Technological Innovation, Productivity and Competitivenes

—Evidence from China's IT Manufacturing

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ABSTRACT

The purpose of this article is to investigate the impact of technological innovation on the labour productivity and competitiveness of China's IT manufacturing, and compare with seven countries of advanced IT industry. Technological innovation is identified by six key indexes, uses Pearson relationship coefficient matrix, Granger causality test, and regression analysis to examine their relationships from 1995 to 2004. Conclusions show that total R&D expenditure increase 1% in IT manufacturing, output will increase 0.995%. The R&D input for IT new product increase 1%, its output can enhance 0.55%, and earn benefit within one year, but the technological introduction and improvement will take more than there years. The effect of R&D expenditure on industrial competitiveness is 97.6%, It shows the strong international competitiveness especially on basic and low end product of IT. Comparative to advanced countries, the shortage of R&D investment and the lower efficiency are the major sources of weak industrial competitiveness. the intensity of R&D is only one-fifth of advanced countries in electronic and telecommunications equipment manufacturing, one-seventh in computers and office equipments manufacturing. Their labour productivity has about 20 percent and 25 percent, correspondingly. These have the important policy implication for technological innovation and structural upgrade of China's IT manufacturing. If China devote to shift from 'global IT factory' to leaders of IT innovation, it must improve the environment for innovation and incentive mechanisms, enhance the efficiency of the innovation system, pursue independence innovation and international frontier research in this sector.

Keyword R&D IT Manufacturing New product Productivity Competitiveness

INTRODUCTION

In the second half of the 20^{th} century, the revolution in information technology is the main driving force of economic growth, and it plays a key role in enhancing the international competitiveness for enterprises and industries. The competition among countries is focused on scientific and technological innovation and economic strength. According to development history of technology and economy, technological innovation only contributed to 5 percent of economic growth in the beginning of the 20^{th} century, and the quotient rose to about 15 percent in 1920-1930s, then up to 40 percent in 1940-1950s, 60 percent in 1970-1980s, and even to over 70% in 1990s (Xiyao Li, 1999, p24). In the United States, technological progress contributed to 40 percent of economic growth from 1929 to 1978, 20 percent of allocation of resources, 15 percent of per person capital, and 13 percent of economic scale, and 12 percent in improving the labor force quality. Technological innovation contributed to 63.9 percent of economic growth in British in 1950-1962, German is 81.9%, Japan is 65 % in 1952-1968, South Korea is 56.4% in 1955-1970s, Hong Kong is 46.5% in 1955-1970s. China is 19 percent in 1952-1982, increase to 30.3 percent in 1979-1990, and reaches 40 percent in 1991-1995 (The Institute of China Information Industry, 2006). All above suggests that technology innovation is an important source of modern economic growth, and also an important way of improving industrial international competitiveness and promoting industry sustained growth.

The innovation and diffusion of information technology has spurred a number of new industries' rapid development. The information technology industry has made great progress as one of strong interrelatedness and leadership in recent 30 years. It takes the place of traditional sector as the biggest industry in economy, such as American, Japan, South Korea and Taiwan. The export of IT-intensive products and services accounted for 40 percent of total exports in the United States. China's IT sector has an annual increase by 32% in recent 10 years, far faster than other ones, becoming an important sector of national economy. More importantly, the development of information industry is beneficial to the equipment's reconstruction of traditional industries and is useful for the adjustment and upgrading of the industrial structure, improving the overall economic competitiveness. Generally speaking, in the process of participation to international competition, China's industries have gone through the early labor-intensive stage and entered the new industrial upgrading stage driven by the independent innovation and the technology introduction.

According to innovation theory, technological innovation mainly relates to process innovation and product innovation, process innovation aims to improve productivity and reduce the input of unit output. while by contrast, the latter —for which the goal of R&D input lies in making product newer, quality-higher and function-better—is more of importance. For example, 75%-90% of total industrial expenditure for R&D in Swedish is for product innovation, so did 68% in American, and 36% in Japan. No matter what kind of innovation, its impact must be reflected in the final products or services, only in this way, can innovation be truly and accurately evaluated. In the study of this, the signification of technical innovation followed the basic idea of Schumpeterian approach, It is suggested that technological innovation is refers to effective combinations of existing technologies and the creation and introduction of various of new knowledge, and provide better products or services for market.

This article focuses on the contribution of technological innovation to the growth and competitiveness of China's IT manufacturing. The second part of the paper defines the indexes of technological innovation and chooses the appropriate analysis method. In the third part, it shows the activities of technology innovation and the industrial growth speed in China's IT manufacturing sector for recent 10 years. The forth part tests the correlation between technological innovation and the growth of information technology industry, especially the impact of R&D on the growth of product and outputs. The fifth part analyses the effect of technology innovation to IT manufacturing industry's international competitiveness, evidence indicates that the R&D input intensity, that is share of the R&D input in the industrial the added value, is the key factor of industrial competitiveness. The sixth part is the international comparison between China and developed countries. The last is the conclusion and the policy suggestion.

