RD inputs and productivity growth in China

Zheng, Yan

22 March 2004

R&D inputs and productivity growth in China

Yan Zheng
(Xiamen University Tan Kah Kee College)

Abstract: The relationship between investment in R&D and productivity growth have been well documented in the literature. So far little research has been done on this topic for China, in part due to data limitations. Using the perpetual inventory method (PIM), this paper first estimates the R&D stock in China between 1978 and 2002. If R&D stock is measured, we can then estimate the elasticity of output with respect to R&D, thus estimate the contribution of R&D investment to output in China. The paper finds China's economic growth mainly depends on capital input and that the impact of R&D capital on China's growth is insignificant between 1978 and 2002. Then the essay examines the impact of R&D input on Total Factor Productivity (TFP), and finds that R&D input explains 30% of TFP change in China between 1980 and 2000 and that one percent increase in R&D input leads to 0.27 percent increase in TFP in China. The essay also finds that TFP in China has experienced an unusual fall since 1995.
Key words: Growth, R&D, Total Factor Productivity

1、Introduction

The relationship between investment in R&D and productivity growth have been well documented in the literature. First, Romer (1986) and Lucas (1988) endogenized technology and assumed that technology was created by the R&D efforts of firms and by externalities stemming from capital accumulation. Hulya (2003) investigated the relationship between R&D, invention and economic growth using international panel data of R&D expenditure and patent applications from 20 OECD countries for the period of 1981 and 1997. He found that though only countries with larger markets can increase their invention by investing in R&D, in most countries invention has a positive effect on per capita income growth[1]. Griliches studied the relationship between output, employment and physical and R&D capital, for a sample of 133 large U.S. firms covering the years 1966 through 1977 and found that there was a strong relationship between firm productivity and its level of R&D investment[2]. Many economic studies have pointed to the contribution of R&D activities to the productivity growth at firm and sector level. The main framework for this kind of studies is the Cobb-Douglas production function. Various versions of the model have been estimated by Griliches (1980, 1986, 1995, and 2000), Griliches and Mairesse (1984, 1990), Jaffe (1986), Cuneo and Mairesse (1984), Goto

[1] Hulya, R&D, invention and economic growth: an empirical analysis [EB/ OL]. http://www.ecomod.net/conferences/ecomod2003/ecomod2003_papers/Ulku.pdf

[2] Zvil Griliches & Mairesse, Productivity and R&D at firm level.[EB/OL]. http://www.nber.org/papers/w0826.pdf

and Suzuki (1989), Hall and Mairesse (1995), Husso (1997) and Bartelsman et al. (1996). However, few studies have been done about China, partly due to the limitation of data. One exception was Ling Wang and Adam Szirmai (2003) who applied the R&D model to study the technological inputs and productivity growth in China's high-tech industries. They found the R&D stock of the electronic industry plays special role for the whole of the high-tech sector and that other technological inputs play a less important role in productivity growth, than the R&D stock. Though their works, based on 6 years data, also suffered from the problem of limited data, it offered a methodology for analyzing R&D stock and its role in economic growth. Our study has benefited from the methodology and insight of their essay.

Domestic scholars have made vast studies in China's economic growth under the framework of Cobb-Douglas production function. Though most of these studies have treated technological change as exogenous, thereby ignoring the role of R&D investment in growth, our study has also benefited from these studies. One most important essay is about China's TFP trend since 1995 written by Hu angang[3] (2004), who pointed out that since 1995 TFP change in China experienced an unusual fall and analyzed its causality. Our model estimating impact of R&D input on TFP is built on their conclusion that TFP trend since 1995 is unusual.

2、Measuring the stock of R&D in China

A standard procedure for analyzing the relationship between R&D expenditures and productivity is to employ a Cobb-Douglas production function, using the stock of R&D capital as an input along with the conventional inputs such as capital and labor. R&D capital represents the stock of knowledge a firm or an industry possesses at a certain point of time. It is accumulated through the R&D efforts of a firm or an industry. Like physical capital it depreciates and becomes obsolete[4].

