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INDUSTRIAL ENTERPRISES' INNOVATION EFFICIENCY AND THE INFLUENCE OF CAPITAL SOURCE: BASED ON STATISTICAL DATA OF INDUSTRIAL ENTERPRISES IN JIANGSU PROVINCE

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Abstract

This study chooses industrial enterprises with great innovative capacity and above a designated size in Jiangsu as the research object to examine the real mechanism of their innovative activities. We apply the DEA model to calculate the technical efficiency, technical

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progress, and total factor productivity (TFP) of industrial enterprises from 1999 to 2009, finding that technical progress is the most significant factor in increasing TFP. In order to ensure the efficient flow of capital and labor, the empirical results of this study provide useful evidence to promote the industry frontier technical progress and to improve the average efficiency level.

Keywords: R&D investment, technical progress, industrial enterprises, fund sources, DEA
JEL Classification Codes: D29, L16, R11

I. *Introduction*

China has in recent years entered a period of economic adjustment, with the economic growth mode changing from extensive to intensive, which means innovative activities are needed to achieve industrial upgrading and industrial restructuring, thereby enhancing the added value created by the unit elements. Despite increased awareness of the multiple benefits from research and development (R&D), Even though China is a large country by population and area, it still has a wide gap for R&D expenses compared to other large economies around the world (Zhou, 2009; Fu, 2009).

Academic studies have generally focused more on the innovation and R&D activities of China's high-tech industries such as Yang and Jiang (2007), Asakawa and Som (2008), Lin et al. (2008) and Xu and Zhang (2008). However, up to now they have focused mainly upon R&D efficiency, total productivity, and efficiency effects. In fact, there are many studies on R&D efficiency, including Cooper et al. (1996), Dutta et al. (1999), Shiha (1996), Zhang et al. (2003), Frantzen (2008), Guan and Chen (2009, 2010), Fan et al. (2011), Materia and Aldeab (2012), Castiglione (2012), and Chen and Chen (2012).

There is an abundant amount of studies on TFP (Total-Factor Productivity) growth using macro data in China. There is also some literature based on panel data at the enterprise level, using a stochastic frontier model to measure and decompose the TFP growth of various industries. However, the existing literature does have its limitation. Because of different natural endowments, preferential policies in earlier periods, and the differences in total wealth levels and average income, there are obvious regional differences of innovation ability in China (Zhou, 2009; Zhou and Cheng, 2012). At present, innovation activities are mainly concentrated in Beijing, Guangdong, Shandong, Shanghai, and Zhejiang, where the average number of invention patents in large-middle industrial enterprises is 2996, which is higher than the other provinces, especially Jiangsu and Shanghai. Due to their relative solid economic base, higher concentration of industries, more foreign invested enterprises, and tougher competition, Jiangsu and Shanghai pay more attention on R&D investment in order to strength the ability of innovation, thus becoming the center regions of technological innovation and knowledge spillovers for China (Wu and Liu, 2008). Moreover, as the progress of technology is faster, China's technology gap is relative smaller compared to other countries (Wu, 2008).

The contribution of this paper is two-fold: (1) We choose industrial enterprises above a designated size in Jiangsu as samples, measure their TFP growth, decompose TFP into technical progresses and technical efficiency, and then compute the contributions separately. Because the aggregated statistical data are on an annual basis, the calculation results are not so meticulous, but could be offset by the features of industry and ownership. Thus, we analyze the trend of the change in TFP and the factors of change from the angles of industry and ownership for further analysis. (2) Some regions in China attract factor inflows through preferential financial revenue policies, unique fiscal expenditure policies, and relevant institutional innovations, thus helping them achieve rapid economic growth on their own. As the input for scientific research plays a core role in this process, we divide R&D funds according to their sources and empirically study the incentive effects of government funds to technical progress, the function of the norms and constraints of debt contracts, and fund allocation for economic benefits, which are aimed at enhancing the region's competitiveness.

Some scholars use the indicator of TFP for measuring technical progress in a broad sense (Long, 2008; Zhou, 2009; Guo, 2010). Some divide TFP into technical efficiency and technical progress (Madden et al., 2001; Bönte, 2003; Wang and Yan, 2007; Yao, 2009; Research Group of Chinese economic growth and macroeconomic stability, 2010; Zhang and Shi, 2011). In regards to the efficiency effects, many studies have implemented DEA-Malmquist methods to discuss the relationship between efficiency performance and R&D activities under different economies, such as Huang and Xu (1998), Dutta et al. (1999), Hu (2001), Madden et al. (2001), Zhang (2003), Wu and Yang (2006), Yang and Liu (2006), Isobe and Makino (2008), Xu and Zhang (2009), and Guana and Chen (2010, 2012).

The technical progress that is taken from TFP is an indicator in the narrow sense, as essentially it means the level of industry frontier technical progress. In this paper we believe that technical progress should reflect just the advanced level, but technical progress in general not only includes the advanced level, but also the usage status, thus turning itself into a complex concept. We follow the study of the Research Group of economic growth and macroeconomic stability to distinguish between technical progress and TFP, adopting the indicator of technical progress in the narrow sense and regarding it as a part of TFP. We calculate the technical progress of the total sample, as well as the industry-related sub-sample and the ownership-related sub-sample separately, combined with annual statistical data. In the context of focusing on the existing resource efficiency of industrial enterprises in Jiangsu, we use the DEA method based on output, with the technical details helping to calculate and decompose the Malmquist index. We also use the regression model to investigate what factors affect the efficiency scores.

