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The Influence of Higher Engineering Education Investment and Technical Progress on the Sustainable Development of Manufacturing Industry in China

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ABSTRACT

With SEM analysis, to explore the influence of higher engineering education investment and technical progress on the sustainable development of manufacturing industry, the results show that, to see from the path relationship between the variables, the higher engineering education investment and technical progress has a direct positive effect on China's manufacturing growth, in addition, the higher engineering education investment have an indirect effect on the sustainable development of the manufacturing industry through the intermediary variables of technical progress.

Keywords: higher engineering education, technical progress, manufacturing, sustainable development, influence coefficient

INTRODUCTION

In recent years, with the continuous development of manufacturing industry, China has already established its status as the world's factory (Sansom & Shore, 2013), but at the same time the country is facing unprecedented challenges such as excessive consumption of domestic resources and environmental pollution problems and other issues (Chen, 2010; Feng, 2011), and to see from the quality of industrial manufactured goods, most of them are not high (Wang, 2017), the input-output efficiency and international competitiveness is low (Tang, 2016).

Under the background of knowledge economy, the traditional "quantitative expansion" model of the manufacturing industry has been unsustainable (Mungaray-Lagarda, 2002), it is obliged to pay more attention to the sustainable development of manufacturing industry(Tang, 2014), based on this, this paper, to explores the influence of higher engineering education investment and technical progress on the sustainable development of manufacturing industry from the perspective of education and technical innovation, it has important guiding significance for promoting the orderly and efficient development of China's manufacturing industry, and also has important theoretical and practical significance for the realization of the strategic goal of "made in China 2025".

LITERATURE REVIEW

Recently, many scholars at home and abroad have explored the dynamic factors of sustainable development of manufacturing industry from different angles, and have obtained many important achievements in the related fields, but there still have some content that needs to be further improved and discussed.

Firstly, to see from the research tendency, according to the existing literatures of manufacturing industry sustainable development at home and abroad, presently, in order to change the traditional growth mode of purely pursuing the "factor-quantity expansion" (Riis, 2001), more and more research has been made to the "resource saving and environmental protection", and the technical progress factor has been paid more and more attention.

Secondly, to seen from the research content, the analysis and research on the sustainable development of manufacturing industry has gradually shifted from the traditional research on "factor supply" to "supply structure

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Contribution of this paper to the literature

- In order to more accurately explore the influence of higher engineering education investment and technical progress on the sustainable development of manufacturing industry in China, this paper, to adopt the method of paths coefficient of structural equation model to calculate the direct and indirect effect of the variables, and the research results can effectively solve the problem of ignoring the possible "intermediary effects" among variables in the traditional selection of variables.
- This paper, to adopt the structural equation model (SEM) to test the multiple colinearity among the variables, it can effectively avoid the occurrence of singular matrix, compared with the traditional method, it can more accurately detect the overall fitting degree between the measurement model and the data.

optimization, input-output efficiency" (Wei & Guo, 2011), and more emphasis has been put on the importance of "efficiency improvement".

And from the view of research results, at the present time, the relevant literatures about the sustainable development of manufacturing industry at home and abroad are mainly based on qualitative analysis and relatively few in quantitative analysis, which are mainly confined to the "single direction" research on a specific factor but ignoring the possible "intermediary-effects" of the factors (Koho et al., 2015).

Based on this, considering the requirements of sustainable development of manufacturing industry, it is necessary to build a multivariable comprehensive evaluation model from the perspective of the input-output of capital and labor. To explore the direct influence and indirect conduction effect of higher engineering education investment and technical progress on the growth of manufacturing industry (Harik et al., 2015; Zhu, 2013), which has important practical significance to effectively identify the mutual influence of higher engineering education investment and technical progress on the sustainable development of manufacturing industry.

MODEL BUILDING AND RESEARCH HYPOTHESIS

Method Selection

At present, concerning the study of the influence of higher engineering education investment and technical progress on manufacturing industry, it is mainly based on the analysis of "industry association-coefficient method" with a relatively single decomposition factors, and the research results are mostly lack of systematicness and comparability, and in the selection of indicators, the actual effect of latent variables (hidden variables) cannot be effectively calculated, and it is impossible to avoid the multiple collinear problems that may occur among the factors, in view of the above-mentioned facts, this paper, to introduce the theory of "multivariate data relations processing" in order to avoid the occurrence of singular matrix, and choose structural equation model (SEM) to effectively test the multiple colinearity among the variables, it can more accurately detect the overall fitting degree between the measurement model and the data.

