是人力资本还是 FDI 促进了中国高技术产业的技术进步？

赵国庆，张中元

(中国人民大学经济学院 ，100872)

摘　要：本文通过利用《中国高科技产业统计年鉴》(2002—2007 年）中 5 个行业的 28 个子行业的 1995 —2006 年的相关数据考察了人力资本积累、R&D 投资以及 FDI 外溢效应对中国高科技产业的技术进步的影响。对于包含了人力资本积累、R&D 投资以及 FDI 外溢效应的 C-D 生产函数，同时利用静态模型与估计动态模型进行分析。得到如下结论：第一，静态模型中，FDI 外溢效应对中国高科技产业的技术进步有显著的正向影响，由于模型的设定原因，该结论可能有误导性，因为在动态模型中，该结论不成立；第二，动态模型的分析表明，中国高科技产业的技术进步主要根植于人力资本的积累而非 FDI 外溢效应。通过应用技术创新活动投入的不同代理变量以及区分产业中不同的产权组织形式进一步分析，得到相似的结论，说明论文的这一结论是稳健的。

Outline

1. Introduction

Positive Points:

Haddad and Harrison (1993) :

FDI has a positive effect on domestic firms’ total factor productivity and on their propensity to export.

Glass and Saggi (2002):

FDI benefits domestic firms by lowering the cost of imitation.

Lee(2006):

international knowledge spillovers through inward FDI and the disembodied direct channel are significant **.**

Negative Points:

Aitken and Harrison (1999):

FDI negatively affects the productivity of domestically owned plants.

Veugelersa and Cassimanc(2004):

FDI is not more likely to transfer technology to the local economy as compared to local firms.

Bwalya(2006) :

little evidence in support of intra-industry productivity spillovers from FDI but significant inter-industry knowledge spillovers occurring through linkages.

Zhu and Jeon(2007):

Although bilateral FDI is found to be positively related to international R&D spillovers, their impact on productivity growth is relatively small.

Chinese:

Pan (2005):

FDI has positive effects on the domestic S&T and output productivity.

Lu(2008):

competition with foreign invested enterprises, generally reduces productivity of Chinese indigenous firms. state-owned firms suffer the most from foreign presence, while private firm benefit the most.

Summarizing:

1 Spillovers from FDI depend to a large extent on host country and host industry characteristics and the policy environment in which the multinationals operate.

2 Human capital accumulation and effective indigenous R&D investment are now widely recognized as necessaries for China to sustain its rapid growth and eventually catch up with the developed nations.

Human capital:

Wang (1990):

FDI increases host country’s steady-state growth rate of per capita income when an increase in the growth rate of its human capital.

Borensztein et al.(1998):

FDI is an important vehicle for the transfer of technology, contributing relatively more to growth than domestic investment. However, the higher productivity of FDI holds only when the host country has a minimum threshold stock of human capital.

Wu and Qiu(2007):

human capital is the important factor to influence Chinese absorbability of foreign advanced technology.

Lai et al. (2005):

more accumulation of human capital facilitate long-term economic growth.

Zhao and Wang(2006):

human capital significantly promote China’s total factor productivity, and human capital plays a key role in the technology spillovers.

Dai and Bie(2006):

FDI contributes to economic growth depends on the speed of human capital accumulation in the host country.

Bo et al.(2005):

FDI will benefit China’s technology innovation, if it passes the human capital threshold.

R&D Investment:

Zhang (2005):

FDI does not have significant effect on domestic manufacturing. Lower absorptive capacity of R&D cumbers the growth of TFP. Through the self-innovative and positive competitive effect, but not technological diffusion, R&D and FDI both prompt the technical progress of domestic manufacturing.

Li(2007):

Though higher R&D investment have higher productivity growth rate, R&D investment is not the reason that causes the promotion of productivity growth .

Our Result in this Paper:

The technological progresses are mainly rooting in human capital accumulation other than technology spillover induced by FDI in Chinese high-tech industry.