Our first work is to estimate the R&D capital stock, using the perpetual inventory Method (PIM):

Following Griliches (2000) and Goto and Suzuki (1989), the change in the stock of R&D capital depends on the amount of R&D investment and the previous level of this stock. We represent the R&D stock as follows:

$$R_t = \sum_{i=1}^{n} u_i E_{t-i} + (1-\delta) R_{(t-1)}$$

where R_t is the R&D stock at time t, u_i is the lag operator that connects past R&D expenditure E_{t-i} to the current increase in technological knowledge[5], and

[3]胡鞍钢、郑京海：《中国全要素生产率为何明显下降》（Hu angang & Zheng jinghai :Why TFP in China fell dramatically?）http://www.China.org.cn/chinese/OP-c/524675.htm, viewed on 2004-5-22

[4] Source: http://www.iwep.org.cn/pdf/wangling-wp.pdf, viewed on 2004-4-21

[5] Our assumption here is that it takes time for R&D expenditure to have an impact on economic growth, so we use u_i to denote the impact of R&D expenditure at time i on economic performance at time t. For example, if R&D expenditure at time i does not affect economic performance at time t, we define u_i equals to zero.

δ is the rate of obsolescence of R&D capital.

We follow Wang Ling, in assuming that R&D expenditures in period t-1 constitute the increase in the R&D stock in period t and that the growth rate of E is the same as the growth rate of R. Thus the initial amount of R&D capital, R_0, and the R&D capital at time t, R_t, can be obtained separately as follows:

$$R_0 = E_0 /(g + \delta)$$

$$R_t = E_{t-1} + (1 - \delta) R_{t-1}$$

Where g is the growth rate of E. δ is assumed to be 15 per cent.[6]

Our estimation of R&D stock, among other factors collected from various sources, of China between 1978 and 2002 are showed in table 1.

Table 1、 output and factor inputs in China between 1978 and 2002

year	Y	K	L	R&D expendiure	R&D stock
1978	6579.7	23506	40152	96.82277	452.8661
1979	7079.8	25538	41024	109.2073	545.6923
1980	7632	27614	42360	109.113	638.4383
1981	8028	29625	43725	121.6927	741.8771
1982	8759.5	31657	45295	108.0151	833.69
1983	9714.3	33897	46436	129.3658	943.6509
1984	11190.8	36506	48197	147.8166	1069.295
1985	12701.6	39882	49873	145.3591	1192.85
1986	13819.3	43883	51282	151.1668	1321.342
1987	15422.4	48231	52783	145.4508	1444.975
1988	17165.1	52822	54334	94.84845	1525.596
1989	17868.9	57537	55329	118.6857	1626.479
1990	18547.9	62403	63909	125.43	1733.095
1991	20254.3	68175	64799	133.3247	1846.421
1992	23130.4	75840	65554	146.7461	1971.155
1993	26253	82612	66373	148.5687	2097.438
1994	29560.9	91300	67199	140.3465	2216.733
1995	32664.8	103137	67947	159.7298	2352.503
1996	35800.6	115959	68850	213.3229	2533.828
1997	38951.1	129674	69600	251.8708	2747.918
1998	41989.3	145453	72087	295.3634	2998.977
1999	44970.5	161403	72791	372.0166	3315.191
2000	48568.2	178548	73992	487.4604	3729.532
2001	52113.6	198462	74432	566.3146	4210.9
2002	56453.57	221896.6	75360	693.6654	4800.515

Note: 1、all figures are in 1990 comparable price

2、Y, K, R&D expenditure and R&D stock are measured in 100 million RMB. L is measured in 10,000.

[6] http://www.iwep.org.cn/pdf/wangling-wp.pdf, viewed on 2004-4-21

3、R&D stock is calculated by above-mentioned perpetual inventory method, using data of China statistics yearbook.