In addition, with the existing literatures, the studies focusing on higher engineering education are relatively small, considering the representativeness and availability of the industrial statistics, the data are obtained only 1992-2016 years, and the number of data samples is relatively small, thus to choose the structural equation model based on partial least squares (PLS) is more suitable for the needs of this paper.

Data Sources

Combined with the requirements of sustainable development of manufacturing industry, to make a research from the perspective of capital and labor input-output(as is shown in **Table 1**) (Pardi et al., 2015; Galang, 2010), and the statistical data are taken from "China Statistical Yearbook 1992-2016" and "China Industrial Statistics Yearbook 1992-2016" (in order to keep the continuity and comparability of data, the initial-value-method is adopted to deal with the non dimensional processing).

First of all, with SPSS20.0 software, according to the data provided from **Table 1**, the KMO value is calculated as 0.761 (> 0.7) , and the value of Bartlett sphericity is 0.000 (< 0.001), the results show that the internal consistency of the data is good, and it is suitable for factor analysis. This paper, to carry out the exploratory factor analysis and confirmatory factor analysis for data preprocessing to build the trust model, after calculation, the cumulative contribution rate is 90.619%, which meaning the explaining extent of the model is higher, meeting the research requirements of this paper.

Table 1. Indicators of Sustainable Development Capability of Manufacturing Industry

Influence factors	Measure indicators	
Higher engineering education investment	Financial appropriation for higher engineering education (hundred million)	x1
	The total number of professional teachers in higher engineering education (ten thousand)	x2
	Fixed investment of higher engineering education (ten thousand)	x3
	Number of enrollment size for higher engineering education（ten thousand）	x4
	R&D funds input in higher engineering education (ten thousand)	x5
Industrial technical progress	Number of industrial authorized patents (hundred)	x6
	Growth rate of total factor productivity（%）	x7
	Rate of capital output（%）	x8

Table 2. Evaluation Indicators For Sustainable Development Ability Of Manufacturing Industry

Variable	Measure indicators	
Industrial generating capacity	The proportion of Bachelor degree or above in manufacturing industry (persons with bachelor degree or above / total number of employees in manufacturing industry)	y1
	The proportion of independent intellectual property rights (the number of industrial independent intellectual property rights / the total number of intellectual property rights in China)	y2
	Market share of independent innovation products (the sales of independent products / total sales of industry)	y3
	Profitability of industry independent innovation product (independent product operating profit / operating income)	y4
	R & D investment ratio (R & D annual input / industry annual turnover)	y5
Industrial competitiveness	Industrial market share (Total sales of industrial products of Chinese enterprises / total sales in domestic market)	y6
	Industrial trade competitiveness index (trade gap between imports and exports of industrial products / total import and export trade)	y7
	Industrial dominant comparative advantage index (the proportion of exports to the total value of exports / the proportion of similar goods to the total value of exports in the world)	y8
	Concentration ration of industry (CR6=sales of the top six enterprises /total industrial sales)	y9
Industrial control capability	Market share of Chinese funded enterprises (total sales of Chinese holding manufacturing enterprises / total sales of industrial products)	y10
	Chinese brand share (brand number of Chinese enterprises / industrial total brand)	y11
	Control degree of Chinese enterprises operating decisions (output value of Chinese enterprises / industrial total output value)	y12
	Core technical control degree of Chinese enterprises (total number of industrial core technical in Chinese enterprises / total number of industrial core technical)	y13

MODEL BUILDING

Variable Selection

For the structural equation model (SEM), the variables can be divided into two categories: one is the significant variables (i.e., measurable variables, refers to the variables that can be observed and measured directly), the other is the latent variables (i.e. hidden variables, which cannot be observed and measured directly).

For the model design of manufacturing industrial sustainable development evaluation, this paper, to take "sustainable development ability of manufacturing industry" as dependent variable, and take "higher engineering education investment" and "technical progress" as independent variables in the structural equation model, considering the factors of "higher engineering education investment, technical progress and sustainable development ability of manufacturing industry" cannot be measured directly, to take them as "latent variables" that need to be comprehensively reflected by several measurable variables, thus a complete structural equation model is constructed (as following).