This paper is organized as follows. The first section provides the motivation for the research. The second section offers the methodologies. The third section section shows the empirical results. The final section presents the conclusions.

II. *Research Method*

Malmquist Productivity Index

The Malmquist productivity index have very important advantage: it divides the productivity into efficiency and technology changes. The concept of the Malmquist productivity index was first introduced by Malmquist (1953). This is a new way to look into possible productivity improvements. Based on this opinion, productivity can be improved through two different approaches: improvements in the technologies of the firm (e.g. obtaining new machine) or improvements in the efficiency of the firm by used the existing technologies (e.g. more learning). The idea of analyzing the productivity change was first introduced by Nishimizu and Page (1982) through using a parametric approach for estimating distance functions. Later, Caves et al. (1982) applying it in a non-parametric framework. Fare et al. (1994) developed it into the output-based Malmquist productivity change index. Malmquist Productivity Index used to measure the total factor productivity(TFP) of different periods, it has the advantage on the one hand can be judged by the stability of each assessment unit efficiency, on the other hand it can also be observed by the assessment unit efficiency value the trends. However, those models suffer from a neglect of slacks and give rise to the problem of infeasibility. In order to resolve this problem, we refer to Cooper et al. (2004) for the non-radial and slacks-based Malmquist productivity index in order to calculate the productivities of IT sub-industries.

The Malmquist index measures the total factor productivity change of a DMU between two different time periods by calculating the ratio of the distances under a specific technology. Fare et al. (1992) specifies an Malmquist productivity change index on CRS as:

$$m_o(y^{t+1}, x^{t+1}, y^t, x^t)=\left[\frac{d_o^t(x^{t+1}, y^{t+1})}{d_o^t(x^t, y^t)}\times\frac{d_o^{t+1}(x^{t+1}, y^{t+1})}{d_o^{t+1}(x^t, y^t)}\right]^{1/2}$$

This index is the geometric mean of two output-based Malmquist TFP indices.

(i) if $m_o(y^{t+1}, x^{t+1}, y^t, x^t)>1$, a positive TFP growth from period t to period t+1
(ii) if $m_o(y^{t+1}, x^{t+1}, y^t, x^t)<1$, a negative TFP growth from period t to period t+1

According to Fare et al. (1992), the Malmquist TFP index can be decomposed into technical change (TC) and efficiency change (EC), written as:

$$m_o(y^{t+1}, x^{t+1}, y^t, x^t)=\frac{d_0^{t+1}(X^{t+1}, Y^{t+1})}{d_0^t(X^t, Y^t)}\left[\frac{d_o^t(x^{t+1}, y^{t+1})}{d_o^{t+1}(x^{t+1}, y^{t+1})}\times\frac{d_o^t(x^t, y^t)}{d_o^{t+1}(x^t, y^t)}\right]^{1/2} \quad (1)$$

$$EC=\frac{d_0^{t+1}(X^{t+1}, Y^{t+1})}{d_0^t(X^t, Y^t)} \quad (2)$$

$$TC=\left[\frac{d_o^t(x^{t+1}, y^{t+1})}{d_o^{t+1}(x^{t+1}, y^{t+1})}\times\frac{d_o^t(x^t, y^t)}{d_o^{t+1}(x^t, y^t)}\right]^{1/2}. \quad (3)$$

We let x represent inputs, $x\in R_+^N$, and y represent outputs, $y\in R_+^M$. Here, d is the distance function, m takes the geometric mean of the two indices above, the first expression in parentheses captures the change in technical efficiency between periods t and t + 1, and the second expression measures the shift in the technology frontier. Generally, the Malmquist productivity change index decomposes multiplicatively into an efficiency change component (EC) and a technical change component (TC), such that:

$$m_o(y^{t+1}, x^{t+1}, y^t, x^t)= EC\times TC$$

The term EC evaluates the efficiency of managerial manners or decisions.

(i) If $EC>1$, then managerial efficiency improves.
(ii) If $EC<1$, then managerial efficiency worsens.

The term TC measures the technical change of each DMU by calculating the geometric mean of the technical change from t to $t+1$ on different inputs invested.

(i) If $TC>1$, then the technology progresses.
(ii) If $TC<1$, then the technology regresses.

III. *Data Sources and Regression Model*

1. Constructing the Data Sequence

This study chooses industrial enterprises above a designated size in Jiangsu for a total sample of 37, which mainly involve three big industries: mining IA, manufacturing IB, and production and supply of electric power, gas, and water IC. The data are from the Statistics Yearbook from 2000 to 2010 on the website of Jiangsu Bureau of Statistics. In order to maintain continuity of the statistical data, we eliminate the samples of other mining and waste materials and the resource recycling industry, because the former lack data in 2004, 2008, and 2009, the latter lack data from 1999 to 2002, 2008, 2009, and the data of each indicator makes up a small fraction in the total industry.

In the process of calculation, we need to set up an input-output variable to calculate productivity change. The MI index reflects the change of productivity with time, and so we need to deflate each variable first. Based on the input-output variable after using the deflator, we form panel data spanning 11 years, based on the beginning of the period.

Output indicator

We take gross industrial output value of each industry as the output variable. For the deflator of output, we follow the method of Liu and Wu (2009) and apply the index of the price of industrial products each year by transforming between a fixed base index and the price index. This is based on the last year of this paper's research period, and we then form a set of fixed base price indices with the index equal to 100 for the year 1999.

