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Symbiotic Relationship between Higher Engineering Education and Manufacturing Industry in China

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ABSTRACT

According to the requirements of the current “knowledge economy era” background, to explore the harmonious symbiosis between higher engineering education and manufacturing industry with the state space model, the results show that: the investment of higher engineering education has obvious influence on the factor of “higher engineering teachers’ input”, and the intermediary effect of “higher engineering teachers’ input” is obvious.

Keywords: higher engineering education, manufacturing industry, coordination relationship, causal relationship

INTRODUCTION

At present, in the context of economic growth, which is relying more and more on the production, diffusion and application of knowledge in the world, “knowledge economy” emerges as the times require, for knowledge economy, it is a knowledge-based economy, and it is based on the production, distribution and use (consumption) of knowledge, and it is seen as “the knowledge-based economy” that regards the accumulation of knowledge as an endogenous independent factor of economic growth, it believes that: the knowledge can improve the benefit of investment, the accumulation of knowledge is the source of modern economic growth, and human capital is playing an important role of the technological progress and knowledge accumulation, and considers that special and specialized human capital is the real source of economic growth. Now, with the developing of information and network technology, the updating of knowledge is very fast, to get an education and learning has become one of the most important activities in life.

Higher engineering education aims at training advanced engineering and technical personnel with high professional knowledge and operation skills, and it is the basic force to improve the manufacturing knowledge and technology level. In recent years, China’s higher engineering education has achieved rapid development in line with the requirements of the era of “knowledge economy”, as of 2016, the number of engineering students in colleges and universities in China has reached 5.12 million, accounting for 40% of the total number of engineering students in the world, and it is the largest scale of higher engineering education in the world. Under the influence of global strategy of “industry 4.0 and manufacturing return”, in order to effectively identify the development efficiency of higher engineering education in China, it is necessary to study the coordination and symbiosis between higher engineering education and manufacturing industry, and this study is of great practical significance for

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Contribution of this paper to the literature

- Foresight this paper, taking full account of the intermediary variable factors, to study the harmonious symbiosis relationship between higher engineering education and manufacturing industry, compared with the traditional research, it has important innovative and practical significance in the selection of variable factors.
- This paper, to adopt the state space model, which can be more practically reflected the time-varying effect of educational input on economic growth in different periods, it has important contribution to the existing literature to explore the symbiotic relationship between higher engineering education and manufacturing industry more accurately.

improving the quality and efficiency of higher engineering education, and improving the knowledge and technology content of China's manufacturing industry.

LITERATURE REVIEW

Recently, the relationship between education investment and industrial economic growth has been a hot issue in academic research, and more and more achievements have been made, which include that:

The Contribution Rate of Educational Input to Industrial Economic Growth

Denison. E. F first set the education as an input to human capital (Denison, 1983; Gao and Wang, 2017), and made a research to calculate "the return of educational capital" to measure "the contribution of education investment to the economy", and in China, many scholars have made great achievement in the quantitative measurement of the contribution rate of higher education investment to regional economic growth (Hui Min Qian, 2013; Lin, 2017; Song et al., 2017).

The Relationship between Educational Input and Industrial Economic Growth

In this field, R. Blundell, L. Dearden and B. Sianesi believed that education development is the driving force of economic growth (Blundell et al., 2015; Park and Kim, 2017), and M.E. Menon believed that the reason for the education development is economic growth (Menon, 1997), and education is the result of economic development, and the education investment promotes economic development, and later, Bing. G and King. X. Lee divided the investment of higher education into broad definitions of human and financial factors (Bing, 2010; King and Wang, 2009), and made a quantitative measurement on the "grainger causality" among educational investment and human input and GDP growth.

The Impact of Specific Factors of Education Investment on the Industrial Economic Growth

Many studies have been made to explore the impact of specific factors of education investment on the industrial economic growth (Lolas and Olatun bosun, 2008), and have achieved rich results, but the existing statistical literature has not given a clear scope of the specific indicators-selection of education input, at present, the research on the impact of education investment on economic growth is mostly from the perspective of the total amount of education input, lacking segmentation of the specific content of education input, and it has blurred the actual influence degree of "teacher's personnel input" index, and neglected the importance of human capital in the context of "knowledge economy era".