Latent variables 1: sustainable development ability of manufacturing industry (η)

Drawing on the existing literatures, considering the realistic requirements of sustainable development of manufacturing industry, 13 indicators (as measurable variables) are selected from the aspects of "Industrial generation capacity, industrial competitiveness and industrial control capability", the content of the measure indicators are shown in **Table 2**.

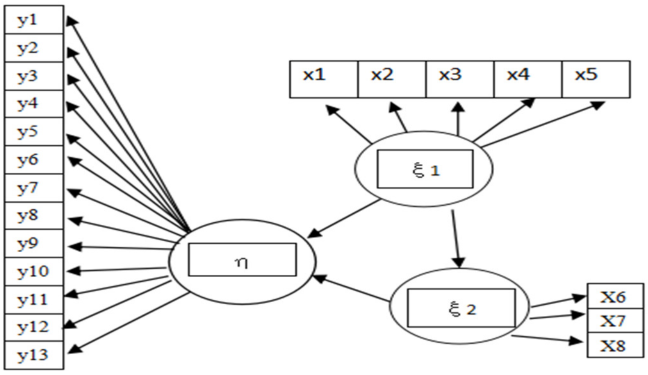

Figure 1. Research hypothesis diagram

Latent variables 2: higher engineering education investment (ξ1)

From the perspective of capital and labor input, five measurable variables are selected, which can be shown as follows: Financial appropriation for higher engineering education (x1) and the total number of professional teachers in higher engineering education (x2), fixed investment of higher engineering education (x3), Number of enrollment size for higher engineering education (x4), R&D funds input in higher engineering education (x5).

Latent variables 3: industry technical progress (ξ2)

And three measurable variables are selected, which can be shown as follows: Number of industrial authorized patents (x6), growth rate of total factor productivity (x7), Rate of capital output (x8).

Model Hypothesis

Using Smart PLS 2.0 analysis software, to take "higher engineering education investment, technical progress and manufacturing sustainable development ability" as latent variables, x1-x8 and y1-y13 as measurable variables to build structural model, and the relationship between the latent variables can be expressed in the form of path diagram (or equation), and the following research hypotheses are proposed (the research hypothesis diagram is shown in **Figure 1**).

H1: Higher engineering education investment (ξ1) has a positive influence on the sustainable development ability of manufacturing industry (η).

H2: Industrial technical progress (ξ2) has a positive influence on the sustainable development ability of manufacturing industry (η).

H3: Higher engineering education investment (ξ1) has a positive influence on industrial technical progress (ξ2).

SEM MODEL CHECKING

Validity Analysis of Model Interpretation

In order to make an evaluation on the explaining extent of the model, firstly, to adopt the structural equation and partial least squares method with Smart PLS 2 software, and the adjusted chi-square test (χ^2/df), the root mean square error (RMSEA) and the comparative fit index (CFI) are chosen as the evaluation indexes, which are less affected by the sample size (the acceptable range of each fitting index are shown in **Table 3**), thus the results of the fitting degree can be calculated (as shown in **Table 3**), and it can be seen that the values of all the fitting indexes are within the acceptable range, and all the hypotheses have passed the test, which shows that the fitting degree between the measurement model and the data is better, and the overall explanatory validity of the model is higher.

Table 3. Values of the Fitting Degree

	χ^2/df	RMSEA	CFI	Fitting results
Hypothesis 1	2.41	.069	.933	adopt
Hypothesis 2	2.34	.061	.960	adopt
Hypothesis 3	1.82	.053	.911	adopt
Acceptable range	[1-3]	<0.08	>0.9	--

Table 4. Standardized Path Coefficient Analysis

Paths	Standardized path coefficient	Significance test at 0.01 level	Hypothesis test results
H1 : η（ξ1）	.8273	remarkable	support H1
H2 : η（ξ2）	.5881	remarkable	support H2
H3 : ξ2（ξ1）	.4986	remarkable	support H3