Source: Ye feiwen: Factor input and China's economic growth, Page 136、208，China statistics yearbook (叶飞文：《要素投入与中国经济增长》136 页、208 页，中国统计年鉴)

3、Constant return to scale Model

If R&D capital is something similar to physical capital but with a different elasticity with respect to output, then we can incorporate R&D input variable into Cobb-Douglas function:

$Y=K^{\alpha}L^{\beta}R^{\gamma}$ (1)

Where Y is output, K and L represent physical capital input and labor input respectively, R is R&D capital input. α is the elasticity of output with respect to capital input, β is the elasticity of output with respect to labor. β is the elasticity of output with respect to R&D capital[7].

Take the log of (1) and get:

$LNY=\alpha LNK+\beta LNL+\gamma LNR+\varepsilon$ (2)

Now we use data from table 1 to estimate equation (2), the aim is to see if R&D capital and physical capital differ in term of their elasticity with respect to output. The estimation result is shown in Table 2.

Table 2、 estimation result

	LNK	LNL	LNR	Constant
coefficient	0.633041	0.642971	0.178215	-5.51496
t values	8.011618*	2.808575*	1.825435**	-2.87835*

Note: F value= 1398.114； R square=0.995018; Degree of Freedom=21

* significant at α=0.05, ** significant at α= 0.10

In consideration of constant return to scale ($\alpha+\beta+\gamma= 1$), we adjust our estimation as follows:

$\alpha'= \alpha/(\alpha+\beta+\gamma)$, $\beta'= \beta/(\alpha+\beta+\gamma)$, $\gamma'=\gamma/(\alpha+\beta+\gamma)$

Then we get the adjusted elasticity of K, L and R with respect to Y:

Table 3、Adjusted elasticity of K, L and R with respect to Y

	K	L	R
Elasticity with respect to Y	0.435311	0.442139	0.122549

Because the coefficient of R is much smaller and also less significant than K and L, we need to exclude variable R and estimate again to see if equation (2) works as well without R and we get:

Table 4、 estimation result

[7] We assume constant return to scale, so $\alpha+\beta+\gamma= 1$.

	LNK	LNL	Constant
coefficient	0.729329	0.866349	-7.70371
t values	11.67527*	4.257686*	-4.90155

Note: F value=1894.653; R square= 0.994228; Degree of Freedom= 22; * significant at $\alpha=0.05$

We can see from table 4 that physical capital and labor input already explain 99.4% economic growth in China and that there is no need to separate R&D capital from physical capital to explain China's economic performance.

Using the above-mentioned method, we can get adjusted elasticity of K and L with respect to Y and their contributions to economic growth between 1978 and 2002. (Table 5)

Table 5、 the adjusted elasticity of K and L with respect to Y and their contributions to China's economic growth

	K	L	TFP
Elasticity with respect to Y	0.457	0.543	N.A.
Contribution to economic growth (%)	47.8	15.4	36.8

Note: Average growth rate of Y, K and L is 9.3692, 9.8054 and 2.6581 respectively.

Source: author (based on table 1 and 5)

Conclusion: Physical capital and labor input explain about 99 percent of China's economic growth, while the impact of R&D capital on growth is insignificant. The elasticity of K with respect to Y is around 0.45 and the contribution of capital and labor inputs to growth in China is about 65 percent. And according to classical growth theory, the rest 35 percent growth is due to technological change (TFP).

4、Increasing return to scale model

A second view is to see R&D input differs from other factor inputs in that it generates long term technological change. So we also need to estimate increasing return to scale model as follows:

$Y=A_0e^{at}K^{\alpha}L^{1-\alpha}R^{\beta}$ (3)

Where a is exogenous technological change, K, L, R and Y are the same as constant return to scale model. Denote y=Y/L, k=K/L and we get:

$y= A_0e^{at}k^{\alpha}R^{\beta}$ (4)

Take the derivative of equation (4) and we get:

$LNy=C+at+\alpha LNk+\beta LNR$ (5)

Using data in table 1, we estimation equation (5) and the result is given in table 6:

Table 6、estimation result

	LNk	LNR	t	Constant
coefficient	0.403862	0.046577	0.034304	-1.92957
t values	3.223383*	0.39255	2.176238*	-2.71843*

Note: R square= 0.991086, F value= 778.3175, degree of freedom= 21, * significant at α=0.05

Conclusion: Similar to constant return to scale model, we find that the impact of R&D input on growth is insignificant and that the elasticity of capital per labor with respect to output per labor is estimated to be about 0.40.