INDEXES SYSTEM AND ANALYSING FRAME

China has referred to the catalogue about high and new technology industry in terms of method OECD's, it includes industries of Aircraft and Spacecraft, Medical and Pharmaceutical Appliance, Electronic and Telecommunications Equipment, Computers and Office Equipments. Therefore, information technology is regarded as

Electronic and Telecommunications Equipment and the Computers and Office Equipments Manufacturing. Both input and output indexes are used to quantify the technology innovation.

Input indexes include R&D input and human resource input. R&D input comprises of five indexes in detail in total R&D expenditure, internal R&D expenditure by enterprise, R&D in new products, technology transformation and acquisition.

Output indexes are made up of five sub-indexes too. The first is the new product value(NPV) representing the real output of technology innovation .NPV is the income of selling new products during the current period for the industries and represents the final output of total or relative input in technology innovation. The second is the export delivery value that represents the relative output of technology innovation. It weighs the level of industrial development and the industrial international competitiveness. The third is the amount of patent, it represents the potential commercializing opportunity of invention and creation. The fourth is the gross value added of industries, which weighs the industry productivity. The last is products sell profit, represents the capacity of payoff, Table 1 lists the indexes and their meanings.

Table 1 about here.

The empirical analysis applied Pearson relationship coefficient matrix to examine the relativity between the technology innovation and the output growth, Granger causality test and the principal components analytic method distinguishes the causes and effects between the factors, and establish the regression equation of industrial growth and competitiveness with technology innovation as dependent variable , thus determined the influencing extent of innovation on new product value added, industrial output growth and competitiveness.

INPUT OF TECHNOLOGY INNOVATION AND GROWTH PERFORMANCE OF IT MANUFACTURING

1、Technological Innovation of China’s IT Manufacturing

The total R&D input in China's IT manufacturing sector in 1995 is 30.2 billion Yuan RMB, of which 8.9% was from the government, and 80% is from the enterprises. In 2004, the total investment increased to 428.47 billion Yuan RMB, the proportion of government investment dropped to 2%, the share of enterprises investment rise to 87%. The total expenditure for R&D grew 14.1 times; the rate of rise has been much higher than other industries in 10 years.

The R&D input from the government rose by 3.1 times from 278 million to 837 million Yuan RMB from 1995 to 2004. As to the enterprises, it rose by 12.76 times, from 2,485 million to 31.717 billion Yuan RMB, which grew 12.76 times. So we find the R&D input in China's IT manufacturing is mainly from the enterprises, the source of innovation is the income acquired by selling products.(see table 2)

Table 2 about here.

As a component of industrial technology innovation(see table 3), the number of the organizations that engaged in innovation dropped from 964 in 1995 to 537 in 2003, but up to 847 in 2004 and was in unstable condition. However the total number of people who participate to technological innovation rose continuously by annual 8,000 people, the scientists and engineers engaged in technology innovation increased by over 50 thousand.

The proportion of each kind of technological innovation expenditure is obviously changed, and the technological transformations expenditure occupied the biggest proportion from 1995 to 1997, but it was the smallest proportion in 2004. While the input of R&D for new products and the internal R&D ran to the top in 2004 from the smallest in 1995. These two kind of investments accounted for about 85% of the total R&D expenditure. In the middle of 90s, the technological innovation investment was mainly in the form of technological transformations and introduction, but it shifted to the new product development since 2000. This reflected that model of innovation is experiencing the change from the technology introduction and transformation to the self-dependent R&D in China's IT manufacturing.

Table 3 here.

2、The Output Growth and Economic Performance of IT Manufacturing

The total output of China’s information technology manufacturing was 253.6 billion Yuan RMB in 1999; the value added of industry is 63.6 billion Yuan, the profits and taxes is 18.6 billion Yuan. By 2004, the total output had reached 2.2699 trillion Yuan, the value added of industry was 459.2 billion Yuan and the profits and taxes was 103.1 billion Yuan. The total output grew 8.9 times with annual growth of 200 billion Yuan in 10 years, annual increases 200 billion Yuan. The value added of industry grew 7.2 times with annual increase 39.56 billion Yuan. The profits and taxes grew 5.5 times with annual increase 8.45 billion Yuan (see table 4). The growth of information technology industry accounts for about 10% of China’s economic output and becomes an important industry in China.

However, the value added of new product which reflects the achievements in technological innovation was 53.7 billion Yuan in 1999, accounting for the 20% of the industrial value added. In 2004, although the its share only rises 5%，the sales revenue increased from 38.7 billion Yuan to 536.8 billion Yuan, which grew 13.8 times with annual increase 49.81 billion Yuan. The profits increased from 4.4 billion Yuan in 1995 to 38.2 billion Yuan, growing by 8.7 times. From the comparison of data, it can be seen that the economic performance of the new products is superior of the whole industry.

