A Study on the Technological Innovation Performance of the Manufacturing Industry in Zhejiang Province of China[1]

Jing Hu, Yong Zhang
China Jiliang University, College of Economics and Management, Hangzhou, P.R.China

Abstract--**Manufacturing is the main body of the industry and the major area of the technological innovation in Zhejiang province. In view of the mismatch of the development scale, speed and innovation ability of the manufacturing industry in Zhejiang province, the paper focused on studying the technological innovation performance of the manufacturing industry. Enhancing the technological innovation performance is the foundation of improving the technological innovation ability, and it is also the basic premise of the empirical analysis on this topic. Through taking the manufacturing industry of Zhejiang province as the research object, its industry differences, the effect and efficiency of the technological innovation are emphatically researched by using the parametric and nonparametric techniques. As a result, the changes and the influence factors of the manufacturing industry performance in Zhejiang province are systemically investigated in this paper.**

I. INTRODUCTION

Manufacturing industry plays an essential role in boosting the economic development of a region, and its development scale and technological innovation capability determine the status in the international division of labor and the international competitiveness of a country's industry to a great extent. Since the reform and opening up especially the mid-1990s, the soaring development of manufacturing industry together with the top ranks of many products in international market share witnesses the manufacturing industry of Zhejiang province and China at large becoming the major node of the global manufacturing network. However, the manufacturing industry of China is still in the low-end link of the global value chain with relatively weak industrial international competitiveness, which is because of the undesirable innovation effect as well as the insufficient technological innovation capability. Therefore, the independent technological innovation capability of the manufacturing industry in China should be enhanced on the basis of the improvement of the technological innovation effects, which is also the practical significance of the technological innovation performance research. In this paper, the important aspect of the innovation effect — the contribution of the innovation input to the productivity growth will be studied empirically.

Manufacturing is the industry sector which has intensive activities of technological innovation (or research) . Since the late 1970s, the research of the relationship between R&D input and the productivity growth of manufacturing industry have gradually become the hot areas where many scholars focus on. The basic research approach of the relationship between R&D input and productivity growth is to expand the classic production function Cobb—Douglas, add the R&D capital (also known as intellectual capital) on the basis of factor inputs such as traditional physical capital and labor, and then estimate the output elasticity of R&D capital. The above function should be estimated after calculating R&D capital. For the specific innovation project, R&D input is often a continuous process in a specific period. Therefore, a R&D input not only produces direct effect in the current period, but also promotes the increase of intellectual stock, intellectual overflow and transmission which often bring about convenience for the subsequent and relative innovation activities. For this reason, the intellectual input should not be investigated only by calculating the current R&D expenditure, but fully calculating the intellectual capital accumulation formed by the past R&D input[1][6]. Based on this, R&D capital is generally considered as the intellectual capital stock on the basis of the depreciation of the past multi-period R&D expenditure, which also refers to the intellectual capital with certain depreciation rate [11]. Due to the involvement of the confirmation of depreciation rate and average lag phase, the calculation of R&D capital is relatively difficult. Many scholars adopt the approach which takes logarithm on the two sides of the production function and differentiates the time. In this way, the intensity index instead of the explanatory variable such as R&D increment and output increment can be reached, and then the return rate of R&D investment (as known as R&D intensity model) can be produced. In this way, the estimation of R&D capital can be avoided.[5][16] Although the two methods both have advantages and disadvantages, the empirical researches of the output elasticity of R&D capital and the return rate of R&D investment are still carried out at the same time. Therefore, by estimating the output elasticity of R&D (intellectual) capital and the return rate of R&D investment, the contribution of innovation input to productivity growth in Zhejiang province will be studied in this paper.

II. THE MEASUREMENT OF THE TECHNOLOGICAL INNOVATION EFFECT OF THE MANUFACTURING INDUSTRY IN ZHEJIANG PROVINCE – BASED ON THE PERSPECTIVE OF THE OUTPUT ELASTICITY OF INTELLECTUAL CAPITAL

For a long time, physical capital and labor have been regarded as the basic input factors of the enterprise/industry

This Paper is sponsored by project of Zhejiang Provincial Key Research Base of Humanities and Social Sciences—Standardization and Intellectual Property Management: Performance Research on Technological Innovation in Manufacturing Industry in Zhejiang Province [SIPM3221].

growth. But with the increase of the technological advance effect in the enterprise/industry growth, especially the rapid development of the manufacturing industry, intellectual capital has become the conclusive power of the enterprise/industry growth. In the recent decade, the manufacturing industry of Zhejiang province has developed rapidly, and has also become the industry sector which has concentrated technological innovation activities. The manufacturing industry of Zhejiang province has relatively low quality as well as rapid development, which is mainly embodied in the excessive dependence on the abundant physical capital, energy input and extensive growth. There is obvious gap between the manufacturing industry of China and that of developed countries. But it cannot be denied that technological innovation has played an indispensable role in the development of the manufacturing industry in Zhejiang province since the 1990s. Consequently, for the manufacturing industry of Zhejiang province, how to measure the intellectual capital stock? How great is the contribution of intellectual capital to industry growth, especially to the labor productivity growth? Is there any difference between various industries? These problems which need further research are the focus of the study in this part.

A. Model construction and data resources

1) Model construction

Cobb – Douglas, the extensive production function model used in this chapter. That is

$$Q_{it} = Ae^{\lambda t}K_{it}^{\alpha}L_{it}^{\beta}R_{it}^{\gamma} \qquad (1)$$

Hereinto, Q, K, L and R respectively represent added value, physical capital, labor and intellectual capital. t represents temporal trend (subscript t refers to year) . A is a constant. Subscript i represents industry. α, β and γ respectively represent the output elasticity of physical capital, of labor and of R&D capital. λ is the technological progress rate.