5、Estimating links between Total factor productivity (TFP) and R&D input

Endogenous growth theories believe that technology change is created by the R&D efforts of firms and by externalities stemming from capital accumulation. So our next task is to examine whether R&D behavior has an impact on technological change (TFP) and to what extent R&D input can explain technological change.

Take the derivative of formula (5) and we get:

$$g_y = a+\alpha g_k+\beta g_R \qquad (6)$$

$$TFP=a+\beta g_R+\varepsilon \qquad (7)$$

Table 7 gives TFP and R&D expenditure growth rate between 1978 and 2002:

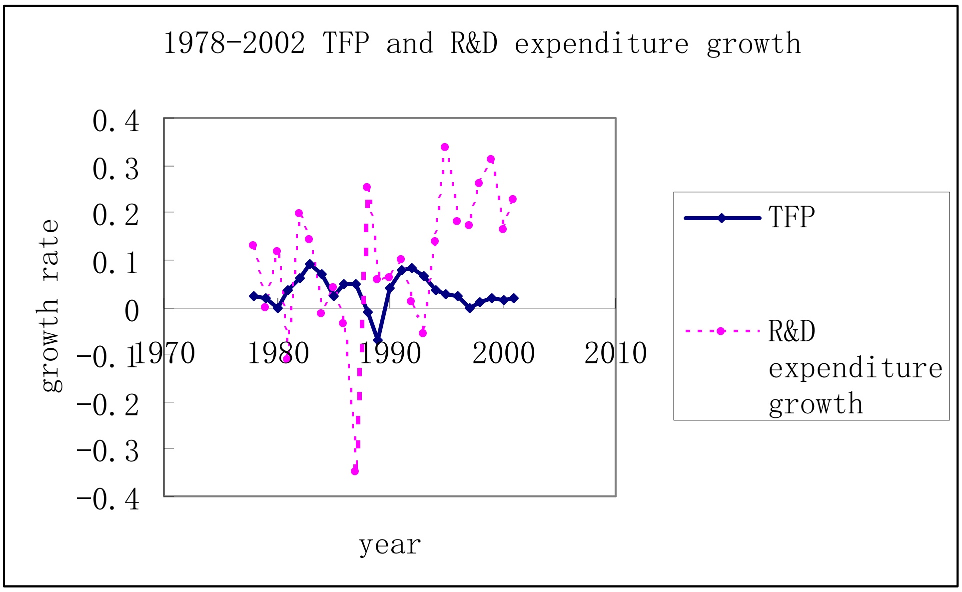
Table 7、TFP and growth rate of R&D expenditure

year	gR&D	TFP	year	gR&D	TFP
1979	0.127909	0.021459	1991	0.062941	0.038256
1980	-0.00086	0.020404	1992	0.100667	0.079037
1981	0.115291	-0.00062	1993	0.01242	0.083069
1982	-0.11239	0.037523	1994	-0.05534	0.066369
1983	0.197664	0.059528	1995	0.13811	0.034229
1984	0.142625	0.091092	1996	0.335523	0.026838
1985	-0.01663	0.068979	1997	0.180702	0.023165
1986	0.039954	0.023059	1998	0.172678	-0.00068
1987	-0.03781	0.050355	1999	0.259522	0.011178
1988	-0.3479	0.049264	2000	0.310319	0.018337
1989	0.251319	-0.01256	2001	0.161765	0.014174
1990	0.056825	-0.07084	2002	0.224876	0.017783

Note: TFP is calculated by $TFP= g_y-0.5\cdot g_k$, g_y and g_k are growth rate of y and k that year.