Besides, the export of China’s IT industry is also gradually increasing. The export delivery value increases by from 93.1 billion in 1995 to 1410.6 billion Yuan in 2004, 15 times growth in 10 years. Meanwhile, the export share grows from 38.2% to 69.4%. It is the first time the export exceeds the import in high-tech sector since the year of 2004, which reflects that the international competitiveness of China’s IT manufacturing improves increasingly. It is also owed to increasing input of R&D, technology improvement and independence innovation.

We compute labor productivity by the industrial value added / the number of employment. The labor productivity of high-tech industry has always maintained a relatively high growth trend since 1995, with an average growth rate 1.7 percentage points higher than that of the manufacturing sector, and reached 20.5%. The labor productivity of electronics and telecommunications equipment manufacturing grew 2.5 times, 1.8 times of the electronic computer and office supplies manufacturing grew. The productivity of the two industries amounted to 111,000 Yuan/per person and 148,000 Yuan/person respectively, which are much higher than the labor productivity of the manufacturing sector, and also higher than other three high-tech industries (see table 5)

Table 4 about here.

Table 5 about here.

THE ANALYSIS ON CORRELATION BETWEEN THE TECHNOLOGY INNOVATION AND THE OUTPUT OF IT MANUFACTURING

1、The Relationship Test for Technology Innovation and Output of IT Manufacturing

The most immediate index that measures the performance of R&D input is the output of new product Y_3, the degree of correlate with input indexes can be described as:

$$Y_3=a_1X_2+a_2X_3+a_3X_4+a_4X_5+a_5X_6 \qquad (1)$$

Take logarithm form of each variable above and the result of test by the Pearson relationship coefficients matrix as follows:

Table 6 about here.

Table 6 shows that the output of new product is relate with various input variables, the influence of various input on output of new product is significant. However, three problems should come to consideration.

First, if we establish multiple regression equation, there will be multicollinearity problems which drop the interpretation of the equations, so we need to use single-variable linear regression equation to separate each index.

Second, even though the Pearson relationship coefficients test shows the correlation among variables is strong, this will not be enough to testify that there is causality in variables. If we directly establish a regression model, there may lead to a fake regression problem.

Third, there is a time lag in output growth and input of technology innovation. Because of these problems, we need to do Granger causality test for every variable to avoid the impact of multicollinearity. The time span for sample is 1995-2004 year, the result at lag one year and two year is shown in table 7 and 8, respectively.

Table 7 about here.

Table 8 about here.

The result shows that only the R&D expenditure of new product(X_3) to the output value of new products (Y_3) is relatively evident at lag one year, only internal R&D input (X_2) is significantly Granger cause of new products output (Y_3) at lag two year.

This indicates that the expenditure for R&D of new product can go into effect as long as one year, and the intramural expenditure need two years to produce benefits. Because we have only 10 years samples of the data, Eviews software can't give Granger causality test under 3 lagged differences. Therefore this study makes empirical test of correlation between the output of new product R&D and internal R&D input and new product R&D input.

2、The impact of Internal R&D Input on Output Growth of New Product

According to the result of Granger causality test, the equation is acquired under 2 year lagged differences:

$$\ln Y_3 = a_2 \ln X_2(-2) + b_2 \quad (2)$$

After adjustment, the time span of sample is: 1997-2004, sample number is 8, the regression result is:

$$\ln Y_3 = 0.550 \ln X_2(-2) + 5.665 \quad (3)$$

Sample	Regression Coefficient	Standard Derivation	T-test	Probability
LnX_2 (-2)	0.549964	0.030882	17.80842	0.0000
C	5.664913	0.115598	49.00549	0.0000

R^2	**0.981432**	Average Changes of Independent Variable	**7.646363**
Adjusted of R^2	0.978338	**Standard Derivation of Independent Variable**	0.602499
Standard Errors of Regression	0.088677	Akaike Info Criterion	-1.795320
Sum Squared of Residual	0.047181	Schwarz Criterion	-1.775460
Likelihood Logarithms	9.181280	F-test	317.1399
D-W Test	1.944536	Probability (F—test)	0.000002

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The equation above can explain the reality well and there is no serial autocorrelation problem. Regression coefficient a_2=0.550, that is , 1% increase of R&D input in new product leads 0.550% new product output growth. This indicates that the performance of internal R&D input in China's IT manufacturing is relatively low, and lower than that of the R&D input in new products.