After taking natural logarithm on both sides of Equation (1) and adding random error term, Equation (1) converts into:

$$q_{it} = \alpha + \lambda t + \alpha k_{it} + \beta l_{it} + \gamma r_{it} + \varepsilon_{it} \qquad (2)$$

Hereinto, *q, k, 1* and *r* respectively represent the natural logarithm forms of the original value of the variable *Q, K, L* and *R*. ε represents the random error term. Thus, $r = \frac{dlnQ_{it}}{dlnR_{it}}$ means that the output elasticity of intellectual capital represents the increased percentage of the gross output that comes from the 1 percent increase of the intellectual capital. In order to reduce the co linearity degree among different variables and further highlight the analysis of the relationship between intellectual capital and productivity, Equation (2) can be organized into the following form:

$$(q-l)_{it} = \alpha + \lambda t + \alpha(k-l)_{it} + \gamma(r-l)_{it} + \xi l_{it} + \varepsilon_{it} \qquad (3)$$

Hereinto, $(q-l)_{it} = ln\,(Q_{it}/L_{it})$ 、 $(k-l)_{it} = ln\,(K_{it}/L_{it})$ 、 $(r-l)_{it} = ln\,(Q_{it}/L_{it})$ and $\xi = \alpha + \beta + \gamma - l$ represent scale parameters. $\xi > 0$, $\xi < 0$ and $\xi = 0$ respectively represent increasing returns to scale, decreasing returns to scale and constant returns to scale of the industry. The term ξl_n in Equation (3) can be removed when the extensive production function is imposed on the restriction of constant returns to scale. In Equation (3) , the dependent variable is actually the labor productivity of each industry. Therefore, r becomes the direct manifestation of the contribution degree of intellectual capital to labor productivity growth. In addition, the industry or time dummy variable can be added on the basis of Equation (3) to distinguish and compare the difference and variation γ in various industries and times. Thus, equation (3) can be extended into:

$$(q-l)_{it} = \alpha + \lambda t + \alpha\,(k-l)_{it} + \gamma\,(r-l)_{it} + \xi l_{it} + \alpha_1 D_n\,(k-l)_{it} + \gamma_1 D_n\,(r-l)_{it} + \xi_1 D_n l_{it} + \theta D_n + \varepsilon_{it} \qquad (4)$$

D_n represents the dummy variable of industry/time. n=1, 2, 3… If the output elasticity of each factor of the industry 1 is estimated, which means D_1=1, Equation (4) can be adjusted into:

$$(q-l)_{it} = \alpha + \lambda t + (\alpha + \alpha_1)\,(k-l)_{it} + (\gamma + \gamma_1)\,(r-l)_{it} + (\xi + \xi_1)\,l_{it} + \theta + \varepsilon_{it} \qquad (5)$$

Hereinto, $\gamma + \gamma_1$ represents the output elasticity of intellectual capital of industry 1.

2) Data Resources and Instructions

The data in this part comes from the panel data of sub-sector industry from 2006 to 2012, which was published in the *Zhejiang Statistical Yearbook on Science and Technology* from 2007 to 2013. In this part, manufacturing industry was divided into 28 subdivision industries according to the double-digit code in the National Industries Classification and Code (GBT4754-2002) . They are (1) Farm and Sideline Products Processing, (2) Food Manufacturing, (3) Beverages Manufacturing, (4) Tobacco Manufacturing, (5) Textile Industry, (6) Garment, Shoes and Hats Manufacturing, (7) Leather, Furs, Feather and Related Products, (8) Timber Processing, Bamboo, Rattan, Cane Palm and Straw Products, (9) Furniture Manufacturing, (10) Paper-making and Paper Products Manufacturing, (11) Printing and Record Duplicating, (12) Stationery, Educational, Sports Goods Manufacturing, (13) Petroleum Processing. Coking and Nuclear Fuel Processing, (14) Raw Chemical Materials and Chemical Products, (15) Medicines Manufacturing, (16) Chemical Fiber Manufacturing, (17) Rubber Manufacturing, (18) Plastic Products Manufacturing, (19) Non-metal Mineral Products, (20) Smelting and Pressing of Ferrous Metals, (21) Smelting and Pressing of Non-ferrous Metals, (22) Metal Products Manufacturing, (23) General Purpose Equipment Manufacturing, (24) Special Purpose Equipment Manufacturing, (25) Transportation Equipment Manufacturing, (26) Electric Equipment and Machinery Manufacturing, (27) Communication Equipment, Computer and Other Electronic Equipment Manufacturing, and (28) Instruments, Meters, Cultural and Office Equipment.

a) The calculation of the intellectual capital stock of sub-sector industry

Intellectual capital input, just like physical capital, will be gradually depreciated and devaluated. Therefore, Perpetual Inventory Method (PIM) was used in this research to calculate the intellectual capital stock, which means that the intellectual capital stock can be expressed as follows.

$$R_{it} = E_{i\,(t-\theta)} + (1-\delta)\,R_{i\,(t-1)} \qquad (6)$$

R_{it} represents the intellectual capital stocks of the industry *i* in the year *t*. δ represents the depreciation rate of intellectual capital. θ represents the average lag phase. $E_{i\,(t-\theta)}$ represents the R&D expenditure input (the manufacturing sample is the internal expenditure of the scientific and technological activities) of industry i which had been discounted from year t to year θ. In addition, assuming that the growth rate of intellectual capital is equal to the growth rate of E, the initial value of intellectual capital can be $R_0 = E_{i(t-\theta)}/\,(g-\delta)$, and g is the average annual growth rate of *E*. However, for the manufacturing industry, the time series data is relatively short due to the quite difference among various industries. In this chapter, the short cut method used by most researchers was used for reference, namely θ=1. For the depreciation rate of intellectual capital *δ*, the depreciation rate 15% was used to analyze the data of China by many experts[2] [4] [13] [14]. Therefore, θ=15% was adopted in this chapter.

b) The calculation of the physical capital stock of sub-sector industry

In this chapter, PIM was still been used to calculate the physical capital stock of the manufacturing industry and the high-tech industry in Zhejiang province. The computational formula can be expressed as follows.

$$K_{it} = NL_{it} + (1-\varpi)\,K_{i\,(t-1)} \qquad (7)$$

In this formula, K_{it} represents the physical capital stock of industry *I* in the year *t*. *NIit* represents the net capital investment of industry *i* in the year *t*. *ω* represents the depreciation rate.

For the manufacturing samples, there is a research result which shows that the depreciation rate of the building assets of the manufacturing industry in China is 2.4% and the depreciation rate of the equipment assets is 7.8%[15], which was used in this paper.

