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ECONOMIC OPENNESS, TECHNOLOGY GAP AND TOTAL FACTOR PRODUCTIVITY BASED ON SEMI-PARAMETRIC ESTIMATION OF CHINA'S MANUFACTURING INDUSTRY PANEL DATA

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Abstract
By selecting the panel data from 26 sectors in China's manufacturing industry from 2002 to 2011 and using the semi-parametric estimation method,this paper discusses the effects of economic openness, technology gap and human capital on total factor productivity. On the basis of handling the multi-collinearity problem, the empirical research finds that both China's economic openness and reasonable technology gap significantly promote the technological level of the industry. This effect is obviously enhanced by joining a series of control variables. The level of human capital has shown a negative correlation with the technology gap. Classified samples test results indicate that the promoting effects are more obvious in sectors that have higher human capital level and research and development ("R&D") ratios.
Keywords: economic openness; technology gap; total factor productivity; multicollinearity problem; semi-parametric estimation

1. INTRODUCTION

In an open economy, how to improve the productivity in China's Manufacturing Industry is always a research hotspot. For a developing country which has relatively weaker R&D strength and lower human capital level, it is meaningful to improve the technical level of the industry domestically by opening up. Edwards (1998) conducted an empirical research to study the impact of nine indicators of openness on total factor productivity by using multinational data from 1960 to 1990. This paper found that a country's openness has significant positive correlation with its total factor productivity, and this positive correlation does not change with different indices or estimation techniques. Miller et al. (2000) examined the impact of differing degrees of openness and human capital on total factor productivity within 83 countries. The results showed that trade openness has significant effect in promoting total factor productivity, however, the influence of human capital on the total factor productivity is uncertain. Slderbom & Teal's (2003) empirical study also found that trade openness has a significant effect on productivity growth, however, human capital had no significant influence on productivity. Xiangyang Wang et al. (2011) used the co-integration and granger causality test to discuss the influence of foreign capital on the total factor productivity. The results of this study showed that the inflow of foreign capital have a certain role in promoting the total factor productivity, however, this effect has a time lag and a long-term trend. ShujingYue et al. (2006) applied the Malmquist index to measure the total factor productivity in 30 provincial-level administrative regions in China from 1996 to 2003, and then focused on the influence of human capital to the total factor productivity. The results of this study showed that by adding the human capital factor regional total factor productivity increased rapidly, thus this paper verified the key role that human capital plays in determining total factor productivity. Xiahai Wei(2009) used quantile regression method and conducted an empirical research on the relationship amongst human capital, trade openness and total factor productivity. The results showed that, on a national scale, human capital promotes the growth of the total factor productivity, impacting such factor instantly. However, the strength of this impact is not that great. While the impact of human capital on trade openness has shown through a lagged effect, the influence of these two factors on total factor productivity in each quantile present distinct regional differences. This impact has been strong only in the eastern region, where the instant effect of human capital on total factor productivity growth was strong. In the western region, trade openness has had a lagging effect on total factor productivity, which has been relatively long in comparison. The central region has shown a similar performance in comparison to the nation.

Integrated the relevant literature, this paper found: first, domestic and foreign scholars generally believe that the trade openness, foreign capital can significantly improve the productivity, however, whether the human capital can significantly promote total factor productivity remains controversial. [1]Second, many scholars ignored the technology gap between domestic and foreign enterprises in the empirical research, and this variable plays a pivotal role to improve the productivity. Some scholars (such as Mingyong Lai (2005), HelianXu (2006), Huihuang Liu (2009) believe that reasonable technology gap is the key element to ensure the successful completion of technology spillover.In this paper, the economic openness level, technology gap between domestic and foreign enterprise, human capital level and total

[1]This paper argues that the main reason that scholars have dispute is the complicated impact that human capital has on total factor productivity. Firstly, various levels of human capital have different effect on total factor productivity; Secondly, the effect of human capital on total factor productivity can be direct, but it also has indirect effect through other factors. Therefore, it is not reasonable to measure the complex effects through parameter econometric model.

factor productivity are placed within one econometric model to study the impact of the first three factors on total factor productivity. Considering the complex influence of human capital on total factor productivity, semi-parametric estimation econometric model is established.We will discuss the construction of econometric model and description for each variable, the empirical analysis, and the conclusion in the remainder of this article.