3、The Contribution of R&D Input to Output Growth

In order to analyze the effect of R&D input to growth of IT manufacturing, we choose the total expenditure for R&D (X_1) and the total number of employment engaged in R&D (X_6) as input indexes to measure the IT industry's input of R&D, and the output of new product (Y_3) and total output of industry (Y_4) as output indexes to reflect industry growth.. The equation to measure the correlation of the four indexes is:

$$aY_3+bY_4=c_1X_1+c_2X_6 \qquad (4)$$

The results of Pearson relationship test is showed in table 9:

Table 9 about here.

It can be seen that the four indexes are strong positive linearity correlation and there is very high reliability at the significance level of 0.1 percent. This shows that R&D input in IT manufacturing is highly correlated with industrial output growth since the correlation coefficients are over 0.98 between X_1 and X_6 as well as $Y_3$and Y_4. What's more, the result of double-tail test is significant too.

However, the correlation among many variables is complicated. There is notable simple correlation between any two of the four variables, and mixed with influence of the other variables.

Actually simple correlation coefficient is not able to fully reflect the pure correlativity of two variables. For example, the output of new products (Y_3) is influenced by the total expenditure for R&D(X_1) and the total number of employment of R&D. But total R&D input must have influence on the total number of employment of R&D and vice versa. In order to reflect accurately the relationship among the variables, Therefore, in order to accurately reflect the relation between the variables, we use partial correlation coefficient test, namely, we measure respectively the partial correlation coefficient between X_1 and Y_3 or Y_4 when X_6 is control variable, as well as the partial correlation coefficient between X_6 and the Y_3 or Y_4 when X_1 is control variable. In this way, we can respectively observe the influence of the R&D input and the human capital input on the industrial growth. The test results are as follow:

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Controlling for..     X6

                    X1            Y3            Y4

X1               1.0000         .6923         .8107
                (     0)       (     7)      (     7)
                P= .           P= .039       P= .008

Y3                .6923        1.0000         .5379
                (     7)       (     0)      (     7)
                P= .039        P= .          P= .135

Y4                .8107         .5379        1.0000
                (     7)       (     7)      (     0)
                P= .008        P= .135       P= .

(Coefficient / (D.F.) / 2-tailed Significance)
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Controlling for..     X1

                    Y3            Y4            X6

Y3               1.0000         .3312         .5756
                (     0)       (     7)      (     7)
                P= .           P= .384       P= .105

Y4                .3312        1.0000         .6360
                (     7)       (     0)      (     7)
                P= .384        P= .          P= .066

X6                .5756         .6360        1.0000
                (     7)       (     7)      (     0)
                P= .105        P= .066       P= .

(Coefficient / (D.F.) / 2-tailed Significance)
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The results shows that, when the impact of X_6 is fixed, the correlation coefficient between X_1 and Y_3 and Y_4 is high and the reliability of the statistical result is also high (both are less than 0.05). The correlation coefficient between X_6 and Y_3 and Y_4 is obviously low when the impact of X_6 is fixed, which suggests output growth in IT manufacturing is more dependant on R&D input than on HR input of R&D. In order to establishment of the regression equation, we use analytical software SPSS and take principal component analysis method to measure R&D input and industrial growth, which generate a principal component respectively (recorded XI and YI). Table 10 shows the results:

Table 10 about here.

From the table above we find that XI contains 98.387% of information of X_1 and X_6, and the main factor YI contains 99.052% of information of Y_3 and Y_4. So it is ideal to take the two main factors of R&D input as industrial growth in IT manufacturing. We build the regression equation about the impact of R&D input on the industrial growth as following:

$$YI = a + b\ XI \tag{5}$$

Use sample data from 1995-2004 and the result of regression is:

$$YI = 0.995*XI \tag{6}$$

Since the constant term can't pass the test, omits it. The results of equation (6) show that addition one unit of R&D input can bring about 0.995 unit of output growth in IT manufacturing, which is less than 1. So we believe that there is still large potentiality to improve performance of IT manufacturing from R&D input.

From the above analysis, we can be draw four conclusions.

First, input of internal R&D and new product R&D are fastest to generate effect and the time lag is only one year. The expenditure for the introduction and the transformation of technology and the input of technology staff have longer time lags which are at least three years.

Second, the output performance of the expenditure for R&D of new products is better than that of the internal expenditure for R&D.

Third, every increase of one unit R&D input can pull about 0.995 units of industrial output growth, which has still a significant potentiality for growth.

Fourth, the expenditure of R&D which can generate short-term benefit is larger the share in the total expenditure for R&D of China's IT manufacturing. It suggests that the independent innovation has the fastest of effect. The expenditure of technological innovation which has the relatively long cycle is a small proportion. The most effective way of technological innovation is increase the input R&D of new products in IT industry. Though there is a time lag of human capital input, this should not be ignored in the long term.