Research Review

Seen from the current literature, on the whole, in the study of the relationship between education input and economic growth at home and abroad, most studies limit the content of education input into the category of "educational investment", and other factors such as the number of teachers etc are not considered, and the targeted

research on higher engineering education is relatively few (Yin and Qing, 2007; Chen and Han, 2008), and for the study results, the actual degree of influence between engineering education and economic growth is blurred.

Then, seen from the point of view of research methods, the traditional regression model is often used in the measurement of the relationship between educational input and economic growth, and it is assumed that the estimation parameters are unchanged, then it is failed to consider the time-varying effect of educational input on economic growth in different periods (Tang, 2013).

This paper, taking full account of the intermediary variable factors, to study the harmonious symbiosis relationship between higher engineering education and manufacturing industry with the state space model, compared with the traditional research, it has important innovative and practical significance in the selection of variables and the choice of research methods, and it has important contribution to the existing literature to explore the symbiotic relationship between higher engineering education and manufacturing industry more accurately.

STAGE CHARACTERISTICS OF HIGHER ENGINEERING EDUCATION IN CHINA

Since 1990s, the higher engineering education in our country has undergone great changes, mainly in the school scale, number of engineering teachers and educational funds:

The Scale of Engineering College Students

In 1995 China's engineering college students was 1.23 million, as to 2016, the number of engineering college students has reached 5.12 million (Wang and Li, 2009), and from the development characteristics of each period, it can be roughly divided into three stages:

1995-1998 is the steady growth stage of engineering students scale, at this stage, although the scale of engineering students has expanded year by year, the growth trend is relatively mild.

1999-2006 is the rapid expansion stage, the first reason is the increase in population base (That is, the peak birth rate started in early 1980s, which resulted in an increase in the number of school-age candidates), and the popularization of higher education in China has also led to the rapid expansion of engineering college students.

And 2007 so far is transformation and adjustment stage of engineering students scale, at this time, because of the one-child policy, resulting in a decline in population, the number of school-age students decreased, the higher engineering education has entered a stage of transformation and adjustment from denotative quantity expansion to connotation quality upgrading.

Number of Employed Teachers in Engineering Education

1998-2001 is gentle development stage, the total number of employed teachers in engineering has little changes, the number of professional teachers has increased by about 83.1 thousand, compared with the growth rate of students, the growth rate of teachers is relatively slow.

2002-2009 is the expand and ascending stage, since 2002, the enrollment expansion in colleges and universities led to the marked increase of internal students, in order to complete the task of education and teaching, large-scale recruitment of teachers has been carried out, among which the total number of full-time engineering teachers has increased by 508.9 thousand.

2009 so far is steady growth stage, since 2009, China's Ministry of education has begun to carry out teaching quality inspection, along with the stability of the number of students enrollment, the colleges and universities began to focus on improving the teachers' overall quality, the number of engineering teachers gradually slowed down and entered a steady growth period.

Table 1. Stationary Test Results of Residual Sequence

Variable	Lagged rank	P	Test results (0.05%)
lnA1	2	0.0110	Stationary
lnA2	1	0.0106	Stationary
lnA3	2	0.0061	Stationary

Educational Funds Input

Since 1995, the total amount of funds input in engineering education in China has shown a continuous upward trend, in 1995, China’s higher engineering educational funds invested 10.21 billion, in 2016, it is up to 682.69 billion, from the development characteristics of stage, 2003 can be seen the dividing line, showing inverted “V” shape of “first rose and then fell”, the growth rate of investment was higher before 2003 and then began to decline.

From the above analysis, it can be seen that, on the whole, China’s higher engineering education has achieved rapid development in the past decade and more years, teacher input and educational investment have provided strong support for the development of higher engineering education (Lang, 2004; Ming., 2012), but compared with the scale growth of higher engineering education, the investment of full-time engineering teachers and educational funds is still insufficient (Wei and Guo, 2011), in some extent, it also affected the quality of China’s manufacturing industry growth (now, China’s manufacturing industry is still in the stage of high investment, high emission and low production, the quality of products is unstable, and there are not many star enterprises and star products in the manufacturing field).

