal conditions of the new economy, we must do a good job in industrial transformation and upgrading[1], and enhance the stamina of industrial development. Industrial upgrading is defined as 'the process by which economic actors—nations, firms, and workers—move from low-value to relatively high-value activities in global production networks[2]. Industrial upgrading means improvement of industrial structure and improvement of industrial quality and efficiency. The improvement of industrial structure is manifested by the coordinated development of the industry and the improvement of structure; the improvement of industrial quality and efficiency is manifested by the optimal combination of production factors, technical level and management level, and improvement of product quality. How to achieve industrial upgrading and thus enhance the international competitiveness of the industry is an important issue in China's economic development. What are the key factors influencing the further optimization and upgrading of China's industrial structure?

2. LITERATURE REVIEW

Many literatures have studied the factors affecting industrial upgrading, and believe that human capital is an important factor affecting industrial upgrading. The mechanism of human capital's role in industrial restructuring can be summarized as three points: (1) human capital promotes industrial restructuring through changes in product supply and demand; (2) human capital promotes industrial restructuring through resource allocation; (3) human capital affects the transformation of industrial resources through production Efficiency[3-6]. There is an interactive relationship between industrial structure upgrading and human capital. The upgrading of industrial structure can increase human capital investment, thereby increasing the stock of human capital. At the same time, the process of industrial upgrading is accompanied by the optimization of human capital structure and the increase of human capital utilization rate. The transfer of labor to high-income industries promotes the upgrading and optimization of industrial structure. At the same time, the increase in income leads to the change of consumption and demand structure, and also promotes the upgrading of industrial structure; human capital can effectively integrate other production factors and improve labor productivity[4]. Niu et al.[5] considered the impact mechanism of human capital on industrial structure changes from the perspective of the production effect and allocation effect of human capital. The production effect of human capital, that is, human capital, through continuous accumulation and widening of the difference in profits of different industrial sectors, provides the necessary conditions and motivation for the industrial structure change, and determines the

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direction of industrial restructuring. The allocation effect of human capital, that is, human capital accelerates the averaging of profit margins among industrial sectors by reconfiguring various production factors, and determines the speed of industrial restructuring. Sub-regional research on China shows that human capital has a positive impact on industrial upgrading in the eastern region and negatively impacts industrial upgrading in the northeast region[7]. When the marketization level is the threshold, the role of human capital in China's industrial upgrading shows a clear threshold. With the improvement of marketization level, the promotion of human capital to industrial upgrading will gradually increase[8]. Human capital has a significant role in promoting the upgrading of China's manufacturing industry. At the same time, this promotion has a regional difference, showing a decreasing trend from east to west[9]. Zhou[10] has constructed panel dataset for 15 industrial categories in 92 countries over the period 1970–2010, the results suggest that the extent to which increased tertiary human capital promotes industrial upgrading is contingent on the level of institutional quality, which is measured by an index including size of government, legal structure, access to sound money, freedom to trade and market regulations.

Another important factor affecting industrial upgrading is technological innovation. Zheng et al.[11] selected the technical human capital level, the patent authorization rate and the R&D expenditure internal expenditure as the index of technological innovation as an indicator to measure technological innovation, and studied the relationship between technological innovation and the upgrading of advanced manufacturing industry in Fujian Province. The empirical research results show that the technical manpower Capital levels, patent licensing rates, and internal expenditures for R&D funds all have a positive impact on industrial upgrading. Wang et al.[12] divided technological innovation into independent innovation and technological imitation. The impact of independent innovation on industrial upgrading is very significant, while the impact of technological imitation on industrial upgrading has a threshold effect: when the marketization level is lower than the threshold, technology Imitation has a significant positive impact on industrial upgrading, and its impact is not obvious when the marketization level is higher than the threshold. Sub-regional research on China shows that technological progress is positively related to industrial upgrading in the eastern and central regions, and negatively related to industrial upgrading in the northeast region[7]. Technological innovation has a significant role in promoting China's manufacturing upgrade, but presents The trend of decreasing from east to west[9]. Li et al.[13] showed that there is a positive interaction between technological innovation, industrial upgrading and economic growth in eastern China, but no such positive interaction is formed in the central and western regions.