Capital indicator

In this study, capital stock only means fixed capital, not including inventory. We take the original price of fixed assets disclosed in the Statistical Yearbook as the capital data. According to the price index of investment in fixed assets each year, we use a similar method as above to form a set of fixed base price indices with the index equal to 100 for the year 1999. It should be noted that the indicator of the original price of fixed assets for 2004 is not found in Statistical Yearbook (2005). As such, we first calculate the ratio of the average balance of net value and original price of fixed assets for the years 2003 and 2005 separately, then take the mean as the ratio for 2004, at finally the average balance of net value divided by the ratio for 2004 equals the indicator of the original price of fixed assets for 2004. At the same time, the indicator of the original price of fixed assets for 2008 is not found in Statistical Yearbook (2009), but Statistical Yearbook (2010) covers the related data for 2008 and 2009.

Labor indicator

We take the average of all employees from each industry from the Statistical Yearbook directly.

2. Regression Model of Variable Selection and Model Design

This paper measures the technological progress of industrial enterprises above a designated size as dependent variables and large-and-medium-sized industrial enterprise technology input recorded in the statistical yearbook as independent variables,[1] combined with appropriate control variables for regression analysis. As the measured technological progress rate represents growth compared with the previous year and for the purpose of eliminating endogeneity in the model, this paper takes the ratio process on the input and output indicators of the explanatory variables when establishing the regression model with the measured overall industrial enterprise technological progress rate as explanatory variables. With reference to the research of Shi and Zhang (2010), this paper defines the explanatory variables as follows.

DPP: patent application variation per capita, which is the difference between current patent application number/employees and per capita of the previous year, indicating the role of independent research in technological progress.

DTK: technology funds raising the growth rate of current annual technology funds to the growth rate of the previous year, indicating the change of research funding.

DTL: change of the proportion of professionals engaged in science and technology, which is the difference between personnel engaged in technology/employees of the current year with that of the previous year, indicating the change in R&D human capital investment.

DGIOsoe, DGIOpe, DGIOffe: as the above analysis indicates technological progress of different ownership-based enterprises is different, it is necessary to take ownership into account when analyzing the effects of R&D input upon technological progress. They respectively stand for the proportion change in gross industrial output value of state-owned enterprises, private enterprises, and foreign-funded enterprises to the gross industrial output value of Jiangsu Province, indicating the influence of different ownership changes on the economy.

In line with the classification by the statistical yearbook, this paper uses research fund indicators of the three sources of funds to present the research fund input so as to carry out a regression analysis on the technological progress rate. DTKgf, DTKbd, and DTKec respectively stand for annual proportion change in the appropriation from higher authorities, loans from financing institutions, and enterprises' self-raised funds to the total amount of technology funds, indicating the rising variable of technology funds. Table 1 defines the variables.
Therefore, this paper constructs the following model.

$$Y_i = \alpha + \beta_1 DPP + \beta_{21} DTK_{gf} + \beta_{22} DTK_{bd} + \beta_{23} DTK_{ec} + \beta_3 DTL + \beta_4 DGIO_{soe} + \beta_5 DGIO_{pe} + \beta_6 DGIO_{ffe} + \mu$$

In the equation, Y_i is an explained variable, which stands for TC. DTKgf stands for $\triangle$TKgf/TK, DTKbd stands for $\triangle$TKbd/TK, DTKec stands for $\triangle$TKec/TK, DTL stands for $\triangle$TL/L, DGIOsoe stands for $\triangle$GIOsoe/GIO, DGIOpe stands for $\triangle$GIOpe/GIO, and DGIOffe stands for $\triangle$GIOffe/GIO. They are all explanatory variables.

[1] Large-and-medium-sized industrial enterprise assets and gross industrial output value account for over 60% of the related indicators of industrial enterprises above a designated size. This paper argues that, as the subject of research and development activities, the relative number of large-and-medium-sized industrial enterprise scientific research input indicators can explain the efficiency change of industrial enterprises above a designated size.

Table 1. Variable Definition List

Variable type	Variable code	Definition
Explained variable	TC	technological progress rate
Explanatory variable	DPP	patent application variation per capita
	$\triangle TK_{gf}/TK$	proportion change in the appropriation from higher authorities to technology funds
	$\triangle TK_{bd}/TK$	proportion change in financial funds to technology funds
	$\triangle TK_{ec}/TK$	proportion change in self-raised funds to technology funds
	$\triangle TL/L$	proportion change in technical personnel to employees
	$\triangle GIO_{soe}/GIO$	proportion change in state-owned enterprises' gross industrial output value to gross industrial output value
	$\triangle GIO_{pe}/GIO$	proportion change in private enterprises' gross industrial output value to gross industrial output value
	$\triangle GIO_{ffe}/GIO$	proportion change in foreign-funded enterprises' gross industrial output value to gross industrial output value

IV. *Empirical Results*

1. Calculation of Technical Progress and Analysis of Results

Table 2 presents the descriptive statistics of the input and output variable data for Jiangsu Province's industrial enterprises as: (A) Output indicator: From 1999 to 2009 the average is 34404.03. The highest output indicator for 1999 to 2009 is 73200.02, while the lowest output indicator is 10450.90. (B) Capital indicator: From 1999 to 2009 the average is 126.902. The highest capital indicator for 1999 to 2009 is 269.52, while the lowest is 22.44. (C) Labor indicator: From 1999 to 2009 the average is 19.758. The highest labor indicator for 1999 to 2009 is 29.34, while the lowest is 14.711.