2 Econometric Framework

2.1 The Basic Model

Technology is described as Cobb- Douglas production

function: $Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta}$ (1)

Where

Y_{it} is output of industry ,

L_{it} is the number of employees of industry ,

K_{it} is capital,

i and t denote industry and time.

Assume:

$A_{it} = e^{c_i t} H_{it}^{\beta_1} E_{it}^{\beta_2} FDI^{\beta_3}$ (2)

Where

c_i can vary among industries,

H_{it} is human capital

E_{it} is R&D investment ,

FDI is the magnitude of foreign direct investment

Difference both side of technology equation with t we have:

$$\frac{T\dot{F}P_{it}}{TFP_{it}} = \frac{\dot{A}_{it}}{A_{it}} = c_i + \beta_1 \cdot \frac{\dot{H}_{it}}{H_{it}} + \beta_2 \cdot \frac{\dot{E}_{it}}{E_{it}} + \beta_3 \cdot \frac{FD\dot{I}_{it}}{FDI_{it}} + \varepsilon_{it} \qquad (4)$$

The final expression:

$$GTFP_{it} = c_i + \beta_1 \cdot GH_{it} + \beta_2 \cdot GE_{it} + \beta_3 \cdot GFDI_{it} + \varepsilon_{it} \qquad (5)$$

Where

$GTFP_{it}$ is growth rate of TFP

GH_{it} is growth rate of human capital

GE_{it} is growth rate of R&D investment

$GFDI_{it}$ is growth rate of foreign direct investment.

2.2 Measuring technological change through total factor productivity (TFP)

In this paper we consider the application of the Malmquist productivity index methods to panel data, which are introduced as a theoretical index by Caves et al. (1982) and popularized as an empirical index by Fare et al. (1994a), which is defined on a benchmark technology satisfying constant returns to scale

$$M_i(x^{t+1}, y^{t+1}; x^t, y^t) = \frac{D_i^{t+1}(x^{t+1}, y^{t+1})}{D_i^t(x^t, y^t)} \times \left[\left(\frac{D_i^t(x^{t+1}, y^{t+1})}{D_i^{t+1}(x^{t+1}, y^{t+1})} \right) \cdot \left(\frac{D_i^t(x^t, y^t)}{D_i^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}}$$

$$= EC_i(x^{t+1}, y^{t+1}; x^t, y^t) \cdot TC_i(x^{t+1}, y^{t+1}; x^t, y^t) \qquad (6)$$

2.3 A Causality Testing Framework for Panel Data

we examine the panel data causality which is provided by Holtz-Eakin *et al*. (1988) , Arellano and Bond (1991).

$$y_{it} = \alpha_{0t} + \sum_{l=1}^{L} \alpha_{lt} y_{t-l} + \sum_{l=1}^{L} \delta_{lt} x_{t-l} + u_{it} \qquad (7)$$

Difference both side of equation leading to the model:

$$y_{it} - y_{it-1} = \sum_{l=1}^{L} \alpha_{lt}(y_{t-l} - y_{t-l-1}) + \sum_{l=1}^{L} \delta_{lt}(x_{t-l} - x_{t-l-1}) + (v_{it} - v_{it-1}) \qquad (8)$$

A 2SLS instrumental variables procedure with a time-varying set of instruments is used to estimate the model and equate the question of whether or not X causes Y with a test of the joint hypothesis:

$\delta_1 =, \cdots, = \delta_L = 0$

3. Sample Data

3.1. Data Source

The sample data come from *China Statistics Yearbook On High Technology Industry* (Year 2002 and Year 2007) and its period spans from 1995 to 2006.Additional data include several price deflators which come from *China Statistical Yearbook* (1996-2008).

3.2. Variables Definition and Descriptive Statistics

Dependent variable, Y, is Value Added of Industry(100 million yuan), which is deflated by the price deflator.

Y_LN is the natural logarithm of Y

Labor force, L, is Annual Average Number of Employed Personnel of Enterprises(10 thousand person) minus Personnel for Scientific and Technologic (S&T) Activities(10 thousand person)

Capital investment, K, is Original Value of Fixed Assets(100 million yuan), which is deflated by the fixed assets deflator.

