The analysis of innovation efficiency and non-technological factors of manufactory companies in the Pearl River Delta of China

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Abstract

Since Guangdong province is the one of the most developed region of China, the innovation activities represent the best level of China. Therefore, our study mainly concentrates on the technological innovation efficiency measurement and comparison base on 36199 companies' data of the manufacture industry of Guangdong province. We also analyze the spread of non-technological innovation in companies in Guangdong Province, especially in the Pearl River Delta. We study their relation to technological innovation efficiency, and their effects to companies' performance and success with product and process innovation, using company data from the Nation Bureau of Statistics. The model results support the point of view that the non-technological innovation serves as an important bridge for a company to develop from pure technical innovation to company with scale effective innovation capability.

Keywords：Technological Innovation Efficiency; Pure Technology Efficiency; Scale Efficiency; Non-technological Innovation; Organizational Innovation; Marketing Innovation

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1 Introduction

Technological progress leads to economic development by raising companies' productivity and innovation activities create better products to fulfill the demand of people. But some companies in China are facing with the problem that a lager amount of innovation capitals are invested, but the effect is not corresponding to the input. That is to say, like another activities, innovation have efficiency which should be measured and which is not only affected by the input elements. Non-technological innovation is an important element of companies' innovation activities that both supplement and complement technological innovation, i.e. the introduction of new products and new processes. Some scholars have point out that innovation in firms is not just about developing and applying new technologies but also to adopt and re-organize business routines, internal organization, external relations and marketing (Baranano, 2003; Boer and During 2001). And others also maintained that innovation management literature stresses the importance of integrating product, process and organizational innovation for successfully transferring new ideas and new business opportunities into market success (Tidd,2001; Cozzarin and Perzival 2006) and emphasizes the crucial role of linking R&D, technological innovation and new marketing approaches (Griffin and Hauser 2001). The study results conclude that non-technological innovation cannot be omitted in the procedure of technological innovation and may have some important influence. Therefore, our study focuses on this problem by researching 36199 companies' data of the manufacture industry of Guangdong province in China, paying special attention to the Pearl River Delta (PRD) region.

Guangdong Province is situated in the southern part of China mainland. Guangdong is an economic powerhouse in southern China but some difficulties in some financial institutions have caused the central government to clamp down on this freewheeling province. More than 60,000 foreign enterprises have gone into business here since 1979. Guangdong was also the site of three or the four special economic zones --- Shenzhen, Zhuhai, and Shantou --- which offered special and generous tax incentives. Guangdong is nationally number one in GDP, Urban population income, retail sales, exports, imports, and ownership of motorcycles and air conditioners. Guangdong is the country's richest province with the highest total GDP among all provinces. Its nominal GDP for 2008 its GDP reached 3.57 trillion yuan (US$522 billion), contributing approximately 12.5% of national economic output. Guangdong also hosts the largest Import and Export Fair in China called the Canton Fair which is hosted by the city of Guangzhou--Guangdong's capital city.

China's economic and political rise has created an important opportunity for Guangdong province, which has a unique advantage as a gateway to and from China. To fully benefit from this advantage, it is critical that Guangdong especially the Pearl River Delta (PRD) region strategically collaborates and integrates with the economies of Hong Kong, Macro and Taiwan. In this effort, innovation will take a key role.

Chart1 The map of Guangdong Province in China

In 1994, the concept 'Pearl River Delta' is initiated. We can see from chart1 above that the red colored cities belongs to the Pearl River Delta Region. The Pearl River Delta Region (PRD), or the Zhu Jiang Delta, in southern China occupies the low-lying areas alongside the Pearl River estuary, where the Pearl River flows into the

South China Sea. Since economic liberalization was adopted by the Communist Party of China in the late 1970s, the portion of the delta in Guangdong Province has become one of the leading economic regions and a major manufacturing center of mainland China. The Chinese government hopes that the manufacturing in Guangdong, combined with the economic and traditional Western influence in Hong Kong, will create an economic gateway attracting more and more foreign capital into mainland China. And the PRD did realize the goal. The delta region had taken the first step in the country's reform and opening-up thirty years ago, which had led to the glorious growth in the region's economy. Under the new State Council Plan, the government would facilitate innovation to bring about more achievements to the region.

Pearl River Delta, an export-oriented region severely hit by the financial crisis, aims to become a "significant innovation center" in the Asia-Pacific region by 2020. In next three years, about 100 state laboratories for engineering innovation and research and development will be established under a plan released by the National Development and Reform Commission. The plan sets the goal that by 2012, three to five industrial clusters powered by high-technology should come into place, generating more than 100 billion yuan (about 14.6 billion U.S. dollars) in aggregate industrial output. The delta region was also expected to incubate three-to-five multinationals whose annual sales would reach 100 billion yuan by 2012. Manufacturing powered by high-technology should generate at least 30 percent of the region's total industrial output by 2020. In recent years, China is turning Pearl River Delta into technological innovation lab.

The manufacturing companies in the Guangdong Province, especially in the PRD region have get through the stage of improving technological capability only by technological innovation and entered the new era of promoting innovation by some non-technological strategies such as change in capital structure or method of management. Faced with the financial crisis, the top task is to maintain stable and fast economic growth. The companies also need to speed up our industrial restructuring and increase our independent innovation abilities to gain an edge in the global market, company-wise or products-wise.