Table 2. Descriptive Statistics of Input-output Variable for Jiangsu Province's Industrial Enterprises

Year		Variables		
		Output indicator	Capital indicator	Labor indicator
1999 to 2009	STDEV	22826.500	93.161	4.928
	MIN	10450.900	22.440	14.710
	MAX	73200.020	269.520	29.340
	AVE	34404.030	126.902	19.758

Data Resource: Authors' collection.

1) Calculation and analysis between the total sample and the three big industries

From Table 3, the average growth rate of TFP is 10.31%, the average growth rate of technical efficiency is -1.13%, and technical progress is as high as 26.41%. The results mean that technical progress plays a main role in TFP growth, achieving a growth effect, but industrial enterprises above a designated size in Jiangsu underwent negative growth

TABLE 3. THE MI INDEX OF INDUSTRIAL ENTERPRISES ABOVE A DESIGNATED SIZE AND THE THREE BIG INDUSTRIES IN JIANGSU AND THEIR DECOMPOSITION

Year	Malmquist Index (MI)		Efficiency Change (EC)		Technical Progress (TC)	
	above designated size	three big industries	above designated size	three big industries	above designated size	three big industries
1999-2000	1.083	1.061	0.917	1.075	1.180	1.025
2000-2001	1.064	1.090	1.045	0.947	1.017	1.173
2001-2002	1.083	1.143	0.913	0.904	1.186	1.274
2002-2003	1.172	1.128	0.880	0.856	1.331	1.330
2003-2004	1.224	1.304	0.968	1.062	1.264	1.240
2004-2005	1.085	1.314	1.008	1.176	1.076	1.109
2005-2006	1.102	1.116	0.815	0.861	1.351	1.303
2006-2007	1.118	1.125	0.994	0.994	1.125	1.131
2007-2008	1.030	1.550	1.314	1.531	0.783	1.038
2008-2009	1.011	0.806	1.016	0.823	1.996	0.951
Average	1.103	1.186	0.989	1.026	1.264	1.172

Note: The three big industries include mining, manufacturing, and the production and supply of electric power, gas, and water.

in technical efficiency overall from 1999 to 2000.

Moreover, for the three big industries, the results are similar to the industrial enterprises above a designated size – namely, technical progress plays a main role in TFP growth, but the growth of technical efficiency is not obvious. We provide concrete analysis below.

First, the growth of technical efficiency is not obvious, as its Contribution to TFP growth is not high. From Table 1, the three big industries' average growth rate of TFP is 18.56%, their average growth rate of technical efficiency is 2.59%, and their technical progress is as high as 17.20%. Jiangsu Province adopted a series of measures to develop its economy in the early 1990s, leading to a huge inflow of foreign investment, which has brought about two effects. On the one hand, foreign-invested enterprises can decrease the technical level gap in each industry and each enterprise and reduce average technical efficiency; on the other hand, foreign-invested enterprises have advanced management experience and ideas. By contrast, due to a shortage of management experience, local enterprises have a lower level of utilization for each factor of production and have lower efficiency in resource collocation. Thus, the gap between practical production and frontier production is larger, and the EC index is low. The big gap in the relative frontier technical efficiency is a characteristic of industrial enterprises that reflect a problem - namely, the market competition pressure faced by domestic enterprises from the entry of foreign-invested enterprises. However, this gap also offers potential for improving the overall technical level in the future from the view of overall economic development (Tu and Xiao, 2005).

Second, technical progress is remarkable, and it is the main promoting factor of TFP. There are two causes for the change of frontier technical progress in Jiangsu Province: the high development of its export-oriented economy and the reform of the market economic system. Enterprises are being forced to introduce advanced technology and to enlarge their innovation investment, which greatly accelerates the frontier technical progress of an industry. On the basis of more advanced technology, multinational enterprises are putting more emphasis on R&D, which is enlarging the gap against the local industry more than before. This gap is pushing the impetus of innovation by domestic enterprises, and the effect of technology diffusion has shortened the time for catching up, thus accelerating technical progress. Jiangsu Province is one of the main areas in China for introducing foreign capital to develop the regional economy. Foreign-invested enterprises have not only driven the development of domestic enterprises, but are also activators for the long-term growth in Jiangsu (Cheng and Liu, 2010).

2）Calculation and analysis of different ownership enterprises

Table 4 presents the calculations. From the viewpoint of average TFP growth (MI index), the biggest percentage jump of MI is for state-owned enterprises at 25.63%, the next biggest is private enterprises at 11.22%, while the smallest goes to foreign-invested enterprises at just 7.47%. The growth of technical progress plays a main role in the productivity growth of state-owned enterprises.

Why can technical progress sustain such big growth of TFP in state-owned enterprises? Before the reform of the structure of state-owned enterprise, their high level of monopoly allowed them to own a large amount of capital and advanced equipment. Moreover, higher barriers of industry policy, a superior market position, and stable monopoly profits resulted in them losing any impetus for technical innovation. However, the gradual deepening of market-oriented reforms intensified competition, and state-owned enterprises have had to reform themselves and enhance their technical innovation in order to remain as industry leaders. If we say the State-Owned Enterprises were content with present situation, innovating only for policy index from 2001 to 2004, then we should say the analysis of the samples in latter, the State-Owned Enterprises relied on the technological innovation, and then brought the growth of technical progress greatly.