THE IMPACT OF R&D INPUT ON INDUSTRIAL COMPETITIVENESS

Set the product sale profits PR as an index that measures the industrial competitiveness, and choose total R&D input, the number of staff engaged in technology innovation, the number of patent applications, as well as the output of new products as indexes that measures the comprehensive capacity of the industry, we establish the following regression model:

$$LnPR=a_1lnX_1+a_2lnX_6+a_3lnY_1+a_4lnY_3+b_1 \tag{7}$$

The sample includes 10 data from 1995 to 2004, and the regression result is as follows:

Sample	Regression Coefficient	**Standard Derivation**	T-Test	Probability
LnX_1	1.408507	0.671663	2.097045	0.0901
LnX_6	2.497149	1.147888	2.145429	0.0816
LnY_1	-0.734049	0.431566	-1.700895	0.1497
LnY_3	0.393233	0.534844	0.735230	0.4952
b_1	-28.62028	12.20045	-2.345839	0.0659

R^2	**0.975581**	Average Changes of Independent Variable	**5.866077**
Adjusted of R^2	0.956047	**Standard Derivation of Independent Variable**	0.857409
Standard Errors of Regression	0.179756	Akaike Info Criterion	-0.287576
Sum Squared of Residual	0.161562	Schwarz Criterion	-0.136283
Likelihood Logarithms	6.437878	F-test	49.94062
D-W Test	1.900932	Probability (F—test)	0.000320

Inevitably, there are some correlations between each two variables, so we use still the principal component analysis to test the regression results and eliminate the influence of multicollinearity. The result is:

Table 11 here.

From the table 11, we find that the correlation is strong among the 4 chosen variables, and the generated principal component can account for 97.61 of the information of the four variables. The regression model about principal component z to the dependent variable LnPR is:

$$LnPR=a_5\, Z+b_2 \qquad (8)$$

The sample includes 10 data from 1995 to 2004. The regression result is:

$$LnPR=0.843Z+5.866 \qquad (9)$$

Sample	Regression Coefficient	**Standard Derivation**	T-Test	Probability
Z	0.842615	0.056072	15.02726	0.0000
b_2	5.866076	0.053195	110.2751	0.0000

R^2	**0.965785**	Average Changes of Independent Variable	**5.866077**
Adjusted of R^2	0.961509	**Standard Derivation of Independent Variable**	0.857409
Standard Errors of Regression	0.168217	Akaike Info Criterion	-0.550267
Sum Squared of Residual	0.226376	Schwarz Criterion	-0.489750
Likelihood Logarithms	4.751334	F-test	225.8185
D-W Test	1.837981	Probability (F—test)	0.000000

Since the model passes D-W test and F-test under significance level of 1%, and both the correlation coefficient (R^2) and the correlation coefficient of the adjusted model are high, which indicate the degree of goodness of fit of the model is high. Generally speaking, the international competitiveness is highly correlated with independent variables. From the variable perspective, the principal component Z has passed the T-test under significance level of 1%, which suggests the variables in the model are correlated with the international competitiveness but extent and direction of influence for each variable is differ. The results show that total R&D input X_1, the total number of staff of R&D X_6, the number of patent applications Y_1, and as well as the output value of new products Y_3 have effect to the competitiveness of IT manufacturing. From the general variable explanatory of the main factor analysis in table 11, we can find that the impact of total expenditure for R&D reaches to 97.61% on the industrial competitiveness, which means R&D input is the most important factor in the process of improving industrial competitiveness.

INTERNATINAL COMPARISON OF TECHNOLOGY INNOVATION

1、International Comparison of Intensity of R&D Input

From table 12, we show that the intensity of R&D input in China's manufacturing, the intensity of R&D in high-tech industry is only 4.6 percent in 2004, and the intensity of manufacturing has only 1.9 percent, the highest is aerospace manufacturing, accounting for 16.9%.We can find that the intensity of R&D in high-tech industry is generally higher than that of the average level of the manufacturing.

By comparison with developed country, the high-tech industry starts in a relatively low level, the R&D investments get behind the developed countries and haven't master core technologies in China. The intensity of R&D is more than 20 percent in many countries of OECD. The globalization of high-tech industry is prominent in the process of economic globalization. The multinational corporations invest heavily in R&D of key technology, while production of the mature technology product transfer to developing countries where labor force is cheaper. The high-tech industries of developing countries can only operate in the form of consigning process to produce external equipment or assemble work, not more than R&D.

In main developed countries, the intensity of R&D input is higher than 20% in the Electronics and Telecommunication Equipment manufacturing , however that is 5.6% in China, only one tenth of the France where that is 57.2%. As to Computers and Office Equipments manufacturing, the intensity of R&D input in Japan is the highest rank by 90.4%, America is 32.8%, China only 3.2%. Though we start at later than developed countries in two sectors and our technology is obviously falling behind, we can't chose a development model of traditional industry. If we still develop IT manufacturing via step by step, we will never catch up with the advanced level of world. So we should increase the R&D input intensity and fully catch the opportunity of international industrial division, which put in practice a 'frog-jumping' strategy.