RESEARCH DESIGN

Variable Selection and Data Resources

In order to highlight the importance of human capital under the background of knowledge economy, to select the number of engineering teachers (A1) as the input factors of manpower, and the total amount of engineering education expenditure (A2) is regarded as the input factor of resources, and the gross domestic product (A3) is used as the indicator of the manufacturing industrial economic output, the sample data can be obtained from the 2000-2016 years of “China Statistical Yearbook”, “China Education Funding Statistics Yearbook” and “China Education Statistics Yearbook”, in order to eliminate the heteroscedasticity of the time series, in this case, the relevant data is processed by the logarithm method (which does not change the relationship between the original variables). as lnA1,lnA2 and lnA3.

Analysis of Symbiotic Relationship between Higher Engineering Education and Manufacturing Industry

In order to study the impact of engineering education investment (A2) and the investment of full-time engineering teachers(A1) on the economic growth of manufacturing industry(A3), this study, “grainger causality test” is applied to test and analyze the linkage of lnA1, lnA2 and lnA3.

Analysis of co-integration test

To avoid pseudo-regression which may be caused by the instability of economic variables, it is needed to test the stationarity of the sample data, that is, unit root test is conducted before the grainger causality test.

With SPSS 19.0 software, to make ADF test for the unit roots of lnA1, lnA2 and lnA3, the results are shown in **Table 1**, and it can be seen that at the significant level of 5%, lnA1, lnA2 and lnA3 are stationary variables, and no spurious regression exists.

Table 2. Results of Granger Test between Variables

Null hypothesis	F-test	Adjoint Probability	Test results
Hypothesis 1: lnA3 is not lnA2's granger cause	1.4504	0.1481	Accept
Hypothesis 2: lnA2 is not lnA3's granger cause	7.6835	0.0099	Refuse
Hypothesis 3: lnA1 is not lnA2's granger cause	0.9661	0.1210	Accept
Hypothesis 4: lnA2 is not lnA1's granger cause	10.9876	0.0081	Refuse
Hypothesis 5: lnA1 is not lnA3's granger cause	8.6311	0.0033	Refuse
Hypothesis 6: lnA3 is not lnA1's granger cause	0.8766	0.1379	Accept

Table 3. State Space Models

	1	2	3
measurement equation	$\ln A3 = c_1 + sv_1 * \ln A2 + sv_2 * \ln A1 + \mu_1$	$\ln A3 = c_2 + sv_3 * \ln A2 + \mu_2$	$\ln A2 = c_3 + sv_3 * \ln A1 + \mu_3$
state equation	$sv_1 = sv_1(-1), sv_2 = sv_2(-1)$	$sv_3 = sv_3(-1)$	$sv_4 = sv_4(-1)$

Granger causality test analysis

In order to see the dependence causality of A1, A2 and A3, Granger causality method should be adopted for further test analysis, now to use the statistical software of Eviews 8.0, to choose minimum principle, perform significant judgment by log-likelihood estimated value, and adopt AIC and SC methods, the calculation results are shown in **Table 2**.

As shown in **Table 2**, at a significant level of 5%, lnA1 and lnA2 is the Grainger reason for lnA3, and lnA2 is lnA1's Grainger reason, lnA2 influences lnA3 through direct effect and mediating effect, and the other causal relationships are not valid.

TIME-VARYING EFFECT ANALYSIS

Concerning the larger span of 2000-2016 years, to build state space models to calculate the direct influence of A2 on A3 and the indirect effects brought by the mediating effect of A1, it can accurately estimate the time-varying effects and vary trends of variables.

Taking into account the mediation effect, it is needed to use the three measurement equations, as: the measured equations of the explanatory variable A3 and mediator variable A1 to the explanatory variable A2, the measured equations of the explanatory variable A3 to the explanatory variable A2, the measurement equation of the mediator variable A1 to the explanatory variable A2, the three state space models are shown in **Table 3**:

Among them, c_1, c_2, c_3 are constant terms, μ_1, μ_2, μ_3 are random interference terms, and sv_1 is the variable coefficient of A2 to A3, sv_2 is the variable coefficient of A1 to A3, sv_3 is the variable coefficient of A2 to A3 when A2 is the only independent variable, sv_4 is the variable coefficient of A2 for A1.