For the MI index and its decomposition of private enterprises and foreign-invested enterprises, the promotion of private enterprises' productivity comes from the promotion of the rate of technical progress as whole, with the index of technical efficiency change being 1. For the foreign-invested enterprises, technical progress plays the main role, and the promotion of technical efficiency is not obvious. The results mean that as the market economic system has taken shape and the opening has deepened, the extent of marketability has greatly improved, and the resource allocation function is constantly strengthening. Therefore, the efficiency of

Table 4. The MI Index and its Decomposition of Different Ownership Enterprises

Year	State-owned enterprises			Foreign-invested enterprises			Private enterprises		
	MI	EC	TC	MI	EC	TC	MI	EC	TC
2001-2002	1.166	1.090	1.070	1.068	1.000	1.068	1.105	1.000	1.105
2002-2003	1.333	1.167	1.142	1.163	1.000	1.163	1.159	1.000	1.159
2003-2004	1.526	1.278	1.194	1.186	1.000	1.186	1.218	1.000	1.218
2004-2005	1.575	1.196	1.317	1.015	1.000	1.015	1.215	1.000	1.215
2005-2006	1.149	1.000	1.149	1.065	1.000	1.065	1.115	1.000	1.115
2006-2007	1.199	1.000	1.199	1.089	1.000	1.089	1.107	1.000	1.107
2007-2008	1.241	1.000	1.241	1.021	0.943	1.083	1.021	1.000	1.021
2008-2009	0.860	1.000	0.860	0.991	1.061	0.934	0.958	1.000	0.958
Avg.	1.256	1.091	1.147	1.075	1.000	1.075	1.112	1.000	1.112

resource distribution of property rights defined (private enterprises and foreign-invested enterprises) has maintained a high level all the time, and the technical efficiency change is not obvious. However, with the development of property rights reform of state-owned enterprises, recent technical efficiency is much lower than it was at the beginning of the reforms, while later it has been kept at basically a higher level.

2. Empirical Analysis on Research Funding Source and Innovation Effectiveness

Related data suggest a great gap between the innovation output contribution of China and that of developed countries. In terms of the technology industry's added value, the U.S. hit an average added value rate of around 43.0% in What Year, with 36.0% for Japan and UK, and above 30.0% for France and Canada. However, the high-tech industry's added value rate was merely 25% in Jiangsu, or 5-18 percentage points below those aforementioned countries. This number is 27.2% for South Korea, or 2 percentage points higher than that in Jiangsu.[2]

What factors affect innovation effectiveness? Based on the existing literature, a couple of factors impact the improvement of institutional innovation efficiency, including government policy, degree of market competition, institutional environment, nature of property rights, ownership concentration, enterprise scale, capital structure, corporate governance, human capital, etc. Nevertheless, institutional R&D is a strategic decision-making process related to long-term resource utilization (Tang et al., 2004) and funds are an important resource affecting institutional R&D input. This is because the R&D input requires massive and sustained financial support, and more importantly, access to material and human resources is part of the foundation of financial resources. Institutional accumulation of R&D capital promotes innovation ability and brings about long-term technological progress and competitiveness.

Statistics from Jiangsu Statistical Yearbook clearly indicate three major sources of industrial enterprise scientific research funds: appropriation from higher authorities, loans granted by financing institutions, and self-raised funds. Appropriation from higher authorities implies funds granted by the government to support the scientific research activities of industrial enterprises for the purpose of promoting technical progress, driving more investment, as well as providing guidance for research direction. Loans from financing institutions are granted, on the one hand, to those industrial enterprises cooperating with state policy on technology innovation encouragement, and on the other hand, to provide creditor's rights with a sounder guarantee as the fixed assets of industrial enterprises take higher shares and can be used as mortgage assets. In addition, scientific research funds are generally on a large scale over a long research period, which can bring a stable inflow of economic interests to financing institutions during that period of time. Self-raised funds are own capital that enterprises use to invest in scientific research activities for the purpose of pursuing economic benefits and enhancing their competitiveness. In this regard, this paper is an empirical study on the influence of funds of different sources upon enterprise innovation ability enhancement.

3. Regression Model of Empirical Results

[2] Data come from one of the authors' research – *New Thoughts and Structures for Jiangsu Private Enterprise Technological Innovation Ability Enhancement* (Zhengying Luo, 2010).

1) The descriptive statistics and test

Table 5 shows the descriptive statistics of Explanatory Variables in the regression model as follows: The averages for patent application variation per capita (TPP) is 11.6001. The highest TPP is 4.0396 while the lowest is 0.1087. In the technology funds, the averages in $\triangle TK_{gf}/TK$, $\triangle TK_{bd}/TK$ and $\triangle TK_{ec}/TK$ are a negative -0.0018, -0.0034and 0.0073, respectively, which means that only self-raised technology funds has a positive growth. The averages for proportion change in technical personnel to employees is a negative -0.0006. In the gross industrial output value, the averages in $\triangle GIO_{soe}/GIO$,$\triangle GIO_{pe}/GIO$ and $\triangle GIO_{ffe}/GIO$ are a negative -0.0122, 0.0299 and0.0157 respectively, which means that private and foreign-funded enterprises' gross industrial output value have a positive growth.