Based on the backgrounds above, our study aims at achieving the technological innovation efficiency measurement and comparison of companies in Guangdong and digging out the relationship or function of non-technological innovation in the technological innovation procedure.

2 Methodologies and Theoretical Model

The optional problems always occur in the microeconomics. In our problem to find out the innovation efficiency, if a company can make good use of its limit resource, we can say that it is effective. In this simple input output model, assuming the input is $X(x_1, x_2, ...x_h)$ and the output is y, then the relationship between them is $y = f(X) = f(x_1, x_2, ...x_h)$.

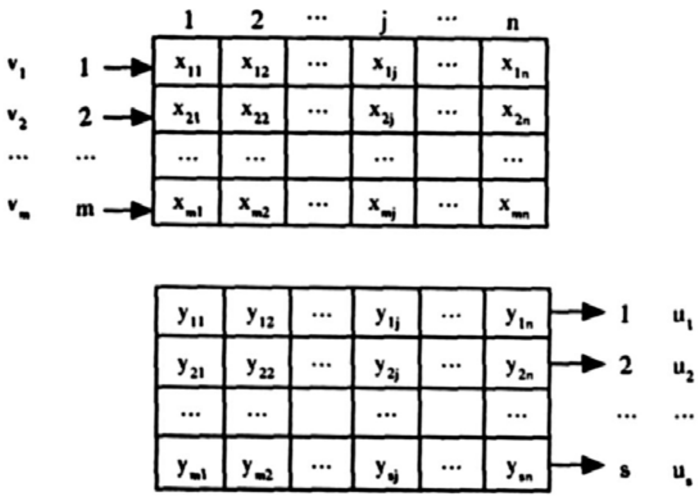
The production efficiency and Data Envelopment Analysis

The concept of production efficiency is brought forward by Farrell (1957), who defined a measurement of efficiency with multi inputs of a company based on the work of Debreu (1951) and Koopmans (1951).The definitions of Farrell were called Technological Efficiency (TE) and Allocative Efficiency (AE). The former means the capability of optimal usage of resources, viz. the maximized output of given certain input elements or the minimized input capability of a certain output level (Lovell, 1993). And the latter indicates the capability of realizing the optimal input-output combination under certain elements prices. These two measurements are composing the concept of Economic Efficiency (EE), with this formula: EE=TE×AE. In addition, Lin(2002) point put in his article an model to measure the Pure Technology Efficiency(PE) by excluding the effect of Scale Efficiency (SE), with this formula: TE ＝PE×SE. The ordinary estimations methods of maximized output frontier are

Stochastic Frontier Analysis and Date Envelopment Analysis (DEA).

Data Envelopment Analysis (DEA) was developed by the famous American mathematician and economist A.chames, W.W.cooper and Rhodes base on the notion of *relatively efficiency appraisement* in 1978.This model aimed at evaluating the relative validity of decision units with multi input and output. It can be said that the method of DEA is an important link of mathematics, economics and data mining. Actually, it is a nonparametric statistics method to find the Pareto frontier by statistics, which can avoid the limitation to parametric methods. DEA does not request a default function to describe the relationship between input and output, and need not to set the weight beforehand[2], which make it quite suitable for evaluating the economic efficiency. Using the tools of convex analysis and linear programming, DEA can consider the optimal project of input and output sufficiently and reflect the information and characteristics of the objects. As our purpose of the research is the innovation efficiency, the DEA method can help find out the key element in the technology innovation by analysis of the shadow price of the input resources. As the innovation efficiency is a systemic problem with both economic benefit and social benefits, the C^2R model in DEA is the best method aim at solving the problem.

In the basic C^2R model, there are n sections or units with m input elements and s output elements for each unit as the following picture.



[2] The method of DEA does not instigate the data directly; therefore, the elements of optimal efficiency of decision units are independent of the dimension of input or output elements. As a result, there is no need to standardized the data before analyze with DEA.

For each decision unit DMU_j, the relative efficiency evaluating index is defined as follows.

$$h_j = \frac{u^T y_i}{v^T x_j} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}, j = 1,2,\ldots,n$$

x_{ij} =The total input of the i input elements to the j decision unit. $x_{ij} > 0$

y_{rj} =The total output of the r output elements to the j decision unit. $y_{rj} > 0$

v_i =the weight coefficient to the i input element

u_r =the weight coefficient to the r output element

$i = 1, 2, \cdots m \quad r = 1, 2, \cdots, s \quad j = 1, 2, \cdots, n$

We can finally find out the approviate weight coefficients of v and u to make $h_j \le 1$, and appraise the efficiency of the j decision unit. Generally, a bigger h_j implies that the DMU_j can achieve relatively high output with relatively low input. Comparing all the DMU_j, we can find the whether the DMU_j is most optimal in the n DMU or not. What is more, we can review the maximum of h_j when the weight changes.