Table 12 here.

2、International Comparison of Labor Productivity

Although the labor productivity has increases largely in China's IT manufacturing and high-tech industry since 1995, the gap with the developed countries is still very obvious. The disparity is associated not just with technology but also with the labor force quality. In OECD countries the total labor productivity is usual over 50 thousand dollars per capita while 13 thousand dollars per capita in China. Even if there is relatively fast growth in the Computers and Office Equipments manufacturing, the labor productivity is only 17.9 thousand dollars per person. Therefore, no matter what in technology level, productivity and competitiveness, China has big gap than the developed countries, which is the largest challenge for China's industrialization process, we should pay full attention in the future.

Table 13 here.

CONCLUSION AND POLICY SUGGESTION

By empirical analysis of the effect of technology innovation on industrial growth and competitiveness of China's IT manufacturing, we can draw four conclusions. First, every 1% increase of new product R&D can bring about 0.550% of new product output, it will generate effect in a year, while the internal expenditure for R&D need at least two years to produce benefits. Second, the ratio of the R&D input to the total input has direct effect on the IT manufacturing's growth, every 1 unit of increase in total R&D input can drive 0.995 unit output growth, and it still remain a large room to enhance the performance of IT industry. Third, the impact of total expenditure for R&D on the industry competitiveness reaches to 97.61%, which means R&D input is the most important factor in the process of improving industrial competitiveness. Fourth, the technological innovation capability has a large gap between IT manufacturing of China and that of the developed countries. The R&D input intensity of IT industry in developed countries is the higher than 20%, the average is 4.4 % in

China, correspondingly. The labor productivity is only a half of that of South Korea, one-ninth of the United States.

On the other hand, the proportion of expenditure which can generate short-term benefits is large in the total R&D expenditure of China's IT industry. The investment of R&D which can to generate effect on long-term has is a little share, which is also disadvantage to corporations' long-term development strategy and the upgrading of the technology.

China's economic is experiencing to transformation from early industrialization stage to the industrialization metaphase, the large-scale and high-tech industries become the key industries. If China wants to improve the industry's competitiveness by the way of technological innovation, the IT industry is regarded as a key high-technology industry. There is only rest on technology introduction and technology transformation, which will never be able to catch up with or exceed the level of developed countries. Only through increasing input for technological innovation, improving the environment for innovation and incentive mechanisms, enhancing the efficiency of the innovation system, strengthening international technical cooperation, decreasing monopolization by State-owned enterprises, opening up market to increase competition, and promoting the IT application and diffusion in other industry, can China shift from 'a world IT factor' to leader of IT innovation.

Paper just examined the impact of technological innovation on the industrial growth and the competitiveness of China's IT manufacturing. However, if China's IT manufacturing has stronger enough capacity to investment R&D, how much input in technological innovation should be appropriate and how to effectively allocate technological innovation resources are the questions that need to be further research.

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Table 1 Input and Output Indexes of Technology Innovation

Category	Symbol	Meaning	Category	Symbol	Meaning
Input Indexes	X_1	Total R&D input	**Output indexes**	Y_1	Number of patents
	X_2	Internal R&D input		Y_2	Export delivery value
	X_3	R&D input of new product		Y_3	New product value added
	X_4	Input in technology transformation		Y_4	total output value of industrial
	X_5	Input in technology introduction	**Profit index**	PR	Product sell profits
	X_6	R&D input in human resource			

Table 2. The R&D Input in China's IT Manufacturing

(Hundred Million YUAN RMB, %)

year	Total R&D Input	Government Input	The Share of Government	Enterprise Input	The Share of Enterprise
1995	30.19	2.78	8.9	24.85	80
1996	32.45	2.34	7.2	22.97	71
1997	43.85	3.31	7.6	29.80	68
1998	73.51	3.48	4.7	55.68	76
1999	100.39	4.62	4.6	82.60	82
2000	170.04	4.74	2.8	142.42	84
2001	198.47	5.38	2.7	172.00	87
2002	230.64	7.54	3.3	187.76	81
2003	311.15	5.93	1.9	260.39	84
2004	428.47	8.37	2.0	371.17	87

Note: all data exclude the data of foreign-owned enterprises.

Data source: The High-Tech Industry Statistical Yearbook (2002), China Statistical Press, 2003; The High-Tech Industry Statistical Yearbook (2005), China Statistical Press, 2006

Table 3. The Input of Technology Innovation in IT Manufacturing

(One，Hundred million YUAN RMB, %)

year	S&T Institute Number	Peoples Technology Innovation	Peoples of Scientists & Engineers	Internal R&D Input	Input in New product R&D	Input in technology transformation	Input in technology introduction	Intensity Of R&D
1995	964	89867	38163	5. 7	13. 8	36	20	0. 23
1996	876	100072	59623	13. 6	19. 9	42	15	0. 48
1997	707	106370	67592	25. 1	30. 2	39	22	0. 67
1998	740	112849	63152	39. 3	47. 4	30	15	0. 86
1999	737	116015	64207	46. 5	66. 9	39	18	0. 82
2000	546	117012	78872	79. 5	87	55	38	1. 06
2001	577	131360	95249	116. 1	104. 6	52	65	1. 29
2002	572	130600	92653	137	124. 4	57	78	1. 23
2003	537	153954	59727	164. 3	156. 7	67	77	1. 17
2004	847	171778	60089	228. 1	366. 1	94	102	1. 12

Note: Input includes domestic enterprises, joint venture and foreign-owned enterprises.