TABLE 5. DESCRIPTIVE STATISTICS OF EXPLANATORY VARIABLES IN THE REGRESSION MODEL

		1999 to 2009		
		Average	MAX	MIN
Explanatory variable	DPP	1.6001	4.0396	0.1087
	$\triangle TK_{gf}/TK$	-0.0018	0.0048	-0.0082
	$\triangle TK_{bd}/TK$	-0.0034	0.0281	-0.0325
	$\triangle TK_{ec}/TK$	0.0073	0.0728	-0.0440
	$\triangle TL/L$	-0.0006	0.0036	-0.0113
	$\triangle GIO_{soe}/GIO$	-0.0122	0.0058	-0.0472
	$\triangle GIO_{pe}/GIO$	0.0299	0.0573	0.0017
	$\triangle GIO_{ffe}/GIO$	0.0157	0.0408	-0.0205

DGIOsoe, DGIOpe, DGIOffe: above are the analysis indicates technological progress of different ownership-based enterprises, which are totally different, we first used the Malmquist index measures the total factor productivity change. Table 6 shows the TFP change of the GIO for Jiangsu Province industrial enterprises as follows: (1) DGIOsoe: from 1999 to 2009 the average TFP growth is 1.2197. (2) DGIOffe average TFP growth is 1.0757. (3) While DGIOsoe average TFP growth is 0.9763. Further, using t-test to verify the GIO three sample's average shows in Table 7. The results show that P-value < 0.05, their average is not the same. Therefore, it is necessary to take ownership into account when analyzing the effects of R & D input upon technological progress.

This study further applies in Pearson correlation analysis among three variables. The proportion change in output values for $\triangle$GIOsoe/GIO, DGIOpe, $\triangle$GIOpe/GIO and $\triangle$GIOffe/GIO without correlation in 1999-2009. To avoid the regression, analysis may produce in multiple co-linearity . The analysis results showed there is insignificant correlation in Table 8.

TABLE 6. THE TFP CHANGE OF GIO FOR JIANGSU PROVINCE INDUSTRIAL ENTERPRISES

Malmquist	2001=>2002	2002=>2003	2003=>2004	2004=>2005	2005=>2006	2006=>2007	2007=>2008	Average
GIOsoe	0.9003	0.8442	1.1104	0.8696	1.1306	0.7405	1.2381	0.9763
GIOpe	1.3901	1.4174	1.1119	1.1022	1.2486	1.0210	1.2465	1.2197
GIOffe	0.8962	1.1036	1.2614	1.2254	1.1032	0.9720	0.9681	1.0757

Table 7. T-test of the TFP Change of GIO for Jiangsu Province Industrial Enterprises

	T-test	P-value	Mean difference
GIOsoe	14.128	.000	.9762
GIOpe	21.546	.000	1.2197
GIOffe	20.740	.000	1.0757

Table 8. Results of Pearson Correlation Analysis for △GIOsoe/GIO,DGIOpe, △GIOpe/GIO and △GIOffe/GIO

		△GIOsoe/GIO	△GIOpe/GIO	△GIOffe/GIO
△GIOsoe/GIO	Pearson	1	-.361	-.498
	Significant (One-tailed)	1.251	.153	.071
△GIOpe/GIO	Pearson	-.361	1	-.146
	Significant (One-tailed)	.153		.344
△GIOffe/GIO	Pearson	-.498	-.146	1
	Significant (One-tailed)	.071	.344	

2）Statistical description of research funding of different sources

From the statistical data of the Statistical Yearbook of Jiangsu Province, most funding sources of the industrial enterprises can be basically divided into three parts: government funding, loans from financial institutions, and corporate self-financing. Different sources of inputs have different purposes, and industrial enterprises also show differences when using these three kinds of inputs for research funding. Government funding is done in order to support industrial research activities, which lead enterprises to increase investment towards research. Loans from financial institutions are based on the policies of the government, which encourages industrial enterprises to make technological innovations. Moreover, the fixed assets of industrial enterprises account for a high proportion of assets used as collateral, and so the creditors can get better insurance. Research funding here is large scale and based on long-term loans, giving financial institutions a steady inflow of economic benefits during the loan period. Self-financing denotes the funds from the enterprise's own business that are devoted to research activities in order to get benefits in pursuit of business competitiveness.

This paper adopts samples with the time interval between 1999 and 2009. Data in 2009 follow the aforementioned processing. Table 9 shows Jiangsu industrial enterprises' research funding, the absolute amount of funds from different sources, and their proportion to total research funding. From the total funding in science and technology, the technology input of these industrial enterprises has increased from RMB 7.624 billion to RMB 74.121 billion from 1999 to 2009, or an increase of 9.72 times.

From the data on the appropriation from higher authorities, we see that although the absolute value rose from RMB 300 million yuan in 1999 to 1.6 billion in 2009, the proportion to total research funding dropped from 3.93% to 2.16%, which means the government attached great importance to R&D activities in large-and-medium-sized industrial enterprises by increasing its appropriation. However, as funds from the other sources witnessed a larger increase, government funds fell in total research funding.