In order to estimate the initial value of capital stock, the method of Kohli [7] was adopted in this paper. Assuming that in the various industrial investments of manufacturing industry from 2006 to 2012, the actual growth rate was equal to the growth rate of actual added value and increased at a constant speed r, the Equation can be obtained as follows.

$$K_{2006} = \frac{I_{2006}}{\gamma+\varpi} \qquad (8)$$

The fixed capital investment value in 2006 is taken by the manufacturing industry I_{2006}, and then the sequence of the net fixed capital investment is calculated by the following method. Firstly, the sub-sector industry's original value of fixed assets in all the manufacturing industries should be divided into the fixed assets of building and equipment according to certain proportion. It is assumed that the proportion of building assets and equipment assets in the original value of fixed assets of all manufacturing industries is consistent with the proportion of the building assets and equipment assets in the fixed capital investment of the whole society [8]. Therefore, according to the proportion of building and equipment investment in the fixed capital investment of the whole society in the *Zhejiang Statistical Year Book*, the original value of fixed assets of high-tech industry and manufacturing industry can be divided into fixed assets of building and equipment. Secondly, the original value of fixed assets of building and equipment should be deflated by the fixed capital investment index (constant price in 1990) of building and equipment, and then the time series of constant price can be obtained. Thirdly, the sequential value of the net fixed capital formation can be obtained by using the first difference of the original value of fixed assets' constant price. In this way, the net investment sequence of the building and equipment constant price can be reached. Finally, according to the computational formula PIM, the fixed capital stock of building and equipment can be calculated respectively. And then the time series value of the capital stock of sub-sector industry can be reached through totaling.

c) Labor input and adjustment

The labor input of all manufacturing industries directly adopts the annual average number of the employees. Due to the double-counting that exists in the estimation of intellectual capital [9], which means that in most researches, the capital and labor used in R&D (or scientific and technological activities) are not removed from the physical capital and labor input of the enterprise/industry. This problem may lead to the underestimation of the output elasticity of intellectual capital. Therefore, the short cut method of removing the number of R&D personnel from the total number of the employees to reduce the impact from the double-counting [10] was adopted in this research, which means that the labor input of the manufacturing industry could be reached by subtracting the number of the personnel in scientific and technological activities from the annual average number of the manufacturing employees.

B. Empirical analysis

1) The regression analysis of the overall industry

For the estimation of all the manufacturing industries, the estimation method – feasible generalized least squares method which can overcome the heteroscedasticity and auto-correlation of the panel data will be used in this chapter. There are 28 cross-section data in panel data of manufacturing industry, which is obviously larger than the number of time series 7. Therefore, FGLS may be preferable (FGLS used maximum likelihood method in STATA8.0). The calculation results can be shown as Table 1.

TABLE 2-1. THE REGRESSION RESULT OF THE OVERALL INDUSTRY IN MANUFACTURING

Explanatory variables	I	II	III	IV	V	VI	VII	VIII
α	0.43^{***} (12.33)	0.53^{***} (13.35)	0.43^{***} (12.35)	0.53^{***} (13.31)	0.37^{***} (7.86)	0.30^{***} (11.15)	0.45^{***} (12.42)	0.52^{***} (15.00)
γ	0.18^{***} (5.28)	0.16^{***} (4.75)	0.20^{***} (5.56)	0.15^{***} (5.12)	0.26^{***} (6.04)	0.28^{***} (8.23)	0.13^{**} (4.56)	0.10^{*} (4.12)
ξ	-0.15^{***} (-6.78)		-0.15^{***} (-6.74)		-0.21^{***} (-13.04)		-0.14^{***} (-6.65)	
λ	0.25^{***} (32.45)	0.24^{***} (34.16)	0.24^{***} (32.35)	0.24^{***} (33.34)	0.24^{***} (26.42)	0.24^{***} (28.46)	0.24^{***} (32.87)	0.24^{***} (34.32)
Value of Log	69.35	66.47	67.82	65.15	63.40	61.98	58.88	56.41
Results of Wald testing	737.42	720.30	739.20	718.65	721.50	729.78	739.50	712.80
observations	56	56	56	56	56	56	49	49
Number of groups	8	8	8	8	8	8	7	7

Note: The line I and line II has adjusted by double-counting effect, line III and line IV has been adjusted by double-counting effect, line V and line VI are the regression of the explanatory variable which lags for a phase, and line VII and line VIII are the regression results of the traditional industry samples adjusted by double-counting. ***, ** and * respectively represent the variables which are obtained through 1%, 2% and 10% significance testing. t value is in the brackets.

It can be seen from the estimation results of Table 1 that each explanatory variable has well passed the significance testing. It is remarkable that the intellectual capital index has passed the significance testing with the level of more than 5%. There is certain gap in the output elasticity of intellectual capital after imposing the restriction of constant returns to scale, but the degree is not high. It is worth noting that the output elasticity of intellectual capital before and after the adjustment of double-counting is relatively consistent. Which means that the problems of double-counting in the estimation of line I, line I, line III and line IV are not serious. Therefore, the followings are all the estimations which have not adjusted by double-counting. Although it overestimates the intellectual capital stock, the output elasticity of intellectual capital, between 0.18 and 0.28, is still relatively low. That is to say when the intellectual capital stock increases 1%, the added value or labor productivity will only increase 0.18% to 0.28%. However, the output elasticity of the synchronous physical capital is 0.43 to 0.52. If the labor output elasticity is not imposed on the restriction of constant returns to scale, β is 0.24 (=1-0.43-0.18-0.15) . If the restriction is not imposed, β is 0.31 (=1-0.53-0.16) , which means it exists between 0.24 and 0.31. For this reason, in the development of the manufacturing industry in Zhejiang province, physical capital and labor input are still the dominant contribution factors, and the contribution of the intellectual capital only accounts for small proportion. In recent years, the large amount of fixed capital investment and labor input has still been the major impetus of the quite extensive manufacturing development. This is also the reason why the manufacturing industry in Zhejiang province has great industry scale but weak technological level and competiveness. If each explanatory variable lags for a phase (line V and line VI) , the output elasticity of intellectual capital will be improved significantly. On the one hand, it shows that simultaneous biased errors may exist in the estimation of line I and line II. On the other hand, it shows that there may be strong delayed effect in the accumulation and function of the intellectual capital of manufacturing industry, and the average lag phase of the intellectual capital measured in this paper seems longer. Because of the overestimation in calculating the intellectual capital, the conservative estimation of line I and line II was taken in this paper. However, the technological advance speed (λ) of the manufacturing industry can also been known as the considerable growth rate of the productivity which reaches 24%. Meanwhile, all the manufacturing production is still in the stage of decreasing returns to scale, the use of each input factor has not reached economic scale, and its availability efficiency is also inefficient.