For example, we aim at the efficiency of the j decision unit under the limitaion of the efficiency indexes of all decision units, then the C^2R model is built as follows.

$$\max h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

$$s.t. \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, j = 1,2,\ldots n$$

$$u \ge 0, v \ge 0$$

The programming above is an Fractional Programming, by Charnes－Cooper conversion and the dual theory, we can get a dual programming ,which can be use to judge whether the point of decision unit is located in the production frontier. On the assumption of constant returns to scale, Charnes, A.Cooper, W.W. Rhodes, E.brought forward the basic C^2R model as follows.

$$\left.\begin{aligned} & P_{TE} = \min \theta_i \\ & s.t.\sum_{j=1}^{n} \lambda_j x_j \le \theta_i x_i \\ & \sum_{j=1}^{n} \lambda_j y_j \ge y_i \\ & \lambda_j \ge 0, i, j = 1,2,\ldots n \end{aligned}\right\} \qquad (1)$$

In the programming (1) above, x_j and y_j denote the input and output vector of unit j respectively. θ_i is the technology efficiency of unit i and λ_i is the weight vector of unit j. TE reflects the maximum output capability of a certain input of the unit under the constant returns to scale(CRS) assumption.

In order to guarantee the validity of the DEA result, the sample amount must at least two times larger than the numbers of input and output elements. The result of model (1) is the TE of the i DMU . If the value equals 1, we can judge that this unit is technologically effective and located on the production frontier; if the value is less than 1, then this unit is technologically non-effective. The judgment of C^2R model follows the three rules below.

1) θ＝1,and $S^+ = 0, S^- = 0$, then the decision unit j is DEA effective;

2) θ＝1, but at least one of the input or output are larger than zero, then the decision unit j is weak DEA effective, which means the optimal input and output is not simultaneity.

3) θ＜1,then the decision unit j is not DEA effective.

When DMU stands for the companies, for the reason of competition and management, the company may not operating in the best scale economic situation, so the technologically non-effective may be caused by the economic scale. In this condition, Banker，R.D.CharnesA. and Cooper w.w. (1984) brought forward a DEA model under the assumption of variable returns to scale (VRS), which was called BC^2 model with the result of Pure Technology Efficiency.

The scale efficiency (SE) can be count by TE and PE.SE equals to the TE under CRS divides by PE under VRS, which means that TE can be divided into PE and SE. The Chart below shows the relationship between TE and SE.

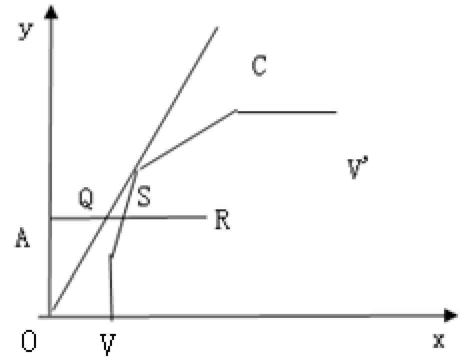


Chart2 The relationship between TE and SE

From chart2 we can see the situation of single input and single output under VRS. Line OC denotes the frontier under CRS, with TE equals to AQ/AR. While VV´ denotes the frontier under VRS, with PE equals to AS/AR, and SE equals AQ/AS. Obviously, (AS/AR)×(AQ/AS)=AQ/AR. Therefore TE can be disassembling to PE and SE. Our analysis below is based on these basic models.

The Tobit model

Using the method of DEA, we can get the evaluation of companies' technological efficiency, but this efficiency is a relative one based on the multi input and multi output system. It can not reveal the factors that affect it. Actually, besides the innovation input and output, some non-technological factors play important roles in influencing the innovation efficiency. In order to dig out the factors behind the innovation efficiency, the Tobit model is quite suitable (Zhang, 2006).

Tobit model is a econometric model to deal with dependent variables with partly continuous distribution and partly discrete distribution.If the data of Y_i^* is truncate data between 0 to 1, and Y_i^* is relative to some factors denotes as X_i then the regression model is

$$Y_i^* = \beta_0 + \beta_1 X_i + u_i \qquad (2)$$

With in the formula (2), $i = 1, 2, ..., n$. Since in our study, the dependent variable Y_i^* is a truncate variable. If we use the Y_i which we have observed directly to estimate the model, the OLS estimation is not consistent. So Tobit model is suitable here by assuming that u_i follow the normal distribution and deducing the likelihood function.

The framework of our study

Since there is great gaps of innovation capability between the provinces in China, and the innovation situation varies since each province concentrates on different industries. So our study take Guangdong for example to research the innovation efficiency for Guangdong is one of the developed provinces in China especially in manufacturing industry. And the innovation activities in Guangdong Province, especially the Pearl River Delta, are on the highest level and widely speared. Therefore, our study will follow the two steps below.

Step1: Calculate the DEA efficiency indexes (θ) and the slack variables of input and output (s^+, s^-) of the 21 cities in Guangdong Province base on the C^2R model.

Step2: Analysis the Non-technological factors of innovation efficiency by the DEA efficiency indexes (θ_l^*) of the companies in Guangdong province. Since the θ_l^* are truncate data, we use the Tobit model here to find the determinants.

In order to eliminate the misunderstanding, we need to clarify that the θ in the first step is calculated on the level of cities to get a general view of the cities and the θ_l^* in the second level is calculated on the level of companies in order to be the dependent variables of the regression models. Theoretically, the order of θ and the order of $\overline{\theta_l^*}$ by cities are the same and which is indeed proofed during our empirical procedure.