In terms of loans from financing institutions, the absolute amount increased from RMB

Table 9. Research Funding of Different Sources for the Years between 1999 and 2009 (100 million yuan, %)

Year	1999	2000	2004	2005	2006	2007	2008	2009
Total technology funding	76.24	95.39	309.48	389.79	480.39	661.50	769.99	741.21
Absolute number of appropriation from higher authorities	3.00	3.58	4.88	8.00	11.25	13.19	18.51	16.00
Proportion of appropriation from higher authorities	3.93%	3.75%	1.58%	2.05%	2.34%	1.99%	2.40%	2.16%
Absolute number of loans from financing institutions	9.85	10.51	25.53	43.09	60.05	67.29	56.61	70.64
Proportion of loans from financing institutions	12.92%	11.02%	8.25%	11.05%	12.50%	10.17%	7.35%	9.53%
Absolute number of self-raised funds	61.78	77.36	271.17	324.39	401.90	571.20	684.84	654.58
Proportion of self-raised funds	81.03%	81.10%	87.62%	83.22%	83.66%	86.35%	88.94%	88.31%

985 million in 1999 to 7.064 billion in 2009, or an increase of 7.18 times, but a slight decline can be seen in 2008 compared with 2007. Its proportion to total research funding witnessed a little fluctuation with an average of 10.46% versus a minimum value of 7.35% in 2008. This paper believes it is caused by the financial crisis as financing institutions cut loans to enterprise research funds in the interest of creditors' assets.

In terms of self-raised funds, the absolute amount increased from RMB 6.178 billion in 1999 to 65.458 billion in 2009, or an increase of 10.60 times with a maximum value of RMB 68.484 billion in 2008. Its proportion to total research funding is all above 80% from 81.03% in 1999 to 88.31% in 2009 with a peak of 88.94% in 2008. The sustained growth of enterprises' self-raised funds and the proportion to total research funding suggest enterprises' emphasis and willingness towards R&D activities. When faced with a widespread economic slowdown, it is those enterprises with the most advanced technology that can lead the market, improve their competitiveness, and gain monopoly profits.

3) Empirical results and analysis

Table 10 lists the regression results of 10-period statistical indicators of all industrial enterprises in Jiangsu.

From the regression results of funding sources, we see that the proportion of appropriation from higher authorities exhibits an inverse proportion to technological progress growth. Loans from financing institutions and self-raised funds promote enterprise technology progress, and the role of financial institution loans is slightly greater than that of enterprise self-raised funds. We now offer a detailed analysis as follows.

The promotion effect of financing institution loans on enterprise technology progress reflects the regulation and restriction function of the debt contract between banks and enterprises upon enterprises' use of such funds. R&D investments tend to require a large amount of funds and a long R&D period. As far as banks and enterprises are concerned, innovation activities suffer from high uncertainties in achievements as well as higher risks. Debt

Table 10. Regression Results

Variable	Coefficient	T value
α	0.705	2.343
DPP	0.161	1.845
DTL	-12.695	-0.410
DTK_{gf}	-13.922	-1.173
DTK_{bd}	30.386	1.882
DTK_{ec}	17.878	1.660
$DGIO_{soe}$	-20.658	-2.347
$DGIO_{pe}$	-0.629	-0.187
$DGIO_{ffe}$	0.581	0.512
R^2	0.987	
F value	9.428	
D-W	2.890	

constraints will increase the possibility of bankruptcy, which will in turn restrict enterprises from an unsound investment impulse (Jensen, 1989), unreasonable investment, and fund abuse. In addition, enterprises' records of previous loan repayments can be easily found, which for banks means lower information costs. Moreover, the support of banks with enterprise R&D activities and long-term cooperation between banks and enterprises can enable the latter to obtain loans at relatively low costs of credit and can enhance their research enthusiasm to some degree.

The promotion effect of self-raised funds on technological progress reflects management's efficient use of such research funding. When such funds are invested in scientific activities, for the purpose of incentive compensation and personal development, management personnel will give priority to fund usage either in respect of independent innovation or the introduction of advanced technology. They will make a more accurate judgment on fund investment direction and intensity, thus boosting the efficient growth of technological progress. From the viewpoint of enterprise owners, only a leading technological level in their industry can help their firms transform technologies into production, increase market share, and gain monopoly profits. Furthermore, monopoly profits also provide the necessary financial support for enterprises to carry out further R&D activities, forming a positive virtuous circle between self-raised funds invested in R&D for technological progress. For this reason, enterprise owners will strengthen effective supervision over management personnel's use of funds. Therefore, the increase in the proportion of enterprises' self-raised funds will produce a significant promotion effect upon technological progress.

Despite constant appropriation from higher authorities, it does not really help enterprises with technological progress promotion, and even a strong policy and weak supervision may restrict an enterprise's innovation ability. Conventional ideas hold that with intensive investment in innovation and admirable innovation opportunities, large-and-medium-sized industrial enterprises can witness rapid technological progress with strong support from the government. Nevertheless, this paper presents a conclusion rather different from the conventional ideas for the following three reasons. First, although large-and-medium-sized industrial enterprises show a more intensive innovation investment than general enterprises, their technical level is not significantly superior to that of the general innovation-oriented enterprises. As a result, despite the appropriation from higher authorities, these enterprises fail to witness any significantly improved technical level. Although the government has clearly defined regulations on innovation input intensity when determining its investment direction, there is no evaluation in terms of fund use efficiency (Lu 2011). Second, engagement in R&D activities can bring direct and indirect benefits, such as tax deductions, government subsidies, and financing convenience. Enterprises are tempted to receive government investment. Innovation investment intensity is considered to be necessary for a government's recognition of investment goals, and so it is not difficult to find excessive packaging or false information in innovation investment intensity indicators during the application process. As some domestic scholars point out in their study on Chinese enterprises' R&D behavior, signal transmission and adverse selection are rather common when enterprises make applications for an R&D subsidy (Ann et al., 2009). In respect of this thinking, it would not be difficult to understand the negative correlation between government funds and enterprise technological progress. Third, most government financial support targets large projects of technological innovation that have a long research cycle. It is difficult to turn research results into product sales revenue within a short term. Furthermore, government funds impose no repayment pressure upon enterprises. The lack of any corresponding supervision and evaluation mechanism as well as a long research cycle fail to help the government effectively supervise enterprises' use of government funds, and thus there is low efficiency of enterprise fund use in innovation investment.