Analysis of the State Space Models Results

To estimate the state space model with SPSS 19.0 software, the temporal variation of the four state variables results are shown in **Figure 1** to **Figure 4**, and it can be seen that A2 and A1 have a continuing positive effect on A3.

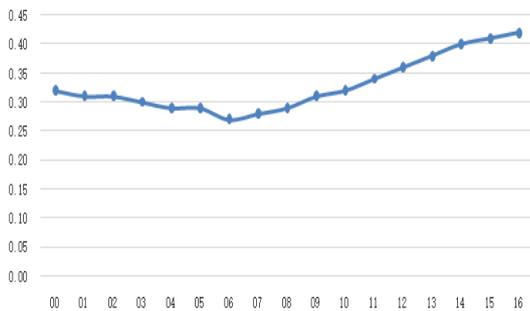


Figure 1. The result of sv_1

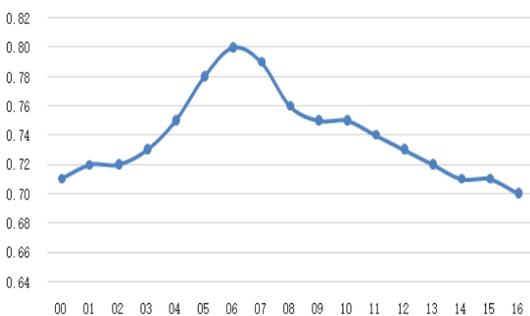


Figure 2. The result of sv_2

As shown in **Figure 1**, the impact of A2 on A3 (sv_1) shows the characteristics of “slow decline in the early stage and slow increase in the later stage” taking 2006 as the dividing line, and it is closely related to the development of higher engineering education in China, during the 2002-2006 years, higher engineering education has been expanding rapidly with the expansion of the national higher education enrollment policy in China, and the huge scale of engineering education has aggravated the shortage of educational funds, which has made the input of engineering educational funds fail to achieve the maximum effectiveness. From 2006, China began to reduce the enrollment rate of engineering education, and gradually increased the input of financial educational funds, and the pulling effect of A2 on A3 gradually increased.

Seen from **Figure 2**, the impact of A1 on A3 (sv_2) shows the characteristics of “slow decline in 2000-2005 and slow increase in 2006-2016”, and mainly due to the expansion of engineering education scale and the increase of scientific research funds and engineering science and technology resources, the positive impact of A1 on A3 is increasing in 2000-2005, but in recent years, because of the transformation and upgrading of the industrial structure in China, the demand for engineering talents has changed, and the engineering education has lagged behind the transformation and development of the manufacturing industry, and there are many problems such as the shortage of teachers with engineering experience, and the separation of teaching activities from engineering practice, which have caused the impact of A1 on A3 is weakening.

sv_3 stands for the full effect of A2 on A3 (shown in **Figure 3**) containing direct effects and mediating effects, its changing trend is consistent with that of sv_1 , showing a dynamic change trajectory of “slight rise - fall - rise”. And sv_4 stands for the full effect of A2 on A1 (shown in **Figure 4**), it is of the dynamic trajectory of “fall - slight rise”, and the effect is always slight rise from 2002, which shows the positive pulling effect of A2 on A1.