Human Capital :

(1) **RDT,** which is defined as Full-time Equivalent of R&D Personnel(man-year) of each year.

(2) **STL,** which is defined as Personnel for Scientific and Technologic (S&T) Activities(10 thousand person) of each year.

R&D investment:

(1) **RDE,** which is defined as Intramural Expenditure for R&D(100 million yuan), which is deflated by the price deflator.

(2) **STE,** which is defined as Intramural Expenditure for S&T Activities(100 million yuan), which is deflated by the price deflator.

FDI: which is defined as Gross Industrial Output Value at Current Prices of Joint Ventures(100 million yuan), which is deflated by the price deflator, at the end of each year.

Table 1 gives summary statistics of all of our variables.

Shows the mean, median, minimum, maximum and standard deviation.

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
Y_LN	4.1400	4.2907	6.8887	1.1363	1.2457	308
L_LN	2.8732	2.7606	5.9218	0.3075	1.1483	308
K_LN	4.4161	4.5060	7.2202	1.3084	1.2900	308
GFDI	0.0904	0.0958	3.6981	-3.5546	0.4706	300
GRDT	0.1292	0.1017	1.5700	-2.0818	0.4444	308
GSTL	0.0603	0.0570	1.1080	-1.1283	0.2766	308
GRDE	0.1530	0.0908	2.6800	-2.0240	0.5820	308
GSTE	0.0674	0.0266	1.7519	-2.2703	0.4196	308

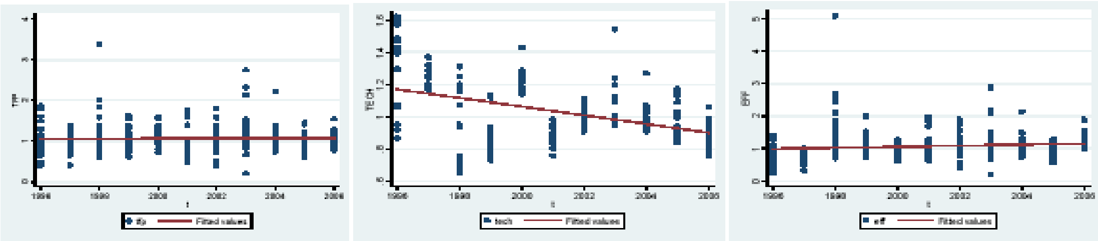
4. Empirical Analysis Result

4.1 The Decomposition of TFP

We calculate Malmquist productivity indexes as well as the efficiency-change, technical-change, and scale-change components for each industry in our sample.

Figure 1 gives a visual summary of TFP, TECH and EFF.

Figure 1 Productivity change (TFP), Technical change (TECH) and Technical efficiency change (EFF)



4.2 Estimate Results of Contemporaneous Correlation

Table 4 reports the results of estimation of equation

$$GTFP_{it} = c_i + \beta_1 \cdot GRDT_{it} + \beta_2 \cdot GRDE_{it} + \beta_3 \cdot GFDI_{it} + \varepsilon_{it} \quad (9)$$

$$GTFP_{it} = c_i + \beta_1 GRDT_{it} + \beta_2 GRDE_{it} + \beta_3 GFDI_{it} + \beta_4 GH_{it} \cdot GFDI_{it} + \beta_5 GE_{it} \cdot GFDI_{it} + \varepsilon_{it} \quad (10)$$