2. THE MODEL

2.1. Construction of econometric model

This paper is based on the new growth theory and lessons drawn from Miller and Upadhyay (2000), and Mingyonglai andQunBao (2005). Assuming that total factor productivity (TFP) is determined by its economic openness, domestic and foreign technology gap and human capital level. On this basis, this paper set the form of production function as:

$$Y = A(open, gap, H, t)\, f(K, L) \qquad (1)$$

In the above equation (1), ***Y*** represents output, ***open*** represents economic openness, ***gap*** represents the domestic and foreign technology gap, ***H*** represents human capital, ***K*** and ***L*** represent the capital investment and workforce respectively. ***A*** is Hicks neutral technical progress function which represent the contribution of other factors besides labor (such as openness level, technical level, and human capital level) to economic growth, it can be expressed as (2)

$$A(open, gap, H, t) = A_{i,0}\, open^{\delta_i} gap^{\varphi_i} H^{\gamma_i} e^{\theta_i t} \qquad (2)$$

plug (2) into (1)

$$Y = A_{i,0}\, open^{\delta_i} gap^{\varphi_i} H^{\gamma_i} e^{\theta_i t} f(K, L) \qquad (3)$$

In equation (3) , $A_{i,0}$ represents the initial productivity level in *i* district, δ_i , φ_i and θ_i represent the contribution coefficient that openness level, technology gap and human capital level on technology level in i district. Divided (3) by $f(K,L)$ on both sides and take the natural logarithm,

$$\ln TFP = \ln A_{i,0} + \delta_i \ln open + \varphi_i \ln gap + \gamma_i \ln H + \theta_i t \qquad (4)$$

Based on (4), this paper set up the initial econometric model as follows:

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$$\ln TFP_{i,t} = \alpha + \beta_1 \ln open_{i,t} + \beta_2 \ln gap_{i,t} + \beta_3 \ln H + \beta_4 \ln TFP_{i,t-1} + \sum_{k\geq 5} \beta_k \ln CONTROL_{i,t} + \mu_{i,t} \quad (5)$$

(5) is a dynamic econometric model, i represent different province, t represent year, TFP represents the total factor productivity, $CONTROL$ represents control variable, $\mu_{i,t}$ represents stochastic error.The explanatory variables in (5) included the explained variable lags, this is mainly because technical progress is a continuous process and should be affected by the previous technology accumulation. Then adding the lags can effectively depict technological progress over time. In order to get more robust estimation results, (5) included some control variables, including per capita capital, governmental expenditures and institutional quality.[2]

2.2. Variables and data sources

Total factors productivity (*TFP*)

This paper uses the nonparametric estimation method proposed by Olley-Pakes (1996) to calculate the total factor productivity; this method can effectively avoid the traditional productivity estimation method that may lead to simultaneity bias and selective bias.

The idea of the method is: suppose the C-D production function as $Y = AL^{\alpha} K^{\beta}$, taking natural logarithms on both sides $y = \alpha \ln l + \beta \ln k + u_i$ and obviously this equation has the endogenous problems. Make $u_i = \varpi + e_i$, then $y = \alpha \ln l + \beta \ln k + \varpi + e_i$, ϖ is recessive productivity.Generally,, the higher ϖ , the more investments the enterprise will add in the current period. Suppose the investment amount is i , $i = i(k, \varpi)$, then $\varpi = i^{-1}(\bullet) = h(i,k)$,

so,

$y = \alpha \ln l + \beta \ln k + h(i,k) + e_i$,

Make $\varphi(k,i) = \beta \ln k + h(i,k)$, then $y = \alpha \ln l + \varphi(k,i) + e_i$, .