Source: author (based on table 1)

Figure 1、1978-2002 TFP and R&D expenditure growth in China



Source: based on table 7

To reduce the impact of annual fluctuation, we calculate the two-year moving average of TFP and three-year moving average of R&D expenditure growth respectively. (Table 8)

Table 8、Moving Average of TFP and R&D expenditure growth

year	MATFP	MAgR&D	dummy	year	MATFP	MAgR&D	dummy
1980	0.018452	0.080779	0	1991	0.081053	0.073478	0
1981	0.048525	0.000677	0	1992	0.074719	0.058676	0
1982	0.07531	0.066853	0	1993	0.050299	0.019248	0
1983	0.080036	0.075965	0	1994	0.030533	0.031729	0
1984	0.046019	0.107888	0	1995	0.025001	0.13943	1
1985	0.036707	0.055318	0	1996	0.011241	0.218112	1
1986	0.04981	-0.00483	0	1997	0.005248	0.229635	1
1987	0.018354	-0.11525	0	1998	0.014757	0.204301	1
1988	-0.0417	-0.0448	0	1999	0.016256	0.247506	1
1989	-0.01629	-0.01325	0	2000	0.015979	0.243869	1
1990	0.058647	0.123695	0				

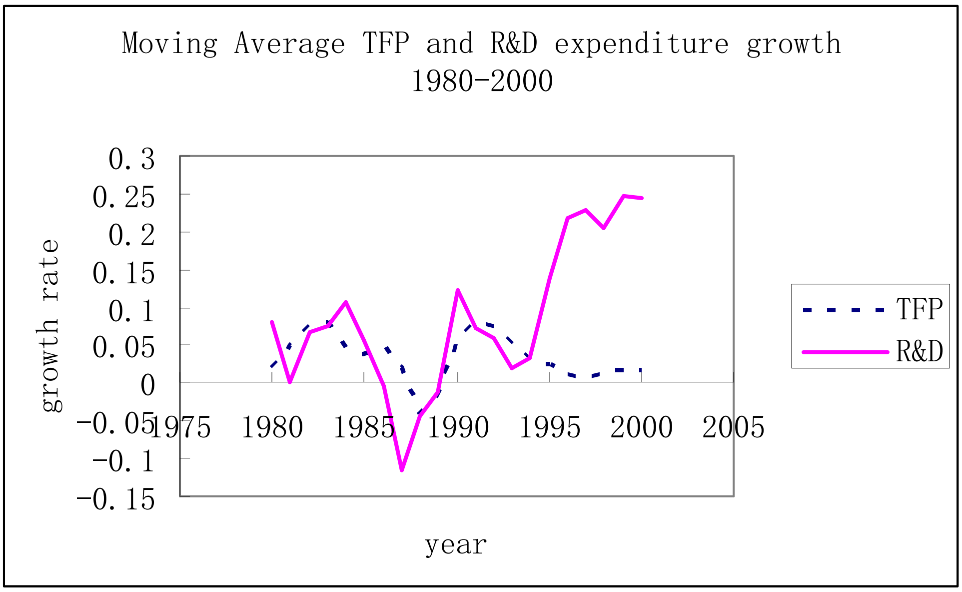
Note: Moving Average TFP (MATFP) and Moving Average gR&D (MAgR&D) are calculated by $MATFP_t = (MATFP_t + MATFP_{t+1})/2$, $MAgR\&D_t = (MAgR\&D_{t-2} + MAgR\&D_{t-1} + MAgR\&D_t)/3$[8]. Dummy variable (Dummy) is used to rule out the impact of the unusual fall in TFP since 1995[9].

Source: author (based on table 1)

Figure 2、Moving Average TFP and R&D expenditure growth

[8] Our assumption here is that the lag between R&D expenditure and TFP change is one or two years, for example, R&D expenditure in 1989, 1990 and 1991 affects TFP in 1991 and 1992.