Table 4

Variable	Coefficient								
	Panel A			Panel B			Panel C		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GRDT	-0.27	-0.27	-0.27	-0.09	-0.09	-0.09	-0.19	-0.19	-0.18
	(-3.3)***	(-3.3)***	(-3.2)***	(-1.81)*	(-1.80)*	(-1.8)*	(-1.99)**	(-2.01)**	(-1.90)*
GRDE	0.06	0.05	0.05	0.07	0.07	0.07	-0.01	-0.02	-0.02
	(0.91)	(0.86)	(0.76)	(1.89)*	(1.91)*	(1.84)*	(-0.18)	(-0.24)	(-0.28)
GFDI	0.18	0.17	0.17	0.02	0.02	0.02	0.16	0.14	0.15
	(2.33)**	(2.19)**	(2.09)**	(0.47)	(0.54)	(0.48)	(1.81)*	(1.65)*	(1.59)
GRDT*GFDI		0.18			-0.06			0.24	
		(1.24)			(-0.69)			(1.46)	
GRDE*GFDI			0.04			-0.01			0.05
			(0.44)			(-0.09)			(0.44)
Dependent V	GTFP			GTECH			GEFF		
Fixed/Random	Random	Random	Random	Random	Random	Random	Random	Random	Random
Adj. R^2	0.05	0.05	0.05	0.01	0.01	0.01	0.02	0.02	0.02
Hausman Test	1.67	1.99	1.91	1.03	1.31	1.08	2.58	3.05	2.76

Note: The t-statistics are in parentheses.

***Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Variables:

GTFP is the first difference of natural logarithm of natural logarithm of productivity change (TFP), which approximates the growth rate of TFP**.**

GTECH is the first difference of natural logarithm of natural logarithm of TECH, which approximates the growth rate of TECH**.**

GEFF is the first difference of natural logarithm of natural logarithm of EFF, which approximates the growth rate of EFF**.**

GRDT, proxy for human capital of R&D personnel, is the first difference of natural logarithm of RDT.
GRDE, proxy for expenditure for R&D, is the first difference of the natural logarithm of RDE.
GFDI, proxy for FDI externality, is the first difference of the natural logarithm of FDI.

4.3 Estimate Results of Dynamic Correlation

Table 5 reports the results of estimation of equation

$$DGTFP_{it} = \gamma DGTFP_{it-1} + \beta_1 \cdot DGTDT_{it-1} + \beta_2 \cdot DGRDE_{it-1} + \beta_3 \cdot DGFDI_{it-1} + (\varepsilon_{it} - \varepsilon_{it-1}) \qquad (11)$$

$$DGTFP_{it} = \gamma \cdot DGTFP_{it-1} + \beta_1 \cdot DGRDT_{it-1} + \beta_2 \cdot DGRDE_{it-1} + \beta_3 \cdot DGFDI_{it-1} + \beta_4 D(GRDT_{it-1} \cdot GFDI_{it-2}) + \beta_5 D(GRDE_{it-1} \cdot GFDI_{it-2}) + (\varepsilon_{it} - \varepsilon_{it-1}) \qquad (12)$$

In the DGTFP equations we consider Z=(ZGTFP(-2), ZGRDT(-1), ZGRDE (-1), ZGFDI (-1)) as potential instruments for Column (1), plus Z`=(ZGSTL(-1)*ZGFDI(-2)) or (ZGSTE(-1)*ZGFDI(-2)) for Column (2) and (3).

Table 5

Variable	Coefficient								
	Panel A			Panel B			Panel C		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$DGTFP_{t-1}$	**-0.34**	**-0.33**	**-0.20**	**-0.04**	**-0.09**	**-0.10**	**-0.21**	**-0.14**	**-0.10**
	(-5.4)***	(-5.8)***	(-1.9)*	(-0.49)	(-1.47)	(-1.61)**	(-3.0)***	(-1.61)	(-1.03)
DGRDT	**0.16**	**0.18**	**0.08**	**0.12**	**0.17**	**0.14**	**0.02**	**0.14**	**-0.02**
	(2.18)**	(2.5)***	(1.08)	(2.11)**	(3.23)***	(2.5)***	(0.39)	(1.29)	(-0.66)
DGRDE	**-0.07**	**-0.12**	**0.01**	**-0.18**	**-0.20**	**-0.18**	**0.03**	**-0.04**	**0.07**
	(-1.15)	(-2.25)**	(0.14)	(-4.2)***	(-5.0)***	(-4.4)***	(0.65)	(-0.77)	(1.44)
DGFDI	**-0.35**	**-0.37**	**-0.45**	**0.06**	**0.06**	**0.07**	**-0.14**	**-0.27**	**-0.30**
	(-3.1)***	(-3.1)***	(-3.2)***	(0.72)	(0.91)	(1.03)	(-1.09)	(-1.98)**	(-2.1)**
D(GRDT*GFDI)		**-0.91**			**-0.12**			**-0.98**	
		(-3.4)***			(-0.60)			(-1.64)*	
D(GRDE*GFDI)			**-0.51**			**-0.12**			**-0.37**
			(-2.5)***			(-1.28)			(-1.80)*
Dep.Variable	DGTFP			DGTECH			DGEFF		
Adj. R^2	0.40	0.46	0.39	0.15	0.23	0.24	0.24	0.33	0.29