In this part, the traditional manufacturing in Zhejiang province was used as samples to investigate the contributions of the intellectual capital stock of the traditional manufacturing to productivity growth. It can be seen from the estimation result of the line VII and line VIII in Table 3-1 that the output elasticity of intellectual capital in traditional manufacturing industry is 0.10 to 0.18 and the result of the intellectual capital parameter has not well passed the significance testing. After imposing the restriction of constant returns to scale, the output elasticity of intellectual capital only passes the significance testing of 10%. The output elasticity of physical capital which is 0.45-0.52 and the output elasticity of labor which is 0.27-0.35 are relatively high. This is relatively consistent with the essential features of the factor contribution of the traditional manufacturing industry in Zhejiang province. Although there are some industries with higher R&D intensity such as Special Purpose Equipment Manufacturing, General Purpose Equipment Manufacturing, Transportation Equipment Manufacturing and Raw Chemical Materials and Chemical Products. The R&D intensity of most industries is relatively low, and the gap between the expenditure input growth of the technological development and the growth of the industrial added value is quite obvious. From 2006 to 2012, in all the 24 industries, there are only 11 industries whose growth rate of intellectual capital stock exceeds the growth rate of added value. From the perspective of this asymmetric relationship, the promotion effect of the intellectual capital accumulation to the productivity of the traditional manufacturing industry remains to be improved.

2) The dynamic change analysis of each input factor's contribution degree

It is difficult to investigate the dynamic change of the contribution degree of each input factor to the industrial development, which is the deficiency of the estimation of the factor output elasticity.

Therefore, the time-dependent situation of the contribution rate can be investigated through substituting the output elasticity data of each input factor into the formula of the factor contribution rate. The formulas of contribution rate are

Contribution rate of physical capital： $\alpha' \cdot \frac{\dot{k}}{k} \Big/ \frac{\dot{Q}}{Q} \times 100\%$

Contribution rate of labor： $\beta' \cdot \frac{\dot{L}}{L} \Big/ \frac{\dot{Q}}{Q} \times 100\%$

Contribution rate of intellectual capital： $\gamma' \cdot \frac{\dot{R}}{R} \Big/ \frac{\dot{Q}}{Q} \times 100\%$

Hereinto, $\frac{\dot{k}}{k}$, $\frac{\dot{L}}{L}$, $\frac{\dot{R}}{R}$ and $\frac{\dot{Q}}{Q}$ respectively represents the growth rate of each input factor. Here all the manufacturing industries are regularized according to the output elasticity of each factor of line III in Chart 1. The calculation result is shown as Chart 2-1.

It can be found from Chart 1 that there is quite difference in the variation track of the contribution rate of each input factor of manufacturing industry to the industry development. From 2006 to 2012, the contribution degree of the manufacturing intellectual capital to the industry development had small change, which grown steadily from23.47% to 26.00%. Before 2009, the substitution degree of physical capital to labor was relatively high, and the labor input and contribution rate of the private manufacturing enterprises in Zhejiang province presented negative growth. On the one hand, it is related to the restructuring and reorganization of the enterprises, which means that the fixed capital investment has become the main force in driving industry growth. On the other hand, it also reflects the high degree of capital deepening in the private enterprises. It is worth noting the knowledge capital contribution, which grew rapidly then and caught up with the contribution of physical capital after its fluctuation during 2006 to 2009. Therefore, the potential of intellectual capital stimulating growth is very impressive

3) Regression analysis of the subdivision industry

In this part, the output elasticity of intellectual capital of the large-scale and small-scale manufacturing industry was estimated by their panel data units. The method FGLS was used in the estimation of the large-scale industry, and the method OLS was directly used in the small-scale industry. At the same time, in order to keep standardized, the estimation of subdivision industry was imposed on the restriction of constant returns to scale. The calculation result is shown as Table 2-2.

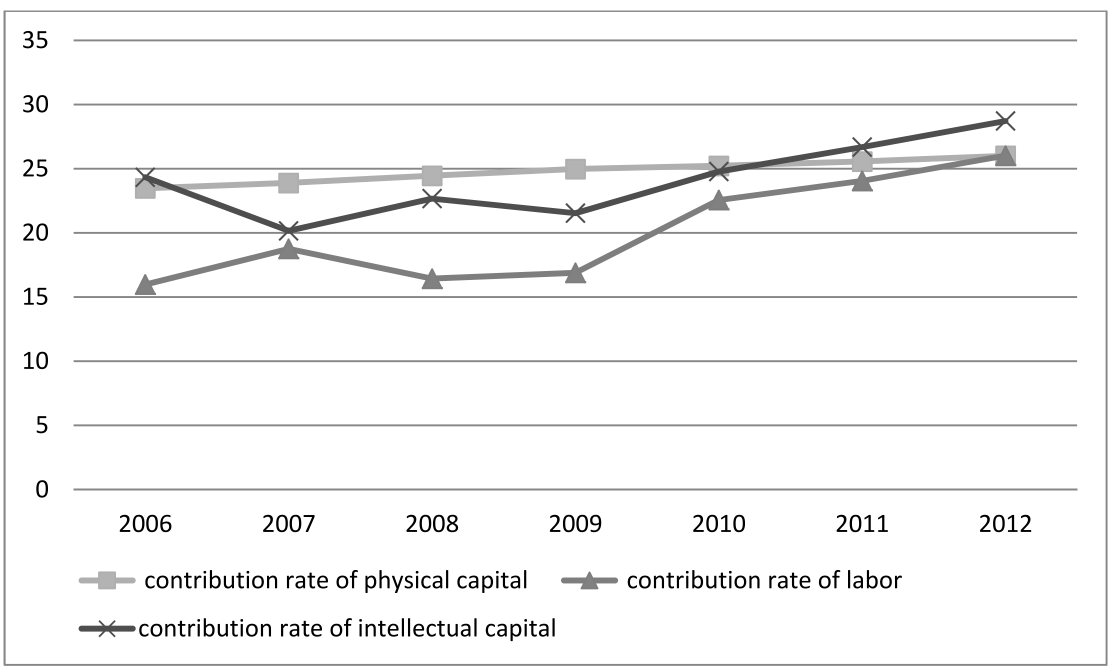

Chart 2-1: Contribution degree change of each input factor in the all manufacturing industries Unit: %