In addition to human capital and technological innovation, there are also some important factors that affect industrial upgrading: FDI (foreign direct investment), fixed asset investment, and trade openness. Trade openness promoted the optimization of industrial structure through import competition, which promoted the upgrading of China's industry. The promotion of trade openness in China's industrial upgrading is more significant in non-state-owned enterprises than in state-owned enterprises, and the performance in enterprises in inland areas is more significant than in coastal areas[14]. Yan et al.[15] showed that there is a positive correlation between financial development, trade opening and China's industrial upgrading. The positive impact of financial development on China's industrial upgrading has shown a downward trend from east to west, while the impact of trade openness on the eastern part of China is not significant. The overall impact of foreign direct investment on China's industrial upgrading is positive. The relationship between foreign direct investment and industrial upgrading is different due to the specific industry: manufacturing FDI has always promoted industrial upgrading, but with technological upgrading, productive services FDI may inhibit industrial upgrading[16]. The role of trade openness, foreign direct investment in promoting industrial upgrading is not limited to China. By comparing the development patterns of China and Mexico, we can find that international trade and FDI have played major roles in promoting industrial upgrading in China and Mexico[17]. The experiences of four Central European (CE) countries (Czech Republic, Hungary, Poland and Slovakia) have implied that FDI acts as an important stimulus for rapid industrial restructuring and production growth, including industrial upgrading and enhanced position in the international division of labor[18].

3. MODEL CONSTRUCTION AND VAR-IABLE SETTING

3.1 Model Construction

This paper mainly studies the impact of human capital and technological innovation on industrial upgrading. Therefore, industrial upgrading is regarded as the explained variable, human capital and technological innovation are the core explanatory variables. The following control variables are set on the basis of reading and combing the existing literature: fixed asset investment, foreign direct investment, trade openness and the model is built as follows:

$$IND_{it} = c_i + \alpha_1 HUM_{i,t-1} + \alpha_2 INNO_{i,t-1} + \alpha_3 INV_{i,t-1} + \alpha_4 FDI_{i,t-1} + \alpha_5 OPEN_{i,t-1} + \mu_{it} \quad (1)$$

i Representing different provinces, t representing different years, c is a constant term, *IND* indicating industrial upgrading, *HUM* representing human capital, *INNO* representing level of technological innovation, *INV* representing investment in fixed assets, *FDI* representing foreign direct investment, *OPEN* representing openness to trade, and μ representing random error term.

3.2 Variable Setting

This paper draws on the practice of Xu et al[19], and uses the industrial structure upgrading index to describe the industrial upgrading. The industrial upgrading index is the sum of ratio of the primary industry, the secondary industry, and the tertiary industry to the total output value multiplied by 1, 2, and 3, respectively. Human capital is calculated by the method of education years, that is, the calculation of the per capita education period. The specific calculation formula is: human capital = (1.5 * education level below primary school population + 6 * primary education level population + 9 * junior high school education level population + 12 * High school education level population +16* tertiary education level and above population) / total population. The level of technological innovation is the domestic granted amount of three kinds of patent of provinces, municipalities and autonomous regions. INV is measured by the total investment in fixed assets of the provinces, municipalities and autonomous regions. FDI is measured by the actual use of foreign direct investment in the provinces, municipalities and autonomous regions. Trade openness is the ratio of total import and export trade to gross domestic product. The formula is: trade openness = import and export trade volume * annual average exchange rate / gross domestic product.

Table 1: *Variable settings, build methods, and data sources*

Index	*Variable*	*Construction Method*	*Data Sources*
Industrial structure upgrading index	*IND*	sum of ratio of the primary industry, the secondary industry, and the tertiary industry to the total output value multiplied by 1, 2, and 3, respectively	Statistical Yearbooks of provinces, municipalities and autonomous regions
Human capital	*HUM*	Average years of schooling	China Statistical Yearbook
Fixed asset investment	*INV*	Total investment in fixed assets	Statistical Yearbooks of provinces, municipalities and autonomous regions
Technological innovation	*INNO*	three kinds of domestic patent authorizations	China National Intellectual Property Office
Foreign Direct Investment	*FDI*	Actual use of foreign direct investment amount	Statistical Yearbooks of provinces, municipalities and autonomous regions
Trade openness	*OPEN*	Import and export trade volume* annual average exchange rate/GDP	Statistical Yearbooks of provinces, municipalities and autonomous regions

4. EMPIRICAL ANALYSIS

4.1 Descriptive Statistics of Variables

This paper uses EViews 9 software to empirically analyze the panel data of 29 provinces (municipalities, autonomous regions) in China from 2001 to 2016, and examine the relationship between human capital, technological innovation and industrial upgrading. Before conducting the empirical test, analyze the descriptive statistics of each variable firstly. The analysis results are shown in Table 2.