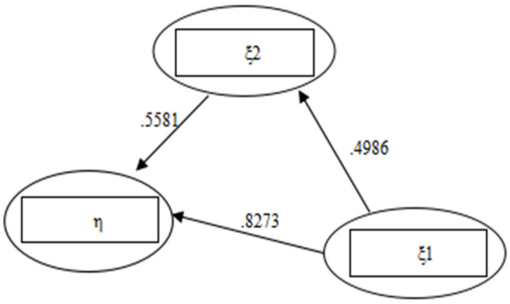

Figure 2. Paths diagram of structural equation model

Table 5. Paths Coefficient and Influence Effect of the Model

Paths	Influence path number	Direct influence coefficient	indirect influence coefficient	Total influence effect
ξ1- η	2	.8273	.2396	1.1205
ξ2- η	1	.5881	——	.5881
ξ1- ξ2	1	.4986	——	.4986

Model Path Validity Analysis

In order to ensure the suitability of the model, the test results of the overall fitting degree of the model need to be calculated, and then to make a validity test of the fitting index and the standardized path coefficient, the path validity is mainly reflected in the standardized path coefficient and the value of T, and the calculation results of T test show that at the significance level of 0.01, all the path coefficients in the model pass the T test, that is, the model path assumptions about H1-H3 are valid (results are shown in **Table 4** and **Figure 2**).

Analysis of Influence Effects of SEM Variables

Combined with the path relationship of the variables in the **Figure 2**, the direct influence coefficient, the indirect influence coefficient and the total influence effect of the latent variables can be calculated (results shown in **Table 4**).

The results show that "ξ1 and ξ2" have a positive and direct impact on η, to sort the variables according to the coefficient of path coefficient are as follows: higher engineering education investment (0.8273), technical progress (0.5881), and ξ1 has relatively higher direct effect on η.

In addition, ξ1 has a significant indirect influence on the η, which can be reflected that ξ1 has positive and direct influence on ξ2 (0.4986), and has an influence on the η through the transitivity path of ξ2, after calculation and analysis, the indirect influence degree of ξ1 on η is obtained (0.2932).

Add up the indirect and direct effect, the total influence effect of the latent variables can be obtained, as: the "ξ1- η" is 1.1205, "ξ2- η" is 0.5881 (as shown in **Table 5**).

RESULTS ANALYSIS

Higher engineering education investment and technical progress are the key factors to promote and guarantee the sustainable development of China's manufacturing industry.

First of all, according to **Table 4**, "higher engineering education investment" has the greatest influence effect and the most associated paths, the main reason is: in China, compared to the developed countries in Europe and America, the total amount of investment in higher engineering education is insufficient, the marginal utility of input-output is large, and the manufacturing industry is still in the extensive quantity expansion stage, which is in the rising period of scale economy, characterized by simultaneously expanding between the higher engineering education investment and manufacturing development, thus the result of the influence degree shows greater. Therefore, it is necessary to continue to increase the investment in higher engineering education, which is the most critical factor to effectively improve the sustainable development ability of manufacturing industry in contemporary China.

Secondly, technical progress has an obvious direct impact on the sustainable development of China's manufacturing industry, and it is the important material basis for the sustainable development of China's manufacturing industry, but according to the total effect calculation result, compared with the "higher engineering education investment" factor variables, the overall impact is relatively small, the main reason is that the overall technical level of China's manufacturing industry is not high, and the share of high-tech industry in the national economy is not large (about 15%), the high-tech industrial chain is relatively short, and it is relatively weak to influence and drive the development of other related industries, the result is the existence of a large number of traditional manufacturing industry blurs the contribution of technical progress to industrial development.

Thirdly, the direct impact coefficient of higher engineering education investment on technical progress is 0.4986, which indicates that the input-output level of higher engineering education in China is low, and the efficiency of engineering education needs to be improved. It is necessary to actively carry out strategic action plans such as "excellent engineer program" and "engineering education accreditation" in the future, so as to effectively promote the contribution of higher engineering education to technical progress.

CONCLUSION AND PROSPECT

In order to realize the sustainable development of China's manufacturing industry, it is necessary to pay more attention to the higher engineering education investment and technical progress, and to increase the investment in higher engineering education, besides, it is also important to effectively improve the input-output level of higher engineering education, and improve the contribution level of higher engineering education to technical progress.

Limited space, the specific strategies for the coordinated development of higher engineering education, technical progress and manufacturing industry in China will be further studied in another manuscript.

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