TABLE 2-2. THE OUTPUT ELASTICITY ESTIMATION OF THE SUB-SECTORS' INTELLECTUAL CAPITAL OF THE MANUFACTURING INDUSTRY

Explanatory variables	Industry								
	1	2	3	4	5	6	7	8	9
α	0.42*** (6.25)	0.32*** (6.43)	0.57*** (9.75)	0.53*** (8.32)	0.29*** (6.84)	0.43*** (6.41)	0.52*** (8.72)	0.59*** (4.57)	0.43*** (4.78)
γ	-0.03*** (-0.17)	0.16*** (3.68)	0.29*** (5.23)	0.20* (4.51)	0.23 (6.12)	0.27*** (3.33)	0.20 (0.72)	-0.04 (-0.18)	0.26** (2.78)
λ	0.07*** (4.06)	0.10*** (8.05)	0.17*** (10.46)	0.15* (8.02)	0.06 (2.72)	0.15*** (9.25)	0.12 (6.83)	0.09 (1.67)	0.10** (11.04)
Value of Log	50.79	57.05	60.21	34.90	34.65	52.17			
Adjust R^2							0.86	0.73	0.81
observations	12	12	12	12	12	12	3	2	6
Number of groups	2	2	2	2	2	2	1	1	1

Note: Industry 1 is Food Manufacturing, industry 2 is Textile Manufacturing, industry 3 is Pharmaceutical Manufacturing, industry 4 is Chemical Manufacturing, industry 5 is Rubber Manufacturing, industry 6 is Instrument Manufacturing. industry 7 is Electric Equipment and Machinery Manufacturing, industry 8 is Tobacco Manufacturing, and industry 9 is Communication Equipment, Computer and Other Electronic Equipment Manufacturing. ***, ** and * respectively represent the variables which are obtained through the 1%, 5% and 10% significance testing. t value is in the brackets.

From the perspective of the large-scale industry of 1 to 6, it is the output elasticity of intellectual capital of Pharmaceutical Manufacturing that is the most prominent. Although it mainly involves in typical capital-intensive industry (the output elasticity of physical capital reaches 0.59) , its growth in recent years increasingly relies on the intellectual capital. The output elasticity of intellectual capital of Rubber Manufacturing ranks third, which does not pass the significance testing although it is relatively high. It shows that in the short period, there is no strong positive interaction formed between the accumulation of Rubber Manufacturing and the industrial productivity growth. It is important to note that the output elasticity of intellectual capital in Textile Manufacturing is 0.16 while that of Food Manufacturing is negative, although they both involve the typical labor-intensive industry (for the former, its labor output elasticity is 0.51, which is larger than the output elasticity of physical capital 0.33. for the later, its labor output elasticity of 0.61 is larger than that of physical capital of 0.42) .We can see as a dominant industries in Zhejiang Province, since the productivity growth of the food industry depends more on the input of physical capital and labor, its growth in recent years has still belonged to low-level extensive growth with relatively low growth quality and that the intellectual capital the Food Manufacturing is not the determinant factor in the industry its development yet , but it has paid more attention to knowledge accumulation the which leads to the low output elasticity of intellectual capital.

Among the three small-scale industries of 7 to 9, the output elasticity of intellectual capital of Communication Equipment, Computer and Other Electronic Equipment Manufacturing is the highest (0.26) , Electric Equipment and Machinery Manufacturing ranks next (0.20) , The high intellectual capital output elasticity of the two industries is closely related to their growth rate of the intellectual capital stock and the intensified expenditure input of the technological development, while and the last rank is Tobacco Manufacturing has both smallest and negative output elasticity of intellectual capital (-0.06) , which shows that compared with physical capital and labor are the more important powers for the industry development .

III. THE MEASUREMENT OF THE TECHNOLOGICAL INNOVATION EFFECT OF THE MANUFACTURING INDUSTRY IN ZHEJIANG PROVINCE – BASED ON THE PERSPECTIVE OF THE RETURN RATE OF INNOVATION INVESTMENT

Further analysis in this part was made based on the previous chapter. The relationship between innovation input and productivity was investigated by using the R&D intensity equation, which means that the return rate level of the innovation investment was calculated, and the contribution degree of innovation investment to the TFP growth of manufacturing industry was investigated by the manufacturing samples of Zhejiang province.

A. Model construction and data resources

1) Model construction

After differentiating the time t in the both sides of Equation (3.2) of the previous chapter and ignoring the random error term, it can be obtained that

$$\frac{\dot{Q}_{it}}{Q} = \lambda + \alpha\frac{\dot{K}_{it}}{K} + \beta\frac{\dot{L}_{it}}{L} + \gamma\frac{\dot{R}_{it}}{R} \tag{9}$$

Hereinto, $\frac{\dot{Q}_{it}}{Q} = \frac{d\ln Q_{it}}{dt} = q \cong \Delta\ln Q_{it}^{\cdot} = \ln Q_{it} - \ln Q_{i\,(t-1)}$, $\frac{\dot{K}_{it}}{K}$、$\frac{\dot{L}_{it}}{L}$and$\frac{\dot{R}_{it}}{R}$ are similar. Consequently, Equation (9) is the difference estimation of each variable of Equation (2) . In this way, the spurious regression problem which is brought by the non-stationary of variable can be eliminated. After further organizing the Equation (9) , it can obtained that

$$\dot{q_{it}} = \lambda + \alpha\frac{\dot{K}_{it}}{K_{it}} + \beta\frac{\dot{L}_{it}}{L_{it}} + \rho\frac{\dot{R}_{it}}{Q_{it}}$$

$$\Delta q = \lambda + \alpha\Delta k + \beta\Delta l + \rho\frac{\Delta R}{Q} \quad (10)$$

Because $\dot{q_{it}} = \lambda + \alpha\frac{\dot{K_{it}}}{K_{it}} + \beta\frac{\dot{L_{it}}}{L_{it}} + \rho\frac{E_{it}}{Q_{it}}$, it can be further abbreviated as:

$$\Delta q = \lambda + \alpha\Delta k + \beta\Delta l + \rho\frac{E}{Q} \quad (11)$$

Hereinto, E refers to the innovation capital input, $\frac{E_{it}}{Q_{it}}$ refers to the innovation capital intensity, and Equation (11) is the R&D intensity equation. Hereinto, $\rho = \frac{dQ_{it}}{dR_{it}} = \gamma\frac{Q_{it}}{R_{it}}$ refers to the return rate of innovation capital, which is the gross output increment comes from the increase of the unit R&D capital.