3 The Analysis of Theological Innovation Efficiency

Data source and specification

The basic data of our research is from the database of state-own and big scale non-state-own manufacturing firms in 2006 from the National Bureau of Statistics. There are 21 cities in Guangdong province and totally 36199 manufacturing companies in all kinds of industries in Guangdong. The nine cities: Guangzhou, Shenzhen, Zhuhai, Foshan, Jiangmen, Zhongshan, Dongguan, Huizhou and Zhaoqing belong to the Pearl River Delta, which can be seen in chart3 below.

Chart3 The map of Pearl River Delta region

The selection of input and output variables

The DEA method to evaluate the efficiency of a company is widely used in Chinese economic studies. Chi and Yu(2004) select the ***R&D*** and ***total assets*** as input variable and ***the amount of export***，***new products value***, ***high quality production index***, ***productivity*** and ***the value added of high-tech industry*** as output variables to analyze the innovation difference between the east and west China. Li and Wang (2006) use the ***innovation employee*** and ***innovation outlay*** as input variables and ***patent citation***, ***technology essays and works published*** and ***the growth rate of gross output*** as output variables to appraise the innovation efficiency of Beijing's manufactory industry. Guan and Liu (2003) chose the ***innovation employee*** and ***R&D*** as input variables and ***patent*** as output variables. What is more, in the study of the innovation index of the USA, some key factors are found, which reflect the accurate and definite information of innovation and highly relative to the successfulness of the innovation system of one country. These key factors are R&D input, ***technological labors***, ***higher education recourse***, ***the level of encouragement from the government to innovation and its commercialization***.According to all this study results by scholars, our study choose the ***R&D outlay*** as input variables. While for other production input, Jia (2003) chose ***gross output*** and ***value added*** as two output variables and the ***fixed asset***, ***current asset***, the ***gross wage*** and ***number of employee*** as input variables in her study to the level of technology progress of textile industries in Shanxi Province. Chen and Ye (2007) use ***the number of labors***, ***fixed asset*** and ***main operation cost*** as input variables to reflect the scale of a company in their study of green competitiveness.

In our study of innovation efficiency, we use the indicators mention above as reference, with the combination of the availability of data, we finally choose four input variables and three output variables. The input variables are ***numbers of employee*** (t1), ***the amount of R&D*** (t2), ***the current assets*** (t3) and ***the fixed assets*** (t4). The output variables are ***gross output value*** (c1), ***the output of new products*** (c2) and ***the sale income*** (c3).

The appraising results of innovation efficiency

First, the description of data is shown on the table1 below. All the input and output variables varied a lot since their standard deviations are much bigger than their average value. Since companies situation differ greatly from one another, we need to find out their innovation efficiency on the city level or even on the company level.

From the correlation table2, we can see that all this factors are highly and significantly related. The fixed assets, current assets reflect the utilization ratio of investment, and the R&D input reveals the technology progress, while the efficiency of labor input implies the progress in management.

Table1 The description of input and output variables

	Average	Standard Deviation	Unit
Numbers of Employee	323.3	1113.2	Person
R&D	516.9	32695.9	Ten Thousand Yuan
Current Assets	45924.4	416541.5	Ten Thousand Yuan
Fixed Assets	22806.1	217080.7	Ten Thousand Yuan
Gross Output	112006.8	1201806.3	Ten Thousand Yuan
Output of New Products	13175.3	657531.9	Ten Thousand Yuan
Sale Income	109446.6	1187726.8	Ten Thousand Yuan

Table2 The correlation between input and output variables

Pearson Correlations	Input				Output		
	t1	t2	t3	t4	c1	c2	c3
	Numbers of Employee	R&D	Current Assets	Fixed Assets	Gross Output	Output of New Products	Sale Income
Numbers of Employee	1.000	0.722**	0.937**	0.900**	0.929**	0.716**	0.929**
R&D	0.722**	1.000	0.872**	0.635**	0.866**	0.993**	0.869**
Current Assets	0.937**	0.872**	1.000	0.922**	0.993**	0.868**	0.994**
Fixed Assets	0.900**	0.635**	0.922**	1.000	0.925**	0.639**	0.925**
Gross Output	0.929**	0.866**	0.993**	0.925**	1.000	0.856**	0.999**
Output of New Products	0.716**	0.993**	0.868**	0.639**	0.856**	1.000	0.859**
Sale Income	0.929**	0.869**	0.994**	0.925**	0.999**	0.859**	1.000

Note: ** Correlation is significant at the 0.01 level (2-tailed).

By using the basic C^2R model of the DEA method with the software DEAP, we can get the value of TE, SE, and PE. Also we will get the result of output slacks value(S^{+}_{k}) (k = 1 ,2 ,3)and input slacks(S^{-}_{i}) (i = 1,2,3,4). The result can be seen from the two tables below.

Decomposing the technical efficiency into the product of pure technology efficiency and scale efficiency, we will find that the pure technology efficiency reflect the innovation level of the company under the current situation, which is a synthesis embodiment of a company or city. Under certain technical situation and input level, a company will achieve high output rate with a higher PE value. And the scale efficiency actually reveals the macro innovation management level. Analyzing from the scale economics angle, the scale efficiency will take on an inverted U shape curve.

When the scale is small, the innovation efficiency is relatively low, and as the scale grows, the efficiency goes up rapidly. While the scale keep on expanding, the management level can not catch up with it, the scale efficiency starts to fall.