Data source: China statistical Yearbook (2005) , China Statistical Press, 2006; The High-Tech Industry Statistical Yearbook (2002) , China Statistical Press, 2003; The High-Tech Industry Statistical Yearbook (2005) , China Statistical Press, 2006

Table 4. The Output Growth of China IT Manufacturing, 1995-2004

Hundred Million YUAN RMB

Year	Total Output	Value Added	Profits& Revenue	New Product Output	New Product Revenue	Export Delivery Value	New Product Profit
1995	2536	636	186	537	387	931	44
1996	3085	725	112	678	559	1054	53
1997	3969	910	317	872	627	1208	76
1998	4968	1136	342	1192	1030	1769	95
1999	5912	1363	461	1451	1296	2135	111
2000	7658	1845	696	2290	2168	3062	168
2001	9100	2054	700	2572	2507	3881	146
2002	11427	2543	685	3016	2959	5607	208
2003	16204	3594	885	4010	4010	8539	329
2004	22699	4592	1031	5316	5368	14106	382

Data source：ibid

Table 5. Labor Productivity of China IT Manufacturing, 1995-2004
(%, Ten thousand Yuan RMB /person)

Year	The Share IT output/ manufacturing output	Growth Rate of IT Manufacturing	LP of Manufacturing	LP of High-Tech Industry	L P of ETEM	LP of MCOE
1995	5.2	--	1.7	2.4	3.0	6.6
1996	6.0	21.6	2.1	2.8	3.3	9.5
1997	6.6	28.7	2.4	3.6	4.2	10.6
1998	8.3	25.2	3.0	4.5	5.3	12.4
1999	9.2	19.0	3.5	5.5	6.7	11.5
2000	10.2	29.5	4.3	7.1	8.5	15.7
2001	10.8	18.8	4.9	7.8	9.2	14.7
2002	11.6	25.6	5.7	8.9	10.1	15.6
2003	12.7	41.8	7.0	10.5	11.5	17.2
2004	16.8	40.1	8.1	10.8	11.1	14.8

Note: LP is Labor Productivity, ETEM is Electronic and Telecommunications Equipment Manufacturing, MCOE is Manufacture of Computers and Office Equipments

Data resource：ibid

Table 6. Pearson Relationship Coefficients Matrix and Test

		LnX_2	LnX_3	LnX_4	LnX_5	LnX_6	LnY_3
LnX_2	**Correlation**	1.000	.974*	.767*	.836*	.934*	.989*
	Significance	.	.000	.010	.003	.000	.000
	N	10	10	10	10	10	10
LnX_3	**Correlation**	.974*	1.000	.831*	.850*	.966*	.987*
	Significance	.000	.	.003	.002	.000	.000
	N	10	10	10	10	10	10
LnX_4	**Correlation**	.767*	.831*	1.000	.906*	.847*	.837*
	Significance	.010	.003	.	.000	.002	.002
	N	10	10	10	10	10	10
LnX_5	**Correlation**	.836*	.850*	.906*	1.000	.847*	.877*
	Significance	.003	.002	.000	.	.002	.001
	N	10	10	10	10	10	10
LnX_6	**Correlation**	.934*	.966*	.847*	.847*	1.000	.955*
	Significance	.000	.000	.002	.002	.	.000
	N	10	10	10	10	10	10
LnY_3	**Correlation**	.989*	.987*	.837*	.877*	.955*	1.000
	Significance	.000	.000	.002	.001	.000	.
	N	10	10	10	10	10	10

Where * is the result under 2 lagged differences and the significance level of 0.01.