By using Solow Residual Method, Equation (2.2) of the previous chapter can be organized into:

$$tfp_{it} = q_{it} - \alpha k_{it} - \beta l_{it} = lnA\lambda t + \gamma r_{it} \quad (12)$$

After differentiating the time t in the both sides of the above equation, it can be obtained that

$$\dot{tfp_{it}} = \dot{q_{it}} - \alpha\dot{k_{it}} - \beta\dot{l_{it}} = \dot{\lambda} + \rho\frac{E_{it}}{Q_{it}} \quad (13)$$

Hereinto, ρ is not only the return rate of innovation investment, but also the contribution elasticity of TFP growth. Therefore, the contribution degree of innovation investment to TFP growth can be obtained through estimating the above equation. It can be seen that Equation (11) and Equation (13) are equivalence.

2) Data resources

The data analysis in this chapter, similar with the previous chapter, comes from the panel data of sub-sector industry from 2006 to 2012, which was published in the *Zhejiang Statistical Yearbook on Science and Technology* from 2007 to 2013. The depreciation rate is still 15%.

B. Empirical analysis

1) The returns rate calculation of innovation investment based on parametric method

Equation (11) is used to estimate the return rate of R&D investment of the manufacturing industry in Zhejiang province, and the result is shown as Table 3-1. Line Ⅰ and line Ⅱ respectively represent the fixed effect regression and random effect regression. The return rate of R&D investment of fixed effect estimation is 34.4%, and the estimation result of random effect is 25.6%. FGLS is used to estimate in order to further eliminate the heteroscedasticity among the panel data. The result of R&D return rate is 24.7%, which is approximate to the result of random effect. And each variable has well passed the significance testing. It indicates that the contribution of the improvement of R&D density to the TFP improvement is about 30%.

In 2010, Wang and Tsai found that the average return rate of R&D investment was 35%, which was obtained from the data of 43 Taiwan high-tech manufacturing enterprises [12]. By contrast, the investment return rate of the manufacturing industry in Zhejiang province is approximate to or even higher than the research result of some developed countries and regions. It can be seen that R&D investment was one of the important impetus of the manufacturing development in Zhejiang province from 2008 to 2012, and the contribution degree of R&D investment will be enhanced greatly in the future.

TABLE 3-1 THE REGRESSION RESULT OF RETURN RATE OF R&D INVESTMENT IN HIGH-TECH INDUSTRY

Explanatory variables	I (FE)	II (RE)	III
constant term	-0.0007 (-0.20)	0.0003 (1.27)	-0.0007 (-0.20)
α	0.144 (1.48)	0.173* (1.75)	0.198*** (5.03)
β	0.578*** (5.43)	0.596*** (5.59)	0.528*** (5.33)
ρ	0.344*** (4.72)	0.256*** (4.05)	0.247*** (8.33)
Adjusted R^2	0.456	0.472	
Value of Log			69.82
observations	56	56	56
Group count	8	8	8

Note: Line I is the fixed effect (FE) regression, and line II is the random effect regression (RE) . Line III is FGLS regression. *, ** and *** respectively represent the variables which have passed the 10%, 5% and 1% significance testing.

Next, based on Equation (11) , the R&D return rate of each subdivision industry is estimated through imposing the industry dummy variable according to the method FGLS. The result is shown as Table 3-2.

It can be seen from table3.2 that the R&D intensity of industry 2 and 4 and the dummy variable have not passed the significance testing. From the perspective of R&D return results, Medicines Manufacturing is still the highest (36.5%) , which Instrument and Meter Manufacturing (33.6%) and Electronic Computer and Office Equipment Manufacturing (29.8%) follow, and Electronic and Communication Equipment Manufacturing (25.5%) is the lowest. It is obvious that the ranking is almost consistent with the output elasticity of R&D capital in the above chapter.

The return rate of R&D investment of the Electronic Apparatus and Communication Equipment Manufacturing in Japan between 1976 and 1984 is 19% to 22%, and that of Medicines Manufacturing is 23% to 42% [3]. By contrast, the return rate of R&D investment of Electronic and Communication Equipment Manufacturing in Zhejiang province is relatively low, which is equivalent to the level of Japan in the 1970s to 1980s, while the return rate of R&D investment of Medicines Manufacturing still remains to be improved.

TABLE 3.2 THE RETURN RATE OF R&D INVESTMENT OF THE SUB-SECTOR IN HIGH-TECH INDUSTRY

Explanatory variables	Industry			
	1	2	3	4
constant term	0.007*** (3.76)	0.008*** (4.89)	0.006*** (5.22)	0.008*** (4.18)
Difference of capital	0.195*** (3.81)	0.173*** (2.82)	0.205* (3.94)	0.130*** (2.25)
Difference of labor	0.566*** (8.03)	0.526*** (7.58)	0.543*** (8.85)	0.581*** (7.34)
Difference of R&D	0.331*** (7.02)	0.284*** (6.14)	0.245*** (5.48)	0.224* (5.22)
The density of R & D ×Dummy variable of industry	-0.123 (-4.03)	0.145*** (2.67)	-0.176*** (-2.14)	0.137* (1.72)
Value of Log	58.43	56.52	49.37	77.15
observations	56	56	56	56
Group count	8	8	8	8
Valuation for return rate of R&D investment	0.255	0.356	0.298	0.326

Note: Industry 1 is Electronic and Communication Equipment Manufacturing, industry 2 is Medicines Manufacturing, industry 3 is Electronic Computer and Office Equipment Manufacturing, and industry 4 is Medical Equipment, Instrument and Meter Manufacturing. *, ** and *** respectively represent the variables which have passed the 10%, 5% and 1% significance testing.

2) The return rate calculation of the innovation investment based on nonparametric method

DEAP2.1, the special software of the data envelopment analysis, is used in calculating the average index of efficiency variation of 28 industries in manufacturing, and Table 3.3 can be obtained. The data of Table 3.3 shows that the average annual growth rate of the technology efficiency of the manufacturing industry in Zhejiang province is 17.5%, the average growth rate of the technological advance is 8.7%, and the average annual growth rate of the TFP is 21.6%. Therefore, the growth of technology efficiency of manufacturing industry is the main cause of the growth of total factor productivity.