Note: The t-statistics are in parentheses.
***Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.
D indicates first differences. A lag length of one was selected due to relatively short time series for each industry.

4.4 Comparison Between the Static and Dynamic Results

To compare the contemporaneous correlation and the dynamic relationship between the dependent variable and the independent variables, the coefficient sign and their significant level are given in Table 6.

Table 6 Coefficient sign comparison between the Static and Dynamic Results

Variable	Coefficient Sign					
	contemporaneous			dynamic		
	GTFP	GTECH	GEFF	DGTFP	DGTECH	DGEFF
$GTFP_{t-1}$/ $DGTFP_{t-1}$				-	- (NS)	-
GRDT/DGRDT	-	-	-	+	+	+ (NS)
GRDE/DGRDE	+ (NS)	+	+ (NS)	- (NS)	-	+ (NS)
GFDI/DGFDI	+	+ (NS)	+	-	+ (NS)	-
GRDT*GFDI	+ (NS)	- (NS)	+ (NS)	-	- (NS)	-
GRDE*GFDI	+ (NS)	- (NS)	+ (NS)	-	- (NS)	-

Note: - indicates negative, + indicates positive, NS indicates statistical insignificant.

Highlights:

1 Our static and dynamic empirical results suggest the effects of FDI and human capital on technological progress depend in part on the adopted approach.

2 We argue that there are several reasons to believe that the contemporaneous correlation model estimates may be misleading in cases like ours.

(1) the results of contemporaneous correlation across the cross-section do not imply the distinguish causation between the hypothesis that increased FDI has led to increased growth, versus the hypothesis that good growth has attracted additional FDI. These methods cannot rule out the possibility that it is the (correct) expectation of future high growth rates that has caused the increased FDI.

(2) contemporaneous correlation model’s estimators lose dynamic information and run increased risk of serious omitted variable bias.

3 The dynamic model

(1) allows including dynamic, lagged dependent variables which can help to control for omitted variable bias and also can be used to test for Granger causality of the variables.

(2) the adjusted R2’s in dynamic model are significantly greater than ones in contemporaneous correlation model, which means the explanatory power of dynamic model dominates contemporaneous correlation model.

4 it is important to clarify that although we find no statistically significant or even negative role for R&D investment in our dynamic model analysis, this does not necessarily imply that R&D investment is unimportant.

5 Robustness Checks

5.1 Different Proxies for Innovation Activities Analysis

Zhu and Jeon (2007) :

the productivity of a country depends not only on domestic R&D, but also on foreign R&D through technology diffusion across countries. The technological resources of China are different from other developed countries because China, as a developing country, has unsubstantial R&D capability.

we use GSTL and GSTE as the substitute measurement indices of human capital accumulation and R&D investment.