Table 2: *Panel data descriptive statistics*

	IND_{it}	HUM_{it}	$INNO_{it}$	INV_{it}	FDI_{it}	$OPEN_{it}$
Mean	2.303058	8.506626	6.836046	7233.231	340.1336	0.330949
Median	2.278948	8.441090	2.483218	3986.945	179.5695	0.128113
Maximum	2.797000	12.17570	79.27746	48312.46	2257.322	3.131471
Minimum	2.07000	6.319886	0.241030	154.8300	1.062119	0.035720
Std. Dev.	0.123856	0.971169	11.43654	8111.424	423.5697	0.420113
Skewness	1.699720	0.744362	3.073548	1.930940	1.881430	2.173256
Kurtosis	6.693709	4.227063	13.23859	7.303348	6.459952	8.535845
Observations	464	464	464	464	464	464
Cross sections	29	29	29	29	29	29

From the statistics of Table 2, it can be found that the standard deviation of industrial structure upgrading index, human capital and trade opening is small, indicating that the gap between industrial structure upgrading index, human capital and trade openness of China's provinces (municipalities and autonomous regions) is small; The standard deviation of asset investment and foreign direct investment is large, indicating that the gap between fixed assets investment and foreign direct investment in China's provinces (municipalities and autonomous regions) is large. This is mainly because the economic development of various provinces (cities, autonomous regions) is uneven, leading to the large differences in financial capacity and ability to attract foreign investment of various provinces (municipalities, autonomous region).

4.2 Stationarity Test of Variables

The stationarity test of the variable is the unit test of the variable unit. Before performing regression analysis, it is necessary to check whether the variables are stable. If it is not stable, it will lead to pseudo-regression problems. The unit root test is performed on

each variable in EViews 9 using the LLC method. The test shows that except for the human capital, the level sequences of the other variables have not passed the unit root test, but the 1st difference sequences of all variables ($dIND_{it}$, $dHUM_{it}$, $dINNO_{it}$, $dINV_{it}$, $dFDI_{it}$, $dOPEN_{it}$) have passed the panel unit root test, it shows that all variables are integrated of order, and can be used to perform equation regression. The unit root test results are shown in Table 3.

Table 3: *Unit root test results*

Variable	*Statistics*	*Prob.*
$dIND_{it}$	-15.5861	0.0000
$dHUM_{it}$	-13.5909	0.0000
$dINNO_{it}$	-6.10098	0.0000
$dINV_{it}$	-6.25991	0.0000
$dFDI_{it}$	-11.1376	0.0000
$dOPEN_{it}$	-10.1709	0.0000

4.3 Panel Cointegration Test

The panel data cointegration test methods are mainly divided into two categories: panel cointegration test based on residuals and Johansen cointegration test. The residual-based panel cointegration test is based on the EG two-step test method, including homogenous panel cointegration test and heterogeneous panel cointegration test. Their original hypothesis is that there is no cointegration relationship between panel variables. . For the homogenous panel cointegration test, if the null hypothesis is rejected, all individuals have a cointegration relationship; for the heterogeneous panel cointegration test, if the null hypothesis is rejected, some of the variables have a cointegration relationship. In EViews, the homogenous panel cointegration test method is Kao[20]test, and the heterogeneous panel cointegration test is Pedroni test[21, 22].

In this paper, the Kao test and Pedroni test are used to perform co-integration test on the selected panel data. The test results are shown in Table 4. It can be seen from the test results that 6 out of 8 statistic rejects the null hypothesis at the level of 1%, so it can be considered that there is a long-term equilibrium and stable relationship between panel variables.

Table 4: *Panel cointegration test result*

Testing method	*Statistic name*	*Statistical value*	*Prob.*
Kao test	ADF	-3.593198	0.0002
Pedroni test	Panel v-statistic	-3.799893	0.9999
	Panel rho-statistic	4.817332	0.0000
	Panel pp-statistic	-3.640451	0.0001
	Panel adf-statistic	-4.459114	0.0000
	Group rho-statistic	7.028508	1.0000
	Group pp-statistic	-5.407608	0.0000
	Group adf-statistic	-4.072739	0.0000

The panel cointegration test results show that the panel variables selected in this paper have a long-term equilibrium relationship, which can be analyzed by regression. The OLS is used to regress the panel data, and the results are shown in Table 5.