Estimated value $\hat{\alpha}$ can be obtained from estimating the above formula. Define $G = y - \hat{\alpha} l = \beta k + v(\varphi_{i,t-1} - \beta k_{i,t-1}) + u_i$, in this formula, $v(\cdot)$ is a function include lagged value φ

[2]In this paper, the selection of control variables drawn reference from the approach of Mao Qilin (2011).

and k ,its estimation can be done through the nonlinear least squares. The numerical values of TFP can be gotten after the coefficient was successfully estimated.

The calculation includes the data of the output value, labor inputs and capital stock. The output value take the regional gross domestic product (GDP) as a substitute, the data are from the regional statistical yearbook, this paper uses GDP deflator to get the actual value. Labor input uses the total number of employees in the whole society in various provinces by the end of the year, the data come from China labor statistical yearbook and manufacturing in China statistical yearbook. Capital stock data has been derived by using the perpetual inventory method. The investment including the sum of the whole society's fixed asset investment and foreign direct investment, the amount of the foreign direct investment are all converted into RMB according to the average exchange rate of the Yuan against the dollar.

Economic Opening (*OPEN*) .

A country's economic openness level should include the level of export, import and foreign direct investment inflows and outflows. [3]A single index is not comprehensive and accurate to measure the region real economic openness level. This paper uses Yongheng Yang's principal component analysis for reference and makes proper correction to calculate weighted average of foreign trade dependence and foreign capital dependence. The foreign trade dependence is the year's total import and export amount divided by GDP, foreign capital dependence is the sum of foreign investment and foreign direct investment divided by GDP. To eliminate the influence of price fluctuation, the above data are adjusted to be deflator data. The foreign trade amount, foreign investment amount and GDP are taken from the annual China statistical yearbook, with the foreign direct investment figures taken from the balance of payments section.

Technological Gap (*TGAP*)

In this paper, the technology gap calculation method is as follows[4]: first, using the total factor productivity as a way to calculate the annual technical level,take the logarithm of the Cobb-Douglas production function $Y = AL^{\alpha} K^{\beta}$ on both sides and make proper arrangement can get total factor

[3]Most scholars ignored the foreign direct investment in calculating economic openness. Considering the rapid development of foreign direct investment in China in recent years this paper includes foreign direct investment in the calculation.

[4] The calculation methods of technology gap are not uniform, one method is technology gap measurement methods based on Data Envelopment Analysis (DEA), such as Chen Yu (2009); method two is the calculation method based on total factor productivity, such as Huang Jing (2008); the third calculation method is based on the index of per capita income, such as Ouyang Yao (2008) . We apply the second method in this paper.

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productivity: $\log TFP = \log Y - \alpha \log L - \beta \log K$. Secondly, according to the domestic and foreign enterprise technology level, get technology gap between domestic and foreign enterprises : $GAP = 1 - \frac{\log TFP_d}{\log TFP_f}$, $\log TFP_d$, $\log TFP_f$ refers to the domestic and foreign technical level respectively.Relevant data mainly comes from China statistical yearbook, China labor statistical yearbook, manufacturing in China statistical yearbook, and new China 55 years statistical data collection.

Human capital (*HUM*)

This paper uses the per capita average length of education to calculate human capital level. The formula for human capital stock is: human capital stock = ∑the number of different education levels in manufacturing department × weight, $H = \sum H_i \times h_i$. H refers to the annual human capital stock, H_i refers to the numbers of manufacturing workers in i degree level, h_i refers to the average length of education in i degree level. In this paper, the education level of Chinese labor force is divided into four groups: the average of length of education of primary school is defined as six years, the degree of the junior middle school as 9 years, the high school education for 12 years, and college degree or above (including college specialized subject and undergraduate course, all kinds of adult education and graduate students) as 16 years. As a result, human capital stock: $H = 6H_1 + 9H_2 + 12H_3 + 16H_4$. The total human capital stock divided by the number of education at different levels is the average length of education. All the used data are from the China statistical yearbook, China's population statistics yearbook and China education network.