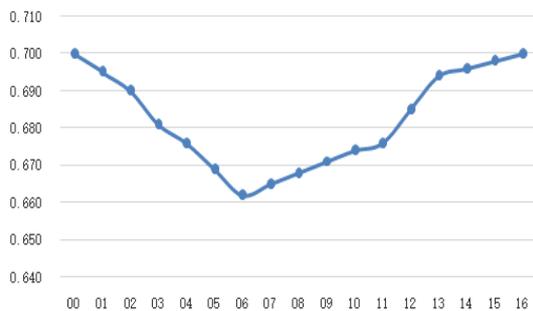


Figure 3. The result of sv₃

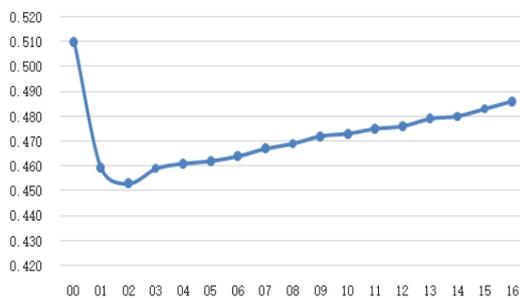


Figure 4. The result of sv₄

Mediator Effect Calculation

Mediating effects are used to measure the effects of independent variables acting on non-independent variables through mediation variables, seen from above, it can be seen that the effect of A2 on A3 is mediated by A1 as a mediator, and A1 has mediating effect as mediator variable, and using the method proposed by Mackinnon, as:

$$m = sv_2sv_3 / (sv_2sv_4 + sv_1) \tag{1}$$

In Equation (1), m is the value of the proportion of intermediary utility, the calculation results are shown in Figure 5.

Seen from Figure 5, an average of 51.6% of the effect of A2 on A3 comes from the mediating effect of A1, in the whole period of 2000-2016, the intermediary effect of A1 generally shows the dynamic track of “rise - fall - rise”, and there are two dividing lines in 2006 and 2012, firstly in 2000-2006, the mediating effect of A1 showed a “rising” trend, and in 2006-2012, it showed a “falling” trend, then in 2012-2016, showed the trend of “rising” again, it is mainly because the ministry of education has put forward the requirement of “renewing the educational paradigm and further promoting the educational system reform”, and the human capital investment of engineering teachers was increased, so the mediator effect of A1 began to rise again.

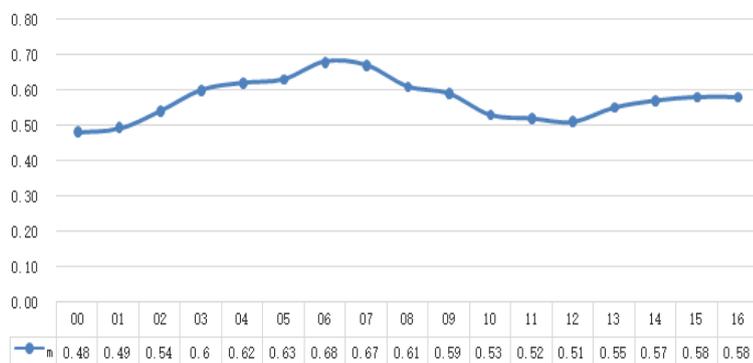


Figure 5. Proportion of intermediary utility

RESEARCH CONCLUSIONS

This paper is to research the symbiotic relationship between higher engineering education and the manufacturing industry in China from 2000 to 2016, and to explore the impact of the investment in higher engineering education and full-time engineering teachers on the manufacturing industry using state space model, and further analyze the intermediary role of full-time teachers in engineering, the following conclusions can be drawn:

Firstly, based on the scale of engineering education and the educational investment in China in 2000-2016, it can be seen that the scale of higher engineering education in China is in the changing stage from the denotative expansion to connotative quality upgrading, and educational funds input is still insufficient relative to the scale of growth of higher engineering education development, the contribution of education to the economic growth of manufacturing industry is relatively low, and it is still in the stage of transition from industrial input-driven economy to knowledge economy.

Secondly, in the view of the impact of higher engineering educational funds and engineering teachers' input on economic growth, the influence of investment in higher engineering education and input of engineering teachers on manufacturing industry growth showing a positive time-varying effect.

Thirdly, as for the intermediary effect of the full-time engineering teachers, in the effect of the input of higher engineering education on economic growth, 51.6% of the average proportion comes from the intermediary effect of the factor of full-time engineering teachers.

In addition, due to limited space, the suggestions on the coordinated development between higher engineering education and manufacturing industry in the context of the "knowledge economy era" will be further studied in another manuscript.

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REFERENCES

Bing, G. (2010). Policy and enlightenment of continuing education development in Hongkong in the era of knowledge economy. *Continuing Education Research*, (04), 13-19. doi:10.3969/j.issn.1009-4156.2010.04.006.