Table 5: *Cointegration regression results*

Variable	*Coefficient (Std. Error)*	*Prob.*
c	2.001569 (0.036446)	0.0000
HUM_{it}	0.032275 (0.004529)	0.0000
$INNO_{it}$	0.000842 (0.000234)	0.0004
INV_{it}	2.60e-06 (3.72E-07)	0.0000
FDI_{it}	-5.05e-06 (1.01E-05)	0.6158
$OPEN_{it}$	0.012479 (0.008559)	0.1456

The level of human capital has a significant positive impact on China's industrial upgrading. The level of human capital has increased by 1%, and the index of China's industrial structure upgrading will increase by 0.03%. The improvement of human capital level will help the production efficiency of the industry and contribute to the improvement of scientific and technological innovation. These are important conditions for industrial upgrading. Secondly, the level of human capital is improved, and the factors can be more efficiently allocated to improve production efficiency. To further promote industrial upgrading.

The level of technological innovation has a significant positive impact on China's industrial upgrading. The level of technological innovation has increased by 1%, and the index of China's industrial structure upgrading will increase by 0.0008%. On the one hand, technological innovation improves industrial production efficiency, reduces production costs, eliminates backward industries, and promotes industrial transformation and upgrading by improving traditional industrial development methods. At the same time, the development of emerging industries also needs to gain momentum through technological innovation. On the other hand, the upgrading of products and processes brought about by technological innovation can stimulate new demands, and products with low technology content will gradually be replaced by high-tech products, thus promoting industrial transformation and upgrading[8, 9]. The level of technological innovation in this paper has little impact on industrial upgrading. The possible reason is that the selection of innovation level indicators is one-sided: it is not enough to measure the innovation level only by the three domestic patent authorizations. At the same time, R&D funding internal expenditure should also be considered.

Fixed asset investment has a significant positive impact on China's industrial upgrading, but its impact on

China's industrial upgrading is relatively small. Industrial upgrading is not only accompanied by an increase in production efficiency, but also with the investment, construction and upgrading of fixed assets, so fixed assets have a significant positive impact on industrial upgrading. The impact of fixed asset investment on industrial upgrading has a strong lag effect, so its impact is small.

Foreign direct investment has a negative impact on China's industrial upgrading, but the impact is not significant. For a long time, foreign capital investment in China has mainly focused on production and manufacturing. Many internationally renowned companies have set up production bases in China, while high-tech links such as design and R&D remain in their own countries, which explains why foreign countries direct investment has a negative impact on China's industrial structure upgrade.

Trade openness has a positive impact on China's industrial upgrading. Trade openness has strengthened economic and trade exchanges between China and the rest of the world, and has played an important role in promoting China's economic development. The economic development has also promoted China's industrial upgrading. However, the positive impact of trade liberalization on China's industrial upgrading is not significant. This shows that with the deepening of reform and opening-up, China's industrial upgrading has become less dependent on import and export trade.

4.4 Error Correction Model

The results of the cointegration test indicate that there is a long-term equilibrium relationship between China's industrial upgrading and human capital stocks and technological innovation levels, but this long-term equilibrium relationship does not necessarily manifest itself in the short term. When they deviate from the long-term equilibrium in the short term, it needs to be adjusted using the Error Correction Model (ECM)[23].

Establish an error correction model:

$$dIND_{it} = \delta_i + \beta_1 dHUM_{i,t-1} + \beta_2 dINNO_{i,t-1} + \beta_3 dINV_{i,t-1} + \beta_4 dFDI_{i,t-1} + \beta_5 dOPEN_{i,t-1} + \beta_6 EC_{i,t-1} + \varepsilon_{it} \quad (2)$$

δ_i represents the intercept term, $dIND_{it}$, $dHUM_{i,t-1}$, $dINNO_{i,t-1}$, $dINV_{i,t-1}$, $dFDI_{i,t-1}$, $dOPEN_{i,t-1}$ represent the first order difference of IND_{it}, $HUM_{i,t-1}$, $INNO_{i,t-1}$, $INV_{i,t-1}$, $FDI_{i,t-1}$, $OPEN_{i,t-1}$ respectively, $EC_{i,t-1}$ is the term of the residual sequence lags one period, ε_{it} is a random error term. The error correction model is regressed, and the results obtained are shown in Table 6.