Control variable (CONTROL)

This paper selects three control variables : per capita, government expenditure on education (GEXP) and institutional quality (SYS). In general, higher per capita capital share contributes to higher industry technology level. The higher government expenditure on education, the higher quality human capital will be, and this is more beneficial to improve the technical level of the industry. A perfect system guarantees the effective system implementation and promotes the patent and intellectual property rights protection. The implementation of research and innovation will promote the technology advancement. The per capita capital is the capital stocks of domestic and foreign enterprises divided by the total labor amount. The government expenditure on education refers to annual government expenditure on education divided by current GDP. The institutional quality indexes in this paper reference Jiang

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Dianchun and Ms. Cheung (2008)'s method to measure the degree of an area through non-state economy development level. In calculation, this paper draws on the Qilin Mao's method (2011), such as selecting the non-state worker proportion and the proportion of non-state-owned industrial added value and using principal component analysis to weight to get institutional quality index.

3. EMPIRICAL ANALYSIS

3.1. Descriptive statistics of variables

This paper selects China's manufacturing industry data from 2002 to 2011 as the research object. According to the national economy industry classification standard (GB/T4754-2002), the manufacturing industry is divided into 30 sectors, however, the foreign investment in some manufacturing industry sectors are strictly controlled and its investment proportion is very low that the elimination of these industry data are needed. [5]In addition, wood and bamboo lumbering industry and mining industry also need to be eliminated due to the incomplete data. Therefore, there are 26 sectors are included into the research. Table 1 shows the descriptive statistics characteristics of each variable and the correlation coefficient.

As can be seen from table 1, there is a strong positive correlation between the total factor productivity, technology gap and economic openness level that is in accordance with the expectation. Although the correlation coefficient of the total factor productivity and human capital is 0.267, it does not pass the significance testing. What's more, the correlation coefficient of the human capital with economy openness and technology gap is 0.313 and 0.702 respectively, and they all have passed the test of significance. This shows that there is a correlation between human capital and the other two variables. This paper also calculated the variable variance inflation factor of the human capital [6]with the value of 10.17 that exceed the maximum value of 10. This shows that human capital and other explanation variables produce significant correlation and equation (5) has serious multicollinearity problems. This problem is actually within the expectation of this paper, because lots of research (e.g., Mingyong Lai, QunBao (2005), Xianzhong Yi (2006) and Qin Zhou (2004) etc.) have confirmed that human capital and the technology gap have the strong reciprocal relationships, namely, higher level of human capital can lead to stronger absorption ability to narrow the technology gap; on the contrary, lower human capital

[5]These sectors are oil and natural gas exploitation sector.
[6]The formula of variance inflation factor is: $VIF_i = 1/(1 - R_i^2)$. Among them, VIF represents the variance inflation factor of variable i. R_i^2 represents the multiple correlation coefficient of variable i and other explanatory variables.

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level lead to weaker technology absorption capacity which may widen the technology gap.The significant correlation between human capital with multiple variables also explained that the impact of human capital on technological progress is complex, it has both direct and indirect impact. In this case, it is unreasonable to use the parameter to estimate the influence of human capital to the total factor productivity.

But considering that human capital is one of the key elements that affect total factor productivity, this variable cannot be deleted, otherwise, the econometric model (5) will faced with the endogenous problems. Therefore, this paper decided to correct the model (5) with establishing a semi-parametric model that put human capital in the nonparametric part of semi-parametric model.[7]

$$\ln TFP_{i,t} = \beta_1 \ln open_{i,t} + \beta_2 \ln gap_{i,t} + \beta_3 \ln TFP_{i,t-1} + g(H) + \sum_{k \geq 4} \beta_k \ln CONTROL_{i,t} + \mu_{i,t} \qquad (6)$$

The equation (6) is a modified econometric model, $g(H)$ is the non-parametric part for the semi-parametric model and it is an unknown equation to describe the complex influence of human capital on technological progress.