Table 7 Coefficient sign comparison between the Static and Dynamic Results

Variable	Coefficient Sign					
	contemporaneous			dynamic		
	GTFP	GTECH	GEFF	DGTFP	DGTECH	DGEFF
$GTFP_{t-1}$/ $DGTFP_{t-1}$				–	–	–
GSTL/DGSTL	–	–	–	+	+	+
GSTE/DGSTE	–	–	–	–(NS)	–	+
GFDI/DGFDI	+	+	+	–	+	–
GSTL*GFDI	+	+(NS)	+(NS)	–	–(NS)	–(NS)
GSTE*GFDI	+(NS)	–(NS)	+(NS)	–	–(NS)	+

5.2 State-owned and State-controlled Enterprises and Joint Ventures

the *China Statistics Yearbook On High Technology Industry* also provides the relevant data of state-owned and state-controlled enterprises and Joint Ventures

Table 8 refer to the time trend estimation results of state-owned and State-controlled enterprises and Joint Ventures.

Table 8 Time Trends in TFP, TECH and EFF of State-owned and State-controlled Enterprises and Joint Ventures

Variable	State			Joint Ventures		
	(1)	(2)	(3)	(4)	(5)	(6)
C	**1.20**	**1.77**	**0.84**	**1.10**	**1.10**	**1.05**
	(25.01)***	(24.41)***	(8.25)***	(39.07)***	(33.89)***	(26.90)***
Time Trend	**-0.02**	**-0.09**	**0.06**	**-0.02**	**-0.02**	**0.00**
	(-3.04)***	(-8.68)***	(4.24)***	(-4.65)***	(-4.54)***	(-0.02)
Dep. Variable	TFP	TECH	EFF	TFP	TECH	EFF
Adj. R^2	0.03	0.20	0.05	0.08	0.07	0.00
D-W stat	2.15	3.13	2.76	2.31	2.37	2.16

Note: The t-statistics are in parentheses.

***Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 9 Coefficient sign comparison between the Static and Dynamic Results of state-owned and state-controlled enterprises

Variable	Coefficient Sign					
	contemporaneous			dynamic		
	GTFP	GTECH	GEFF	DGTFP	DGTECH	DGEFF
$GTFP_{t-1}$/ $DGTFP_{t-1}$				-	-(NS)	-
GRDT/DGRDT	-(NS)	-	+	+	+	-
GRDE/DGRDE	-(NS)	-	-(NS)	+	-(NS)	+
GFDI/DGFDI	+(NS)	-(NS)	-(NS)	-(NS)	-	+
GRDT*GFDI	-(NS)	-(NS)	+(NS)	+(NS)	-	+
GRDE*GFDI	-	+(NS)	-(NS)	+(NS)	-	+

Table 10 Coefficient sign comparison between the Static and Dynamic Results of Joint Ventures

Variable	Coefficient Sign					
	contemporaneous			dynamic		
	GTFP	GTECH	GEFF	DGTFP	DGTECH	DGEFF
$GTFP_{t-1}$/ $DGTFP_{t-1}$				-	-	-
GRDT/DGRDT	-(NS)	-	+	+	+	-
GRDE/DGRDE	-	+	-	+(NS)	-	+(NS)
GFDI/DGFDI	+	-(NS)	+	-	-	-
GRDT*GFDI	+(NS)	-(NS)	+	-	-	-(NS)
GRDE*GFDI	+	-(NS)	+	-(NS)	-(NS)	+(NS)

6 Conclusion and Remarks

Conclusions:

1 we compare a static and a dynamic model to asses these effects. Our empirical results suggest the effects of FDI and human capital on technological progress depend in part on the adopted approach.

2 We believe that the static model estimates may be misleading in cases like ours because static method cannot rule out the possibility that it is the (correct) expectation of future high growth rates that has caused the increased FDI and its estimators lose dynamic information and run increased risk of serious omitted variable bias.

3 The dynamic model can help to control for omitted variable bias and also can be used to test for Granger causality of the variables.

4 Empirical results show the adjusted R2’ s in dynamic model are significantly greater than ones in static model, which means the explanatory power of dynamic model dominates static model.

5 Further studies finds little evidence in support of technological spillovers from FDI in the dynamic method. The dynamic method results indicate that the technological progresses are mainly rooting in human capital accumulation other than technology spillover induced by FDI in Chinese high-tech industry.