From the result in table3 we can see that, there are almost half the cities in Guangdong province have reached the level of pure technology effective, the proportion of which is more in the PRD region than other regions. These cities includes most famous cities in Guangdong such as Guangzhou—the capital city of Guangdong, Shenzhen—the south gate of China, Foshan—the city with richest districts in China, Dongguan and Zhongshan—the famous costume and household appliances manufacture base. When it comes to the scale efficiency, we can see that there are 5 cities: Shenzhen, Huizhou, Zhongshan, Maoming, Shanwei, and Yangjiang keep the scale effective status. And more of them are in the non-PRD region. As we have mentioned above, some of the PRD region have been fully developed at least in the manufacture industry and as a result their scale efficiencies have gone pass the highest point if the inverted U shape curve. And on the contrary, the development of the non-PRD region is affected by the PRD region but some lags still exist. Some labor intensive industries are transplanted to these areas. So the companies there are kind of on the developing and expanding stage. And from the average TE, PE and SE, we can see that the PRD region is little advanced than the non-PRD region in the innovation efficiency, but the gap is not significant.

Table3 The apprising result of innovation efficiency of the 21 cities in Guangdong

Cities	Efficiency Value		
	TE	PE	SE
Guangzhou	0.921	1	0.921
Shenzhen	1	1	1
Zhuhai	0.940	0.988	0.951
Foshan	0.958	1	0.958
Jiangmen	0.825	0.978	0.844
Zhaoqing	0.599	0.603	0.994
Huizhou	1	1	1
Dongguan	0.796	1	0.796
Zhongshan	1	1	1
Shaoguan	0.676	0.790	0.855
Shantou	0.599	0.616	0.974
Zhanjiang	0.882	0.893	0.987
Maoming	1	1	1
Meizhou	0.698	0.933	0.737
Shanwei	1	1	1
Heyuan	0.867	0.993	0.872
Yangjiang	1	1	1
Qingyuan	0.761	0.769	0.990
Chaozhou	0.962	1	0.962
Jieyang	0.912	0.916	0.996
Yunfu	0.741	1	0.741
Average of PRD	0.893	0.952	0.940
Average of non-PRD	0.841	0.909	0.926

Note: The pink cities are in the PRD region and the blue ones are not.

Table4 The slacks of input and output variables

Cities	S_1^+ Gross Output	S_2^+ Output of New Products	S_3^+ Sale Income	S_1^- Numbers of Employee	S_2^- R&D	S_3^- Current Assets	S_4^- Fixed Assets
Guangzhou	0	0	0	0	0	0	0
Shenzhen	0	0	0	0	0	0	0
Zhuhai	0	0	2302381	0	0	0	0
Foshan	0	0	0	0	0	0	0
Jiangmen	434607.1445	0	0	0	0	2114762	4092101
Zhaoqing	147355.4735	0	12419.17	0	0	2341199	0
Huizhou	0	0	0	0	0	0	0
Dongguan	0	0	0	0	0	0	0
Zhongshan	0	0	0	0	0	0	0
Shaoguan	211396.896	449715.2765	186054.1	0	21814.3	4619933	5758190
Shantou	0	0	563308.5	31393.81	0	4012327	0
Zhanjiang	0	729140.923	3036863	0	8456.295	6456720	0
Maoming	0	0	0	0	0	0	0
Meizhou	71988.6995	2338927.105	0	0	0	637359.4	913011.1
Shanwei	0	0	0	0	0	0	0
Heyuan	0	1683720.025	169052.8	0	2231.442	360745.2	229790.4
Yangjiang	0	0	0	0	0	0	0
Qingyuan	0	684173.761	689947.7	10421.61	0	1627260	1423348
Chaozhou	0	0	0	0	0	0	0
Jieyang	320046.3415	59769.2925	0	0	0	1274692	0
Yunfu	0	0	0	0	0	0	0

Note: The pink cities are in the PRD region and the blue ones are not.

The table4 tells us the input surplus and output redundancy of the innovation in the 21 cities. Obviously, the input surplus and output redundancy occurs mostly in the non-PRD region. In the PRD region, Jiangmen and Zhaoqing are relatively less developed city, and the low efficiency is caused by the over input of assets and which is not fully used to promote the innovation but just for expanding production scale. And this same problem happened in some of the non-PRD cities. What is more, a serious problem of the non-PRD cities is the output redundancy of the new products. The reason for this is that there are a lot of small companies in these areas with the production mode of imitation but not innovation by themselves. Although this mode is quite a valid short cut for small firms to seek the first gold, but it can not last as the company growth.

According to the analysis of the innovation efficiency of the 21 cities of Guangdong province above, we can summarize the innovation route in the growing procedure of a company in the chart4 below. On the first step, a small firm will copy or buy some molding board from some bigger companies and stick to the production, gaining the first gold to expand the firm. As the company grows to medium size, it will try to do some technical innovation by itself and improve the innovation quantity and efficiency gradually. As the scale of the company keeps on growing, the top point of the scale efficiency of innovation is passed and the company is facing the bottleneck of how to improve the innovation efficiency. In this stage, the non-technological innovation is in urgent need to change the organization, management or sale strategies and help the company to make breakthrough in innovation. Therefore, to find out how the non-technological affect the innovation efficiency is our work on the next step.