TABLE 1 - THE CORRELATION COEFFICIENT OF VARIABLES AND STATISTICAL FEATURES

Variable	lnTFP	lnOPEN	lnTGAP	lnHUM	lnPCAP	lnGEXP	LNSYS
lnTFP	1.000						
lnOPEN	0.354***	1.000					
lnTGAP	-0.262**	0.103	1.000				
lnHUM	0.267	0.313*	-0.702**	1.000			
lnPCAP	0.102**	0.117	0.094	0.320	1.000		
lnGEXP	-0.172**	0.102	0.088	0.438	0.164	1.000	
LNSYS	0.147***	0.091	0.129	0.472	0.129	0.133	1.000
Maximum	1.2309	0.4923	0.8203	1.1923	17.3222	0.5398	0.5689
Minimum	0.7092	0.1788	0.4982	0.6352	8.7129	0.0843	0.1021
Mean Value	0.9483	0.3502	0.6514	0.8710	11.2234	0.3264	0.3420
Standard Deviation	0.0523	0.3370	0.5832	0.8010	4.3259	0.5634	0.6211
Observations	260	260	260	260	260	260	260

Figure 1 depicts relationship of the openness level and total factor productivity of 26 divisions manufacturing industry from 2002 to 2011 in China. According to the scatter diagram, foreign economic openness level and total factor productivity has a positive correlation relationship. Figure 2 depicts the relationship of technology gap and total factor productivity of 26 divisions manufacturing industry from 2002 to 2011.There is a negative relationship between technology gap and total factor productivity

[7] This not only solves the multicollinearity problems but also prevents the occurrence of the endogenous problems.

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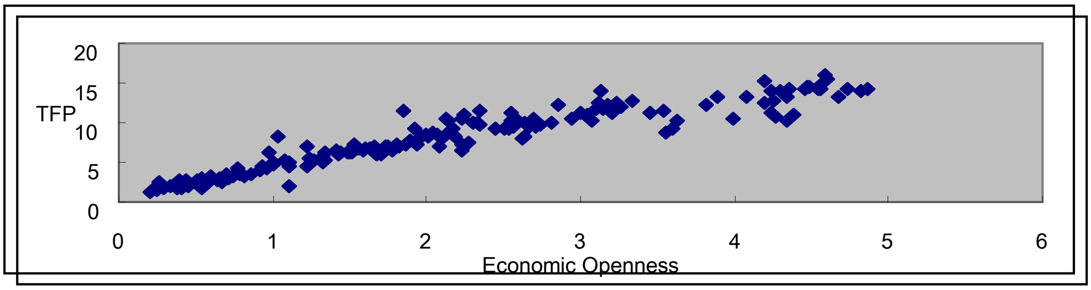