According to Equation (13) , by regarding the TFP growth rate of the Malmquist index as dependent variable and the innovation input intensity as independent variable, the return rate of innovation investment of the manufacturing industry in Zhejiang province from 2006 to 2012 can be calculated. The result is shown as Table 3.4. According to Table 3.4, it is undesirable that the return rate of innovation investment has not passed the significance testing by using the regression of fixed effect model and random effect model. However, the result passes the significance testing after using FGLS to eliminate the interlock heteroscedasticity, and the R&D return rate is 12%. If the TFP which is obtained by using Solow Residual Method is dependent variable, the return rate of innovation investment is 14%. There is certain gap between the two calculation results, but not great. Therefore, it can be considered that the return rate of innovation investment of manufacturing industry is 12% to 14%. Considering the hysteresis of innovation investment, line V to line VIII respectively represent the regression results of the innovation input intensity which lag for one phase to four phases. It can be found that after lagging for one phase to three phases, the return rate of innovation investment increases constantly which reaches the maximum 0.06 in the third phase. But the return rate of innovation investment drops sharply after lagging for four phases. There is hysteresis effect on the contribution degree of innovation investment to TFP growth, and the promotion effect on TFP growth is most obvious during three phases. Even considering the maximum value of the third phase, its result is still in the relatively low level in comparison with the existing research results of the developed countries, but it is close to the research results of the manufacturing industry of America and Japan in the 1970s.

TABLE 3.3 THE AVERAGE GROWTH RATE OF TECHNOLOGY EFFICIENCY, TECHNOLOGICAL ADVANCE AND TFP OF SUB-SECTOR IN MANUFACTURING INDUSTRY

Industry	EFFch	TECHch	TFPch	Industry	EFFch	TECHch	TFPch
1	1.232	1.112	1.196	15	1.157	1.058	1.182
2	1.299	1.111	1.345	16	1.23	1.111	1.254
3	1.156	1.065	1.143	17	1.109	1.068	1.139
4	1.14	1.072	1.165	18	1.203	1.066	1.273
5	1.181	1.112	1.234	19	1.766	1.111	1.174
6	1.138	1.133	1.225	20	1.651	1.111	1.187
7	1.177	1.133	1.160	21	1.265	1.100	1.264
8	1.162	1.048	1.151	22	1.175	1.135	1.255
9	1.2	1.039	1.167	23	1.178	1.100	1.233
10	1.198	1.023	1.208	24	1.097	1.110	1.987
11	1.2	1.142	1.159	25	1.087	1.091	1.205
12	1.151	1.068	1.179	26	1.155	1.090	1.275
13	0.988	1.058	1.182	27	1.233	1.083	1.269
14	1.233	1.024	1.251	28	1.198	1.076	1.328
				Average	1.175	1.087	1.216

Note: Hereinto, EFFch represents the variation of technology efficiency, TECHch represents the technological advance, and TFPch represents the variation of TFP.

TABLE 3.4 THE REGRESSION RESULT OF THE RETURN RATE OF INNOVATION INVESTMENT IN MANUFACTURING INDUSTRY

Explanatory variables	I (PE)	II (RE)	III_t	IV	V_{t-1}	VI_{t-2}	VII_{t-3}	$VIII_{t-4}$
ρ	-0.070 (-0.65)	0.100 (1.98)	0.120^{***} (2.45)	0.140^{***} (1.63)	0.142^{***} (2.76)	0.149^{***} (3.97)	0.153^{***} (4.37)	0.112^{***} (1.05)
Constant Term	1.32^{***} (26.78)	1.22^{***} (57.46)	1.34^{***} (43.57)	0.178^{***} (6.25)	1.21^{***} (89.38)	1.17^{***} (83.88)	1.14^{***} (80.12)	1.20^{***} (75.91)
Adjust R^2	0.06	0.06						
Value of Log			153.43	78.67	74.72	72.61	70.11	65.53
Observations	56	56	56	56	56	56	56	56
Group Count	8	8	8	8	8	8	8	8

Note: The dependent variable in line IV is the TFP growth rate which is calculated by parameter method, and the other dependent variables are all the TFP growth rates of the Malmquist index. V to VIII respectively represent the explanatory variable regressions which lag for on phase, two phases, three phases and four phases. *, ** and *** respectively represent the variables which have passed the 10%, 5% and 1% significance testing. t value is in the brackets.

TABLE 3.5 THE REGRESSION RESULT OF RETURN RATE OF THE LARGE-SCALE MANUFACTURING INDUSTRY'S INNOVATION INVESTMENT (ACCORDING TO THE INDUSTRY CATEGORY)

Explanatory variables	Industry					
	1	2	4	5	8	9
ρ	0.089^{*} (0.97)	-0.012^{*} (-2.21)	0.126^{***} (2.16)	0.186^{***} (2.79)	-0.093^{***} (-1.33)	0.151^{***} (2.44)
constant term	0.089^{***} (67.33)	1.024^{***} (71.11)	0.093^{***} (68.52)	1.025^{***} (72.32)	1.034^{***} (74.67)	1.033^{***} (73.71)
Adjust R^2					0.73	0.81
Value of Log	50.79	57.05	34.90	34.65		
Observations	12	12	12	12	2	6
Group Count	2	2	2	2	1	1

Note: Industry 1 is Food Manufacturing, industry 2 is Textile Manufacturing, industry 4 is Chemistry Manufacturing, industry 5 is Rubber Manufacturing, industry 8 is Tobacco Manufacturing, and industry 9 is Communication Equipment, Computer and Other Electronic Equipment Manufacturing. *, ** and *** respectively represent the variables which have passed the 10%, 5% and 1% significance testing. t value is in the brackets.

Table 3.5 is the regression result of the return rate of each industry's innovation investment according to the calculation of the industry category. It can be seen from the table that only the return rate of R&D investment of Chemistry Manufacturing and Communication Equipment, Rubber Manufacturing and Computer and Other Electronic Equipment Manufacturing have well passed the significance testing, and the results are also relatively high. The result of food manufacturing is positive, but has only passed the significance testing of 10%. The R&D input of Textile Manufacturing and Tobacco Manufacturing have not promoted, but impeded the TFP growth.