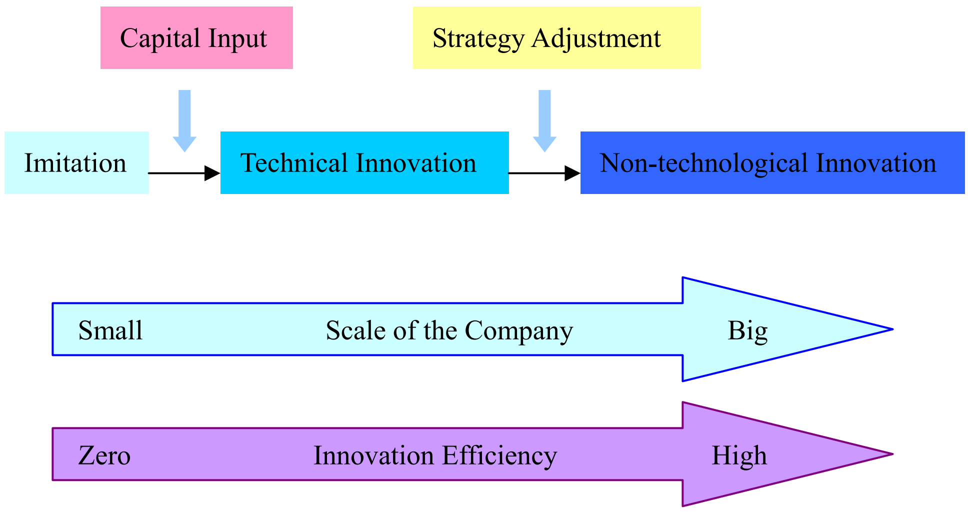


Chart4　The evolution procedure of innovation of companies

4　The Non-technological Factors of Innovation Efficiency

Non-technological innovation is defined as the introduction of new organizational methods or the introduction of new marketing methods. The studies by Tobias Schmidt and Christian Rammer (2007) have found that the determinants of a company's propensity to introduce technological and non-technological innovations are very similar and that both types are closely related. There are only small effects of non-technological innovation on a company's profit margin, which contrasts the strong effects to be found from technological innovation. However, non-technological innovation spurs success with product and process innovation terms of sales with market novelties and cost reductions from new processes.

The third edition of the Oslo Manual, published in 2005, adopted the concept of non-technological innovation and introduced two new types of innovation, organizational innovation and marketing innovation, which complement the standard concepts of product and process innovations. Organizational innovation refers to the implementation of new organizational methods not used in the firm before, while a marketing innovation is the implementation of a new marketing method (OECD and Euro stat, 2005).

"A ***marketing innovation*** *is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing." (OECD and Euro stat, 2005 § 172)*

"An ***organizational innovation*** *is the implementation of a new organizational method in the firm's business practices, workplace organization or external relations." (OECD and Euro stat, 2005 § 180)*

The selection of independent variables

Base on the conclusion of other scholars' study on the function of non-technological innovation, combining with the data we have which are mostly accounting data of companies, our study choose 4 main independent variables to describe the situation of non-technological innovation. We use ***the capital structure of the company*** (STRUC) and ***the ratio of foreign capital of the company*** (FR) to describe the organizational innovation in our model, since in China, most of the companies are state owned, and with relatively low production and innovation efficiency. But in resent years, many companies in Guangdong chose to change their structure of capital and lower the ratio of state owned capital of the company, replacing by private or foreign capitals. For example, Hong Kong accounts for 2/3 of firms investing in Guangdong province. In this case, the productivity and innovation are rapidly promoted because the company owners or shareholders have the eager request for the profit of the company. Therefore, the structure change in companies in Guangdong can reflect the innovation made in the angle of organization.

And the level of marketing innovation is reflected by other two indicators which is ***the management efficiency*** and ***the market efficiency***. The marketing innovation not only includes some new marketing method, but also the change in management.

Therefore it can be describe by the utilization ratio of management expenditure and marketing expenditure.

Also, we consider the scale and the attribute of whether the company located in the Pearl River Delta or not to be two dummy variables in order to see their effects.

The dummy variable for location of the company:

$$PRD_j = \begin{cases} 1 & \text{the company located in the Pearl River Delta} \\ 0 & \text{the company does not located in the Pearl River Delta} \end{cases}$$

The dummy variables for scale of the company

$$SCALE_j = \begin{cases} 1 & \text{big scale company} \\ 0 & \text{medium and small scale company} \end{cases}$$

Our model aims at revealing the relationship between the three kinds of innovation efficiencies we calculate above and all the non-technological factors. So the dependent variables in our models will be the value of TE, PE and SE, respectively. Since the efficiency indexes are all truncate data, Tobit models are need in this situation.

Let θ_l^* be the DEA efficiency indexes calculated based on the company level, and x_j denote the factors that affects the θ_l^* .Then we will have the Tobit model like this.

$$\theta_l^* = a_l + \sum_{j=1}^{6} \beta_{lj} x_{lj} + \varepsilon_l$$

In the formula above, *l* can be TE, PE or SE.