- Blundell, R., Dearden, L., & Sianesi, B. (2005). Evaluating the effect of education on earnings: models, methods and results from the national child development survey. *Journal of the Royal Statistical Society*, (03), 473-512. doi:10.1111/j.1467-985X.2004.00360.x
- Denison, E. F. (1983). The interruption of productivity growth in the United States. *Economics Journal*, (369), 56-57. doi:10.2307/2232164.
- Gao, W., & Wang, W. F. (2017). The fifth geometric-arithmetic index of bridge graph and carbon nanocones. *Journal of Difference Equations and Applications*, 23(1-2SI) 100-109. doi:10.1080/10236198.2016.1197214
- Jiaqing, C., Zhansheng, H., & HengPing, G. (2008). Higher education of engineering in France and its developing tendency. *Research in Higher Education of Engineering*, (04), 27-32. doi:10.3969/j.issn.1001-4233.2008.04.004
- King, X., & Lee, D. W. (2009). Continuing education of high-level professional and technical personnel in knowledge economy. *Education for Chinese After-school*, (01), 133-138. doi:10.3969/j.issn.1004-8502-B.2009.01.112
- Lin, J.-W. (2017). A Cross-Grade Study Validating the Evolutionary Pathway of Student Mental Models in Electric Circuits. *Eurasia Journal of Mathematics Science and Technology Education*, 13(7), 3099-3137. doi:10.12973/eurasia.2017.00707a
- Lolas, S., & Olatunbosun, O. A. (2008). Prediction of vehicle reliability performance using artificial neural networks. *Expert Systems with Applications*, (34), 2360-2369. doi:10.1016/j.eswa.2007.03.014
- Menon, M. E. (1997). Perceived rates of return to higher education in Cyprus. *Economics of Education Review*, (04), 425-430. doi:10.1016/S0272-7757(96)00065-9
- Ming, L. (2012). To research on the problems and countermeasures of higher education funding in China from the perspective of finance. *Journal of Huazhong Normal University*, (3), 154-159. doi:10.3969/j.issn.1000-2456.2012.03.022
- Park, J., & Kim, D.-W. (2017). How can Students Generalize Examples? Focusing on the Generalizing Geometric Properties. *Eurasia Journal of Mathematics Science and Technology Education*, 13(7) 3771-3800. doi:10.12973/eurasia.2017.00758a
- Qian, H. M. (2013). Comparison and reference of professional accreditation of higher engineering education in developed countries. *Theory Research*, (32), 244-247. doi:10.3969/j.issn.1002-2589.2013.32.110
- Song, D., Tavares, A., Pinto, S., & Xu, H. (2017). Setting Engineering Students Up for Success in the 21st Century: Integrating Gamification and Crowdsourcing into a CDIO-based Web Design. *Eurasia Journal of Mathematics Science and Technology Education*, 13(7), 3565-3585. doi:10.12973/eurasia.2017.00745a
- Wang, Z., & Li, S. (2009). The shortage of funds in local normal universities in China draw on the experience of Canada. *Journal of Tianjin Academy of Educational Science*, (01), 76-77. doi:10.3969/j.issn.1671-2277.2010.01.014
- Wei, Y., & Guo, Q. (2011). Analysis on the reform of higher engineering talents training mode to meet the needs of the industrial development. *Education and Vocation*, (20), 38-39. doi:10.3969/j.issn.1004-3985.2011.20.014
- Weizhen, L. (2004). An international compare study on fiscal expenditure on education. *Economic Survey*, (06), 143-145. doi:10.3969/j.issn.1006-1096.2004.06.044
- Yin, X., & Qing, L. (2007). A comparative study on K-12 engineering education in China and America and its link with higher engineering education. *Research in Higher Education of Engineering*, (05), 16-19. doi:10.3969/j.issn.1001-4233.2007.05.004
- Zhi, B. T. (2013). The development of production mode and the change of school running mode of engineering education. *Journal of Hebei Normal University (Educational Science Edition)*, (22), 62-66. doi:1009-413X/201305-0063-6