FIGURE 1 - THE SCATTER DIAGRAM OF ECONOMIC OPENNESS AND TFP FROM 2002 TO 2011

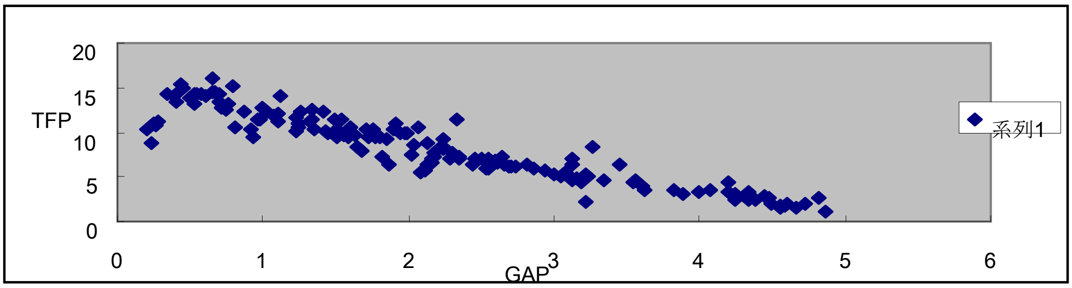

FIGURE 2 - THE SCATTER DIAGRAM OF TECHNOLOGY GAP AND TFP FROM 2002 TO 2011

3.2. The empirical results and analysis

This paper first estimates the overall sample then the classified sample in the empirical analysis process. Table 2 is the overall sample empirical results of model (6).

TABLE 2 - THE ESTIMATION RESULTS OF TOTAL SAMPLE

Explanatory Variables	(1)	(2)	(3)	(4)
lnOPEN	0.3523**	0.3574***	0.3603***	0.3622***
	(3.10)	(10.23)	(9.17)	(9.98)
lnTGAP	-0.4052*	-0.4810***	-0.5014***	-0.5129***
	(2.98)	(18.72)	(17.09)	(15.38)
lnTFP(-1)	0.4702***	0.4744***	0.4751***	0.4729***
	(10.88)	(12.35)	(13.19)	(12.34)
lnPCAP		0.0755	0.0684	0.0678***
		(1.13)	(1.04)	(4.11)
lnGEXP			0.0543***	0.0542***
			(3.34)	(3.46)
lnSYS				0.1023***
				(4.89)
F-statistics	189.34	210.34	177.65	139.03
D.W. value	1.31	1.44	1.45	1.51
Hausman test	154.18	148.45	167.09	122.34
Note	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect

Note：***, **, * represent 1%, 5% and 10% significance level respectively；the value in () is t –statistics .

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The first column of Table 2 is the test result does not contain the control variable, the column s (2) to (4) are the results with adding control variable gradually. As can be seen from the table 2, after adding the control variable, the coefficient of openness level is significantly positive and greater than the value without control variable. This shows that China's foreign economic openness did significantly promote the technological progress of manufacturing and the selection of control variable is reasonable. The coefficient of technology gap is negative and has passed the significance testing (the results are consistent with the scatterplot of figure 2), this result suggest that technology gap will promote technological progress. This is because it is easier to absorb foreign technology with smaller technology gap and more conducive to the technology progress of manufacturing industry. The explained variable lag coefficient is positive which shows that technological progress is a dynamic and continuous process relies on the previous accumulation level. The coefficient of per capita capital share in the model of column (2) and (3) did not pass the test of significance, however, the model in the column (4) has passed the test of significance with 1%. This shows that the pure increase of per capita capital does not necessarily bring the technology progress of the industry, only under the condition which the system of higher quality (that is, the proportion of non-state worker and non-state-owned industrial added value is higher), and the government with higher education spending, the per capita capital will significantly promote the technical progress. The education spending and institutional quality can significantly promote the technical progress in the sector.

TABLE 3 - THE ESTIMATION RESULTS OF CLASSIFIED SAMPLE

Explanatory Varoables	The level of human capital		R&D investment proportion	
	Higher	Lower	Higher	Lower
lnOPEN	0.3506***	0.3242***	0.3918***	0.2623*
	(10.99)	(11.34)	(9.79)	(2.99)
lnTGAP	-0.3927***	-0.2866	-0.3215***	-0.3011
	(5.52)	(1.14)	(4.02)	(0.45)
lnTFP(-1)	0.3804***	0.3871***	0.3829***	0.2845***
	(17.84)	(18.88)	(22.19)	(25.05)
lnPCAP	0.0433**	0.0442***	0.0512***	0.0507**
	(3.13)	(5.35)	(4.98)	(5.03)
lnGEXP	0.0318**	0.0322***	0.0610***	0.0542***
	(3.10)	(3.89)	(4.04)	(4.29)
lnSYS	0.1121***	0.1099***	0.1308***	0.1032
	(3.56)	(4.09)	(4.18)	(1.19)
F-statistics	93.12	85.27	129.12	103.22
D.W.value	1.50	1.51	1.46	1.46
Hausman test	202.12	189.21	166．90	149.85

Note：***, **, * represent 1%, 5% and 10% significance level respectively；the value in () is t –statistics .