Let us have a look at the description statistics of the variables first. We can see that the dependent variables do not varies a lot, while the independent ones have bigger Standard Deviation. And about the two dummy variables, there are 29483 companies which are located in the PRD region and 6716 companies not. And there are 322 companies reached the standard of the big scale company released by the Nation Bureau of Statistics.

Table5 The description of dependent and independent variables in the models

Name	Variable Signification	Average	Standard Deviation
TE	Technical Efficiency	0.474	0.261
PE	Pure Technology Efficiency	0.606	0.269
SE	Scale Efficiency	0.794	0.227
STRUC	The capital structure of the company	0.948	0.212
FR	The ratio of foreign capital of the company	0.374	0.467
ME	The management efficiency	0.676	5.494
MARE	The market efficiency	6.176	96.234
	Number of companies	1-YES	0-NO
PRD	Whether the company located in the Pearl River Delta or not	29483	6716
SCALE	Whether the scale of the company is big or not	322	35877

Note: The standard of big medium and small scale of company is below[3].

[3] The standard of big medium and small scale of company from the Nation Bureau of Startistics

Indicators	Unit	Big	Medium	Small
Numbers of Employee	Person	>2000	300-2000	<300
Sale Income	Ten Thousand Yuan	>30000	3000-30000	<3000
Total Assets	Ten Thousand Yuan	>40000	4000-40000	<4000

The empirical results

Table6 The results of the Tobit models

Model	1		2		3		4		5		6	
Dependent variable	TE		TE		PE		PE		SE		SE	
	all		selected		all		selected		all		selected	
C	-1.020	***	-0.997	***	-0.694	***	-0.694	***	-0.164	*	-0.133	*
STRUC	0.027				0.084	*			-0.072	*	-0.071	*
FR	0.053	**	0.055	**	0.003				0.077	***	0.076	***
ME	1.264	***	1.267	***	1.043	***	1.102	***	0.972	***	0.979	***
MARE	0.303	***	0.304	***	0.342	***	0.359	***	0.042			
PRD	0.070	***	0.070	***	-0.023				0.162	***	0.160	***
SCALE	0.053		0.052	*	0.101	**	0.088	**	-0.008			
Log likelihood	41.950		41.950		39.174		39.193		42.066		42.066	
R-squared	0.207		0.207		0.157		0.152		0.164		0.164	

Note: * Coefficient is significant at the 0.01 level**

**** Coefficient is significant at the 0.051 level**

*** Coefficient is significant at the 0.10 level**

From the result above we can see that, for the TE full models with all the 6 independent variables, the structure and the scale variables are not significant. So in the selected model we omit the structure variable and find that the scale variable becomes significant in this model. Finally, we build the finally model about TE like this.

$$TE^* = -0.997 + 0.055 * FR + 1.267 * ME + 0.304 * MARE + 0.07 * (PRD = 1) + 0.052 * (SCALE = 1) + \varepsilon$$

And for the PE full models, there are also two variables FR and PRD which are not significant. By some trail we finally select the model below.

$$PE^{*} = -0.694 + 1.102 * ME + 0.359 * MARE + 0.088 * (SCALE = 1) + \varepsilon$$

For the SE model, the variables MARE and SCALE can not pass the significance tests. So we omit them to from the final model below.

$$SE^{*} = -0.133 - 0.071 * STRUC + 0.076 * FR + 0.979 * ME + 0.16 * (PRD = 1) + \varepsilon$$

Discussion of empirical results

From the model result we can see that, the pure technological efficiency is mainly affected by the marketing innovation and of course the scale of the company. That is to say, the efficiency of some marking method or policy will promote the sale income in the first place and then give rise to the need to the technical innovation in the aspect of products or production mode. Only by technical innovation can help the company to improve the productivity rapidly to fulfill the market request. Therefore, the marketing innovation in the non-technological innovation is the main factor to support the technical innovation and improve its efficiency. Also, the big scale company is the main body of the technical innovation, which is consistent with our analysis in the first step. That is because the small and medium companies mainly focus on the expanding production scale in order to open their own market and the big company have the superior in capital, human resource and circumstances to do the technical innovation.

When it comes to the SE model result, we can see that the organizational innovation is the main factor to the scale innovation efficiency. When a company wants to exert the scale effect of its innovation activities, it needs to do some change not only in the marketing or management level, but the whole organization of the company. So the variable STRUC which reflect the state own capitals in the company will have negative effect on the scale efficiency. And the positive effect of FR reveals that the foreign capital indeed plays an important role in helping the companies in the PRD region to push their innovation to scale level. And notice that the dummy variables PRD is positive in the model, that is to say the companies in the PRD region have more advantage to develop their innovation maybe on the aspect of location, foreign experience or the early start.

As TE is the product of PE and SE, so the model result is also the combination of the two models. In the TE model, we can see that the both the two aspects of non-technological innovation are of great significant, and also the big scale PRD companies take the advantage to the entire technological innovation efficiency. Therefore, we can conclude that the non-technological innovation is one of the important factors to improve the innovation efficiency.