Table 7. Granger Causality Test Under 1 Lagged Difference

Hypothesis Test	Sample	F-statistic	Probability
Y_3 is not X_2's Granger cause	9	4.11302	0.08890
X_2 is not Y_3's Granger cause	9	0.00425	0.95015
Y_3 is not X_3's Granger cause	9	1.02558	0.35028
X_3 is not Y_3's Granger cause	9	3.97005	0.09339
Y_3 is not X_4's Granger cause	9	2.96122	0.13607
X_4 is not Y_3's Granger cause	9	0.10996	0.75146
Y_3 is not X_5's Granger cause	9	9.65787	0.02091
X_5 is not Y_3's Granger cause	9	0.02233	0.88612
Y_3 is not X_6's Granger cause	9	0.76914	0.41421
X_6 is not Y_3's Granger cause	9	0.42412	0.53901

Table 8. Granger Causality Test Under 2 Lagged Differences

Hypothesis Test	Sample	F-statistic	Probability
Y_3 is not X_2's Granger cause	8	1.86391	0.29776
X_2 is not Y_3's Granger cause	8	12.4797	0.03515
Y_3 is not X_3's Granger cause	8	2.28979	0.24901
X_3 is not Y_3's Granger cause	8	0.74664	0.54555
Y_3 is not X_4's Granger cause	8	2.75872	0.20903
X_4 is not Y_3's Granger cause	8	1.94575	0.28722
Y_3 is not X_5's Granger cause	8	1.39972	0.37205
X_5 is not Y_3's Granger cause	8	0.65899	0.57911
Y_3 is not X_6's Granger cause	8	0.50298	0.64807
X_6 is not Y_3's Granger cause	8	1.76256	0.31174

Table 9. Pearson Relationship Coefficients Matrix and Test

		X_1	X_6	Y_3	Y_4
X_1	**Correlation**	1.000	.968*	.983*	.989*
	significance	.	.000	.000	.000
	N	10	10	10	10
X_6	**correlation**	.968*	1.000	.978*	.981*
	significance	.000	.	.000	.000
	N	10	10	10	10
Y3	**correlation**	.983*	.978*	1.000	.981*
	significance	.000	.000	.	.000
	N	10	10	10	10
Y4	**correlation**	.989*	.981*	.981*	1.000
	significance	.000	.000	.000	.
	N	10	10	10	10

Note: * is the result under 2 lagged differences and the significance level of 0.01.

Table 10. General Variance Explanatory Table for XI and YI

Principal component	XI		YI	
	1	2	1	2
Eigenvalue	1.968	3.226E-02	1.981	1.895E-02
Total Variance Explanation	98.387	1.613	99.052	.948
Accumulated Variance Explanation	98.387	100.000	99.052	100.000
Eigenvalue	1.968		1.981	
Total Variance Explanation	98.387		99.052	
Accumulated Variance Explanation	98.387		99.052	

Table 11. Total Variance Explanatory Table

Principal component	Eigenvalue	Total Variance Explanation	Accumulated Variance Explanation	Eigenvalue	Total Variance Explanation	Accumulated Variance Explanation
1	4.880	97.610	97.610	4.880	97.610	97.610
2	6.959E-02	1.392	99.001			
3	3.221E-02	.644	99.646			
4	1.439E-02	.288	99.933			
5	3.326E-03	6.652E-02	100.000			

Table 12. The Intensity of R&D in High-tech Industry and Manufacturing (%)

Industry		China 2004	USA 2002	Japan 2002	German 2002	France 2002	British 2002	Italy 2002	South Korea 2003
Manufacturing		1.9	7.8	10.4	7.7	7.4	6.9	2.3	7.3
High-tech industry		4.6	27.3	29.9	24.1	28.6	26.0	11.6	18.2
Medical and Pharmaceutical Manufacturing		2.4	21.1	27.0	-	27.2	52.4	6.6	4.4
Aircraft and Spacecraft Manufacturing		16.9	18.5	21.6	-	29.4	23.8	23.4	-
IT manufacturing	**Electronic and Telecommunications Equipment**	5.6	25.4	20.4	39.2	57.2	23.6	19.4	23.4
	Manufacture of Computers and Office Equipments	3.2	32.8	90.4	18.1	15.8	5.9	8.8	4.4
Medical Equipments and Meters Manufacturing		2.5	49.1	30.1	14.0	16.1	8.3	6.4	10.7

Data source: The Statistical Handbook of China's High-tech Industry, China Statistical Press, 2005; OECD Structural Analysis Database, 2005; OECD The Analytical Business Enterprise Research and Development Database, 2006.

Table 13. The Labor Productivity of High-Tech Industry In Main Countries

(Thousand dollars/person)

Industry	China 2004	America 2003	Japan 2003	German 2002	France 2002	Italy 2002
Manufacture	9.8	95.7	78.9	51.7	62.4	41.6
High-tech industry	13.0	141.2	100.0	50.7	78.8	56.4
Medical and Pharmaceutical Manufacturing	12.4	285.4	272.0	-	130.8	92.8
Aircraft and Spacecraft Manufacturing	6.6	120.7	80.3	-	109.4	81.1
Electronic and Telecommunications Equipment	13.4	121.7	93.0	52.2	42.0	40.5
Computers and Office Equipments Manufacturing	17.9	145.2	72.0	62.6	71.0	30.4
Medical Equipments and Meters Manufacturing	8.8	103.8	63.4	48.2	66.3	44.1

Data source: ibid