IV. CONCLUSION

1. In this paper, the panel data of the sub-sector manufacturing industry in Zhejiang province was the first topic. The intellectual capital stock and physical capital stock of the subdivision industries were calculated by using the popular perpetual inventory method. On this basis, the relationship between intellectual capital and productivity growth was analyzed from different levels by using extensive production function. The main conclusion was listed as follows.

(1) The intellectual capital stock of the manufacturing industry in Zhejiang province has made significant contribution to the productivity growth. However, in comparison with the existing research achievements of the western developed countries, the output elasticity of intellectual capital of manufacturing industry is relatively low, which is directly related to the weak input of the intellectual capital of the manufacturing industry in China and the mismatching relation between intellectual capital input and industry growth. In the process of the productivity growth and development of the manufacturing industry in Zhejiang province, physical capital and labor, the two kinds of input, are still the main contribution factors. But there are some industries whose contributions of physical capital and intellectual capital are dominant, and possess the double characteristics of capital and technology intensive. The traditional labor-intensive manufacturing industry still occupies a considerable share, and locates in the medium-low level of the global value chain.

(2) There is considerable difference among the output elasticity of intellectual capital of various subdivision manufacturing industries in Zhejiang province. Among the large-scale industries, the output elasticity of intellectual capital of Pharmaceutical Manufacturing is the most prominent, that of Instrument Manufacturing ranks second. Among the small-scale industries, the output elasticity of intellectual capital of Communication

Equipment, Electronic Computer and other Electronic Equipment Manufacturing is the highest.

2. Next, by adopting the equation of R&D intensity and using two methods, the return rate of innovation investment of the manufacturing industry in Zhejiang province was estimated in this paper. The main conclusion was listed as follows.

(1) The growth of total factor productivity is obtained mainly by the growth of technology efficiency of manufacturing industry, while the effect of technological advance has declined. Although the technological innovation investment of the manufacturing industry in Zhejiang province has a positive effect on TFP growth, the effect is relatively small. The innovation input has certain hysteresis effect on TFP growth.

(2) From the perspective of R&D return results, among high-tech industry the Medicines Manufacturing is still the highest, which Instrument and Meter Manufacturing and Electronic Computer and Office Equipment Manufacturing follow, and Electronic and Communication Equipment Manufacturing is the lowest. From the perspective of innovation investment return, among the only the whole manufacturing industry, the contributions of the innovation investment of Chemistry Manufacturing and Communication Equipment, Rubber Manufacturing and Computer and Other Electronic Equipment Manufacturing to the TFP growth are most significant, and the largest. Therefore, on the one hand, the R&D or innovation investment plays an irreplaceable role in promoting the TFP of the manufacturing industry in Zhejiang province, but it still remains to be improved. On the other hand, in order to enhance the contribution of technological advance to the TFP growth of the manufacturing industry in Zhejiang province, the scale and availability efficiency of innovation investment should be increased.

ACKNOWLEDGMENTS

This Paper is Sponsored by Zhejiang Industrial Development Policy Key Research Centre of Philosophy and Social Science of Zhejiang Province and Zhejiang Provincial Key Research Base of Management Science and Engineering.

REFERENCES

[1] Frantzen.D. “The Causality between R&D and Productivity in Manufacturing: an international panel data study”, *International Review of Applied Economics,* vol.17,pp.124-146,2003.

[2] Gary Jefferson, Albert G.Z., HU. Xiaojing GUAN, and Xiaoyum YU, “Ownership, performance, and innovation in China's large- and medium-size industrial enterprise sector”, *China Economic Review*, vol.14, pp. 89 – 133, 2003.

[3] Goto, A. and K.; “Suzuki R&D Capital Rate of Return on R&D Investment and Spillover of R&D in Japanese Manufacturing Industries,” *Review of Economics and Statistics*, vol.3, pp.555-564, 1989.

[4] Griliches, Z. and J. Mairesse, “R&D and productivity Growth: Comparing Japanese and US Manufacturing Firms,” in *R&D and Productivity* , Z. Griliches ,Ed. Chicago: University,1990.

[5] Hall.B.H. and J.Mairesse. “Exploring the Relationship Between R&D and Productivity in French Manufacturing Firms,” *Journal of Econometries,* vol.65, pp.263-293, 1995.

[6] Hu,A.G.Z.;”Ownership, Government R&D, Private R&D, and Productivity in Chinese Industry, ” *Journal Comparative Economics*, vol. 29,pp.136-157, 2001.

[7] Kohli, Ulrich, “A Cross-National Product Function and the Derived Demand for Imports and Supply of Export,” Canadian Journal of Economics, vol.5,pp.34,1982.

[8] Ling, WANG, “The Measurement on Capital Stock of Chinese Industrial Sector,” *World Economic Statistics*, vol.1, pp.16-25, 2004.

[9] Schankerman, M.; “The Effect of Double Counting and Expensing on the Measured Returns to R&D,” *Review of Economics and Statistics*, vol.3, pp.454, 1981.

[10] Smith, V., Dilling-Hansen., M. Eriksson, T. and Madsen, E.S.; “R&D and Productivity in Danish Films: Some Empirical Evidence,” *Research policy*, vol.27, pp.966-976, 2000.

[11] Tsai.K.H. and J.K.Wang. “R&D Productivity and the Spillover Effect of High-Tech Industry on the Traditional manufacturing Sector, The Case of Taiwan”, *World Economy*, vol.27 issue10, pp.1555-1570, 2004.

[12] Tsai.K.H. and J.K.Wang. “R&D Performance Decline with Firm Size?—A Re-examination in terms of Elasticity,” *Research Policy*, vol.38 issue 4, pp. 966-976, 2010.

[13] Verspagen, B.; “Estimating International Technology Spillover using Technological Flaw Matrices,” *Weltwiruchaftliches Archiv*, vol.23, pp.226-248,1997.

[14] Wang.L. and Szinmai.A, “Technological Inputs and Productivity Growth in China’s High-Tech Indutries”,Ecis, working paper,2003.

[15] Wu, H. X. and Xianchun Xu, “Measuring the Capital of Stock in Chinese Industry,” Academy *of Management Review*,vol.27, pp.185-203, 2002.

[16] Zhu Youwei, “A Study on the Technological Innovation Performance of China’s Manufacturing Industry”, *Southeast University, Management Science and Engineering,* working paper, May, 2003.