[9] A sharp fall in TFP of China since 1995 is well documented in various studies; Hu angang has studied the phenomena and pointed out that it was caused by capital deepening and rising cost of labor. 胡鞍钢、郑京海:《中国全要素生产率为何明显下降》(Hu angang & Zheng jinghai :Why TFP in China fell dramatically?) http://www.China.org.cn/chinese/OP-c/524675.htm, viewed on 2004-5-22



Note: TFP in the figure is two-year moving average of TFP, for example, $TFP_{1990}= (TFP_{1990}+TFP_{1991})/2$. gR&D is three-year moving average of gR&D, for example, $gR\&D_{1990}=(gR\&D_{1988}+ gR\&D_{1989}+ gR\&D_{1990})/3$.

Source: based on table 8

Using data in table 8, we estimate equation (7). As we can see from figure 2, TFP has experienced an unusual fall in China since 1995 and we add a dummy variable to control the impact of effect of such unusual fall (Table 8). The result is showed in table 9.

Table 9、estimation result

	constant	R&D expenditure	dummy
coefficient	0. 031335	0. 272094	-0.07476
T value	4.011419*	2.5496*	-3.23836*

Note：F= 5.273034；Degree of Freedom=18；R square =0.36944；

* Significant at α= 0.05

Conclusion: R&D investment accounts for about 40 percent technological change in China between 1978 and 2002. Other factors, notably, foreign investment and international technological transfer, account for about 60 percent of technological change. One percent increase in R&D expenditure leads to 0.27 percent increase in TFP. Since 1995, China's TFP has experienced a sharp fall by about 7 percent. Hu angang[10] (2004) has studied the phenomena and pointed out that China need to change its growth mode to generate long run economic growth.

6、Comparative study of R&D behavior in China

Though our findings indicate high elasticity of output with respect to R&D stock, investment in R&D in China is still at a low level. Table 10 is an international comparison of R&D investment.

Table 10、international comparison of R&D input

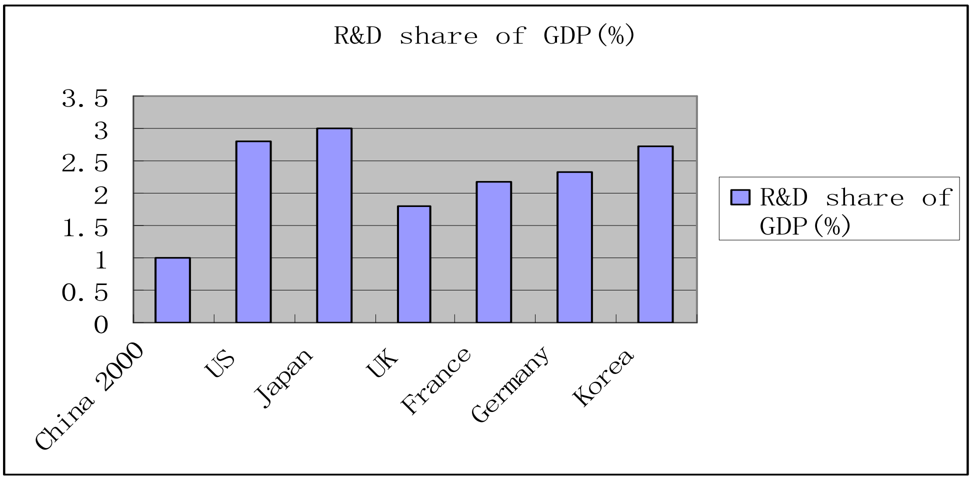
[10] Source: 胡鞍钢、郑京海：《中国全要素生产率为何明显下降》（Hu angang & Zheng jinghai :Why TFP in China fell dramatically?）http://www.China.org.cn/chinese/OP-c/524675.htm, viewed on 2004-5-22

	China 2000	US 1998	Japan 1998	UK 1998	France 1998	Germany 1998	Korea 1998
R&D input*	89.6	227.93	14850.41	14.70	186.91	87.54	11336.62
Share of GDP	1.0	2.79	2.99	1.80	2.18	2.33	2.72

Note: *measured in billion own currency.