Table 6: *Error correction model regression results*

Variable	*Coefficient (Std. Error)*	*Prob.*
δ	0.002937	0.0000
	(0.001073)	
$dHUM_{i,t-1}$	0.001615	0.0534
	(0.002598)	
$dINNO_{i,t-1}$	0.000177	0.0320
	(0.000178)	
$dINV_{i,t-1}$	1.23e-06	0.0000
	(5.87E-07)	
$dFDI_{i,t-1}$	-7.37e-06	0.1761
	(5.44E-06)	
$dOPEN_{i,t-1}$	0.002455	0.3007
	(0.002368)	
$EC_{i,t-1}$	-0.772987	0.0000
	(0.097057)	

The results of the error correction model show that human capital, technological innovation, fixed asset investment, and trade openness have a positive impact on China's industrial structure upgrading in the short term. The positive impact of human capital on China's industrial structure upgrading is significant at 10%. The positive impact of technological innovation on China's industrial structure upgrading is significant at 5%. The positive impact of fixed asset investment on China's industrial structure upgrading is significant at 1%. The impact of trade openness on the upgrading of China's industrial structure is not significant. The impact of human capital, technological innovation, fixed asset investment and trade openness on China's industrial structure upgrading in the short term is less than their impact in the long run. Foreign direct investment has a negative impact on China's industrial structure upgrading in the short term, and the short-term impact is greater than the long-term impact, but its impact is not significant. The coefficient of the error correction term is -0.772989, which indicates that when the previous-phase's industrial structure upgrading index deviates from the long-term equilibrium, in order to maintain the long-term equilibrium relationship between the industrial structure upgrading index and human capital, technological innovation and other influencing factors, the error correction will adjust to the long-term equilibrium state with a reverse force of 0.772989.

5. CONCLUSION AND COUNTERMEASURES

The results of empirical tests show that there is a significant positive correlation between human capital, technological innovation and fixed asset investment and China's industrial upgrading in the long-term and short-term. In the long-term and short-term, the human capital level increased by 1%, China's industrial structure upgrading index increased by 0.03% and 0.0016%, the level of technological innovation increased by 1%, and China's industrial structure upgrading index increased by 0.0008% and 0.0002% respectively. There is a positive correlation between trade openness and China's industrial upgrading. There is a negative correlation between foreign direct investment and China's industrial upgrading, but their impact on China's industrial upgrading is not significant. When the industrial structure upgrading index deviates from the long-term equilibrium, in order

to maintain the long-term equilibrium relationship between the industrial structure upgrading index and human capital, technological innovation and other influencing factors, the error correction item will adjust to the long-term equilibrium state with the reverse strength of 0.772989.

Based on the above empirical results, this article has the following implications: (1) Increase investment in education and form a good interaction between the continuous accumulation of human capital and the continuous improvement of technological innovation. The growth momentum of China's economy is gradually shifts from factor-driven to innovation-driven. Innovation will be the foundation for China's economy to maintain growth and vitality. It is necessary to focus on the role of human capital, accelerate the cultivation of innovative talents, accelerate domestic independent innovation and research and development, and improve the level of domestic technological development, in order to promote the optimization and upgrading of China's industrial structure. (2) Adhere to the basic national policy of opening-up and promote the upgrading of industrial structure by opening-up. For a long time, China's export products are mainly low-value-added and low-tech products. Relevant policies should be introduced to promote the export of high value-added products and high-tech products, change the structure of export industries, and make the composition of export products more balanced. The development of high-tech industries promotes the upgrading of industrial structure. (3) Focus on the quality of foreign investment and introduce advanced technology and experience. With the continuous development of China's economy and science and technology, the gap between China's and developed economies in terms of technology and management experience is shrinking. In addition, in the process of realizing the upgrading of their own industries, developed economies have transferred their low-end industries or industries that are about to be phased out to China. The role of foreign capital in promoting China's industrial upgrading has become less and less obvious, and even has a negative effect. Therefore, when introducing foreign capital, China should pay attention to the quality of foreign capital, combine the development plan of China's economic development and industrial upgrading, and introduce high-quality foreign capital to play a positive role in promoting China's industrial upgrading.

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