VI. *Conclusions and Limitation*

There is a great difference of innovation ability in different regions of China. Jiangsu Province is one of the few provinces that developed the fastest innovative economy, and it can be cited as a model in the field of technology innovation.[3] This paper employs the data envelopment analysis (DEA) model to compute and decompose the total factor productivity growth of industrial enterprises above a designated size in Jiangsu Province, as well as investigates the difference in their innovative distribution between technology progress and technical efficiency. From the aggregated data analysis of industrial enterprises above a designated size from the statistics yearbook, the computing results may be offset, owing to the different industry features and ownership features, and thus may not be detailed enough. From the perspective of industry and ownership, this paper takes a step further to analyze the change trend and the factors of TFP for those enterprises. This paper also systematically makes a finer division of the different sources of R&D expenditure, as well as empirically tests the attractiveness of government funds to the technology progress of industrial enterprises, the standard and restrictive functions of a debt contract for the usage of R&D expenditure, and fund investment in pursuit of economic benefits and enhancement of enterprises' competitiveness. The research conclusions are as follows.

First, during 1999 to 2009, the average increase of TFP for industrial enterprises above a designated size in Jiangsu Province was 10.31%, and the increase was caused by technology progress. From the perspective of industry features, the technical efficiency of the monopolized industries is on the rise and their technology progress also is developing very fast; the technical

[3] Luo Zhengying, Xu Yayun: "Computing and Empirically Test of the Influence from Industrial Enterprises' R&D Investment on the Technology Progress"; working paper for 2012.

efficiency of those industries with a large inflow of foreign capital has trended down, and their technology progress ratio has increased stably; but the technology progress of some industries has developed very slowly. From the perspective of ownership, state-owned enterprises' TFP has shown the largest growth, owing to administration system reform and the enhancement of resource distribution efficiency. Private enterprises take second place with their energetic R&D capacity and their strong ability to transform R&D achievements into productivity in a short time. Though overseas-funded enterprises have the most advanced technology, their growth rate is the smallest due to poor technical efficiency.

Second, from the ratio of invested expenditure from different sources, the government fund ratio is inversely proportional to the technology progress, which indicates that government funding plays an unimportant role in the technology progress of industrial enterprises, and the latter should pay great attention to the usage of government funds. Financial institutions' capital and enterprises' self-raised fund ratio promote technology progress, showing that the debt contract is a better standard and restrictive function for the usage of R&D expenditure. Enterprises' self-raised funds have also promoted their technology progress.

From the conclusions of this paper, we believe that R&D investment is a vital factor to improve firms' technology progress. Moreover, R&D expenditure makes a larger contribution to than does R&D human capital. However, there are still two problems that need to be settled as noted below.

First, from the computing and decomposition of technology progress, each enterprise should have a clear understanding of the features in its own industry, analyze the industry's development prospects, and choose a technology innovation model to maximize its improvement of technical efficiency according to the industry features and its own R&D capability. There often exist a technology association and conduction effect among industries. Those industries running into a bottleneck should fortify their strength at technology innovation, maintain a smooth technology transmission mechanism among industries, strengthen the liquidity of R&D resources, execute system reforms, and resolutely implement an industry exit policy when necessary. Monopolized industries should speed up the industrialization of their technology innovation achievements, which will lead to the development of upstream and downstream enterprises that will develop products by themselves and thus enlarge the economic benefit of technology innovation. The government should be a bridge that connects various related industries, while at the same time guide the transmission of major technological breakthroughs and technology innovation benefits within industries.

Second, R&D funds have played an important role in the process of technology progress in Jiangsu Province. However, the yearly increase in government funds (donated by superior departments) on the role of promoting technological progress is not ideal. This paper suggests that the government can improve the supporting mode for industries' R&D activities, so that when screening for investment projects, the government can pay more attention to the usage status of R&D investment by enterprises and make an ideal judgment as to whether the investment did indeed promote technology progress, rather than only focus on the previous intensity of R&D investment. When formulating industrial policy guidance and enterprise support policies, the government should avoid any direct involvement in the R&D activities. The government should transform its traditional role into a service-oriented role, in order to discover, support, and guide the industries to take up new effective ways of R&D investment. After the funds have been invested, the government should strengthen its supervision and motivation. As an external supervisor, the government can do the following: correctly evaluate and supervise the industries' activities, make up for any fund shortage through ex post performance rewards, perfect financing system reforms, strengthen the protection of creditors' interests, and improve the system of bankruptcy liquidation, and with the help of financial institutions, the government can supervise business capital by effectively using relational-contingent governance.

Limitation of this study: Data in Tables 6, 7, 8 is calculated based on Malmquist TFP model constructed by us. We have tried our best to obtain the reliability of the data.

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