Source: http://www.sts.org.cn/fxyj/zcfx/documents/rdzcfx.htm <viewed on 2004-4-22>

Figure 3、R&D/GDP ratios



Source: author (based on previous table)

As we can see from the above figure, China's R&D/GDP ratio is much lower than OECD countries and some emerging industrial countries such as Korea. Unfortunately, we can not collect specific data about developing countries such as India. However, according to 2001 global competitiveness report, China ranked 53 in technology index and 67 in innovation index respectively, both behind such developing countries as India, Brazil and Chile[11].

And in the firm level, R&D investment is disproportionately allocated too. Statistics show in 2001 investment in advertising at firm level is 1.8 times that of R&D. Table 4 shows the allocation between R&D and advertising in some selected industries in China.

Table 11 allocation between R&D and advertising in 6 industries (year 2001)

sector	Advertising per 10,000 RMB sale	R&D per 10,000 RMB sale
Food	167.85	11.55
beverage	296.91	10.92
Tobacco	97.35	15.45
Home products	39.76	7.94
chemical	65.09	18.73
medicine	317.70	78.19

Source: Economic Reference Newspaper 09-09-2002 (《经济参考报》 2002 年 9 月 09 日) http://www.lianghui.org.cn/chinese/EC-c/201281.htm, viewed on 2004-5-2

[11] http://www.cid.harvard.edu/cr/pdf/2001Growth_Competitiveness.pdf, viewed on 2004-6-6

Chemical and medicine both belong to high-tech industries. However, R&D investment in the two sectors is 3/4 less than advertisement input in China (table 12). China needs to emphasize more on R&D investment and technological change in order to generate its long run economic growth. Other factors held constant, if China's R&D/GDP ratio is as high as UK (i.e. R&D expenditure increases by 80 percent), we can predict that China's Total Factor Productivity will increase by about 20 percent, which will have a far-reaching positive impact on China's economic growth.

7、Brief conclusions

(1) China's economic growth mainly depends on capital input and labor input. Capital input and labor input explain 99 percent of China's economic growth between 1978 and 2002, while the impact of R&D input on growth remains insignificant.

(2) R&D input has a significant impact on technological change in China; R&D expenditure alone explains about 40 percent TFP in China between 1978 and 2002. One percent increase in R&D expenditure will lead to 0.27 percent increase in TFP.

(3) Since 1995, China's Total Factor Productivity has experienced a sharp fall. Compared internationally, China's technology competitiveness is still very low and at the firm level, R&D investment in some high-tech industries seems to be disproportionate. Thus, China should expand its R&D behavior to generate technological change and long run economic growth.

Reference:

[1] Ling Wang & Adam Szimai, Technological inputs and productivity growth in China's high-tech industries [EB/ OL].http://www.iwep.org.cn/pdf/wangling-wp.pdf

[2] Hall& Zvil Griliches, Patent and R&D: search for a lag structure. [EB/ OL]. http://www.nber.org/papers/w1227.pdf

[3] Zvil Griliches, Empirical patterns of firm growth and R&D investment: A quality ladder model interpretation. [EB/ OL]. http://www.nber.org/papers/w6753.pdf

[4] Zvil Griliches & Jacques Mairesse, R&D and productivity growth: comparing Japanese and U.S. manufacturing firms [EB/ OL]. http://papers.nber.org/papers/w1778.pdf

[5] Zvil Griliches & Mairesse, Productivity and R&D at firm level. [EB/ OL]. http://www.nber.org/papers/w0826.pdf

[6] Hulya, R&D, invention and economic growth: an empirical analysis [EB/ OL]. http://www.ecomod.net/conferences/ecomod2003/ecomod2003_papers/Ulku.pdf

[7] 胡鞍钢、郑京海:《中国全要素生产率为何明显下降》(Hu angang & Zheng jinghai :Why TFP in China fell dramatically?) http://www.China.org.cn/chinese/OP-c/524675.htm

[8] 叶飞文:《要素投入与中国经济增长》(Ye feiwen: Factor inputs and economic growth in China, Beijing University Publishing House, 2004)

[9] Lecture notes of Globalization and economic growth