In theory, human capital level and development have very close relationship with industry technology progress, but the overall sample return did not fully consider this. Therefore, it is necessary to subdivide

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the overall sample according to the level of human capital and R&D investment proportion[8], table 3 was the sample test results conducted in accordance with this standard.

The 1 and 2 columns of Table 3 are classified sample test results based on the human capital level and the column 3 and 4 are classified sample test results which is divided according to the level of R&D. The table 3 illustrate that in higher levels of human capital industry, economic openness and the technology gap have a higher contribution rate of technological progress of the industry (35.06% and 39.27% respectively), while in the low level of human capital industry, economic openness and the technology gap have a lower contribution rate of technological progress (32.42% and 28.66% respectively) and the latter failed to pass the test of significance. [9]This suggests that the human capital level do have indirectly influence to the total factor productivity by influencing the economic openness and technology gap. This conclusion is consistent with the results in the third part, the improvement of human capital quality is helpful to the technology progress of the industry, but sometimes this is realized through the influence of other factors. The columns 3 and 4 of Table 3 are the results of classified sample test according to the R&D input ratio. The contribution of openness level and technology gap to the technology progress is higher in the group with higher R&D than lower ones. This is because the improvement of R&D development level will help to digest and absorb foreign technology and enhance the technology spillover effect. The conclusion and the Coe &Helpman (1995) and Keller (2002) research conclusions are consistent.

4. CONCLUSIONS

This paper constructed a dynamic semi-parametric econometric model and conducted an empirical research with 26 manufacturing industry from 2002 to 2011. This model added the technology gap to modify Miller and Upadhyay's (2000) model to examine the influence economic openness, technology gap and human capital on total factor productivity. The research results show that China's foreign economic opening level and reasonable technology gap will significantly promote the rise of the technical level of the industry, this effects will got obvious strengthen after adding a series of control variables. This suggests that the technical progress of China's manufacturing industry is not simply rely

[8]Among them, human capacity level is divided based on the standard of the average human capital. The value of human capital which is higher than 0.8710 belong to the higher group, others are put into lower group. R & D investment proportion is the R & D costs divided by sales revenue. This paper take the method from Chen Zhongchang (2007) and Zhao Liyu (2010) for reference using 4% as the standard of R & D investment proportion level.

[9]The absorption efficiency of foreign technology will be very poor, and the human capital will have a little effect on technology development, if the human capital level is very low. Therefore, in the industries with lower levels of human capital, technology gap have not significantly showed the negative relationship with total factor productivity.

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on the level of openness and the reasonable technological gap, it also affected by per capita capital share, the proportion of government education expenditure and institutional quality, etc. The classified sample test results show that higher level of human capital and R&D investment will significantly promote industry technical progress. At the same time, the analysis also showed that the level of human capital and technology gap has significantly reciprocal relationship, so the two should not be put into the same econometric model; otherwise it will produce serious multicollinearity problems. Also, the influence of human capital to the total factor productivity is complex. It could play a direct role in promoting total factor productivity, but more often, it indirectly promote the industry's technological progress through the influence of other factors (such as the quality of openness, technology gap) and this is why semi-parameter econometric model is established in this paper. Therefore, to improve the technology level of manufacturing industry in our country, China should pay attention to the cultivation and development of the factors that mentioned above. China need to maintain a higher level of economic opening level, introduce appropriate and advanced technology and strengthen the investment of research and development. Meanwhile, more concentration is needed to pay to the cultivation of high quality of human capital and improvement of industry institutional quality.

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