As for the companies in Guangdong province, we can divide them into 4 kinds or 4 stage of development procedure which is show in chart5 below. The original ones are those small companies in the non-PRD region, which are seeking the goal of survive in the market competition and producing mostly common and simple products. When they grow to a relatively big scale, they will try some brush-fire technical innovation and also some marketing research and change. The main competitors of them are the small and medium scale companies in the PRD region. Equipped with advanced technical and management capability due to the regional superiors, these companies are seeking ways to expand their production and innovation scale to achieve the goal of market share improvement. In this stage, some non-technological innovation methods are used. And when it comes to the big scale companies in the PRD region with the highest competitiveness, their market share and profit is already high enough, what they are seeking for is ways to keep their status in the furious competitiveness with foreign enterprises in the same domain. So they resort to the organization innovation to expand the innovation scale and level, from product improvement to technical amelioration and to inventions of their own with relatively low cost.

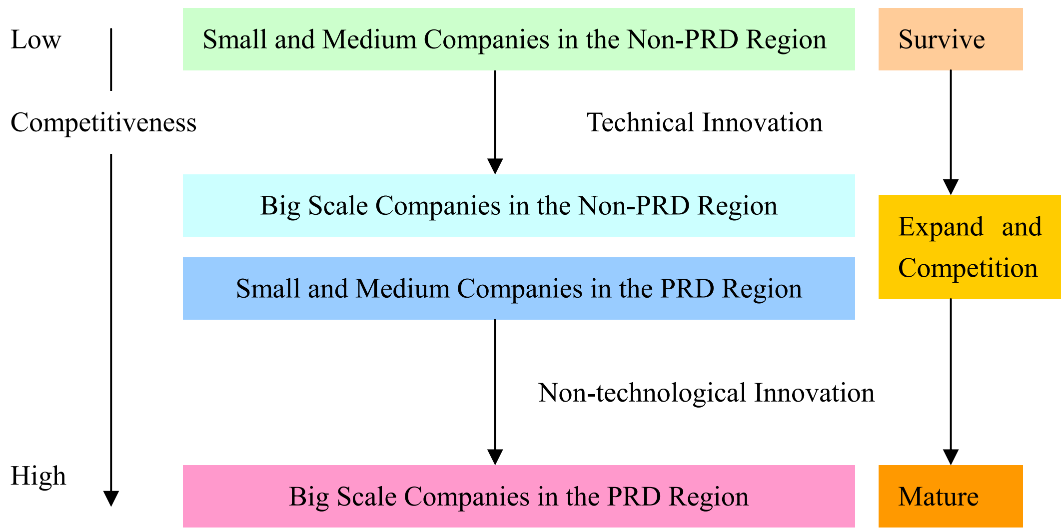


Chart5 The developing route of companies in Guangdong province

5 Conclusions

In this article we have shown that technological and non-technological innovations are linked to each other both at the city level and at the company level. From the result of the DEA appraisement and the Tobit models, we indeed find out the chain from technical innovation to scale technological innovation and the important ligament-- non-technological innovation. Although the result are only base on the data of the Guangdong Province, the conclusion is adaptable to the whole China, since there are noticeable stage difference inside the Guangdong Province, especially between the PRD region and non-PRD region. Therefore there are some advices for the companies.

As to the companies in the non-PRD region with relatively low competiveness, following the route of high competitiveness companies in the PRD region and learn some experience and technology from them is the short cut to upgrade.

As to the development of the companies in PRD region, meeting the challenges faced by PRD region requires strategic planning and action. The companies in the PRD region need to take the lead to cultivate thriving creative industries in the region. It also must stay competitive in the development of its human expertise, which is critical to exploiting the opportunities of its close partnership with other cities in the Guangdong province, which is the backup of the PRD. And, they need to integrate its resources with those available in the region to provide high-level services to the wider world. And the PRD companies should focus on the most innovative industry sectors in knowledge-based economy, such as information and communication industries, which will contribute more over the next decades to help PRD move in a direction that will make the scale innovation goals achievable. Inviting a team of prominent business leaders, renowned scholars and international industry experts to discuses the strategy change in the PRD region to conquer the crisis is necessary. Also, the government needs to do something. An innovation hub comprised of large cities such as Shenzhen, Guangzhou, Hong Kong, and Macao, will serve jointly as the base for regional and international cooperation in science and technologies. The government will also do its part to encourage innovative enterprise by reducing taxes on about 50 of the top competitive companies. By 2012, some 600 new patent applications per one million people are expected and priority will be given to those parents involving independent technological innovations. While some industries such as household appliances, textile and garments, paper-making and Chinese herbal medicine will be upgraded, inefficient energy-consuming sectors will gradually be phased out. The establishment of research institutes will beneficially affect every sector of production and manufacturing in the region. A brighter, hi-tech tomorrow of the Pearl River Delta requires not only the technological innovation but the non-technological innovation to be the invisible pushing hand.

Of course our study is still a regional and simple one. Future studies will have to address several caveats of our study. First thing is to investigate the direction of the link between technological innovations and non-technological ones. We only established that there is an effect of non-technological innovation activities on the technological innovation, but did not investigate the opposite direction. Secondly, the intensity of the link should be investigated. Thirdly, although the small and medium companies lack the capability to innovation on their own, the agglomeration effect should not be omitted especially in the PRD region. Is the agglomeration effect help improve the competitiveness of them? Finally, the effect of the non-technological should not only reveal by hard data but need some soft indicators such as scores from the company employees to complete our reorganization to non-technological innovation. All the answers to these questions would require data beyond that offered from the NBS but gathered through innovation surveys.

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