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Productivity Measurement of Hi-tech Industry of China Malmquist Productivity Index – DEA Approach

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Abstract

The study uses the Panel data of fifteen hi-tech industries over the period of 2000-2010 in order to measure the productivity changes of Chinese hi-tech industries by using the Malmquist productivity index. It concludes that the electronic component and office equipment industries are considered to be efficient. The mix result obtained with respect to productivity changes and its sources. Office Equipment industry is the leading in productivity gain by 3.7% over the study period.

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Keywords: Productivity Growth; Malmquist Index;Data Envelope Analysis

1. Introduction

Among the different sectors, Hi-tech Sector has a great potential for future productivity growth which would raise the living standards by the use of the latest available technology. The rate of production in the Hi-tech Industries is normally greater than the conventional modes of production. Keeping in mind the fact that technology continues to advance the firms are inclined to produce as much as possible, before the technology gets obsolete.

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China is one of the most leading developing countries with an annual average growth of 10.13% since 1990. The productivity growth has been identified by most of the economist and researchers ahead of her growth. The strong infrastructures, progressive development of the institutions, qualitative skilled manpower and dynamic economic policies are the main indicators which account for her astounding productivity growth.

Hi-tech sector significantly contributes to the gross domestic product of China. The ratio of value added of hi-tech industry to the value added of manufacturing has been growing from 9.5% in 2001to 12.7% in 2007.

Promoting the hi-tech industry innovation and development of science and technology are the central objective of the Chinese government. The rising R&D spending, development of S&T institutes and increasing technical staff would make hi-tech industries of China competitive locally as well as internationally, which attracts plenty of foreign direct investments in this industry.

By realizing the importance of the sector, this study is an effort to measurement the productivity growth of the hi-tech industry of China and tries to indentify the main sources of its growth. The productivity changes calculated through the Malmquist Productivity Index by using the DEA Approach.

1.1 Total Factor Productivity

Total Factor Productivity is one of the sources of economic growth besides the primary factors of production (labor and Capital). Productivity improvement leads an economy (industry or firm) to achieve better than before with the unchanged inputs in the production process. According to the Paul Schreyer (2001), total factor productivity is generally defined as a ratio of a volume measure of output to a volume measure of input use.

Solow (1957) presented to measure the Hicksian neutral shift parameter in the production function by using the non-parametric index number approach. He interpreted the shift parameter as the costless increment of output to input ratio. The growth in output which cannot be expressed besides the primary inputs is attributed to the residual. Practically, this residual named "measure of our ignorance" by the Abamovitz (1956). Further, he divided the measure of our ignorance as the effects of technical and organizational innovation which are under the category of wanted and as measurement error, aggregation bias and model misspecification which are categorized as unwanted. The researchers are off course, more interested to measure the effects of technical change, organizational innovation and technical efficiencies by minimizing the other measurement errors.

The consistency of the TFP measurement depends on the careful selection and quality of output and inputs used. By realization of this notation, this paper is an effort to obtain quality output and input variables with respect to hi-tech industry of China.

1.2 Methods to measure TFP

There is a consensus over the view in the literature that productivity could be measure in different ways according to its purpose and availability of data. There are four significant productivity measurement approaches namely, growth accounting, index number, a distance function and the econometric approaches (Mawson et al., 2003).

Assumptions based, growth accounting approach determine the TFP growth residually. It means, by subtraction of observable income share of inputs (labor and Capital) from output growth leads to the TFP growth. Furthermore, growth accounting needs a specification of production function. It also enabled to decompose the output growth into different inputs growth and total factor productivity growth. The growth accounting methodology was extensively widen since 1957 (Solow) and applied on a great scale in empirical research such as, of Griliches (1960, 1963), Dension (1967) and Kendrick (1973, 1976, 1977).

Econometric approach doesn't demand the relationship between the production elasticities and income shares; it is only based on the observations of volume outputs and inputs. The literature regarding the econometric approach could be found in Morrison (1986) or Nadiri and Prucha (2001).

This study employs DEA-Malmquist Productivity Index (distance function approach) to measure the productivity changes over time and to get insight sources of its changes. The Malmquist Productivity Index based on the DEA (Data Envelop Analysis) developed by the Fare et al (1992, 1994). The DEA is a linear programming tool available to DMU (Decision Making Units) to evaluate the performance based on the multiple outputs and inputs and the methodology was originated by Charnes et al (1978) based on the frontier line which was developed by Farell (1957).

The Malmquist Index was first proposed by Sten Malmquist by constructing the quantity indexes for the consumption analysis purpose as ratios of distance functions (Malmquist, 1953). Later, the Fare et al (1992) merged the two ideas, the efficiency measurement presented by the Farrell (1957) and the measurement of productivity presented by the Caves at el (1982) to develop the Malmquist productivity index which is directly measured from the data of input and output by using the DEA.

There are number of captivating features to use DEA Malmquist Productivity Index approach. It is a non-parametric approach which means it doesn't require any functional form and it also shows the best practicing frontier. Secondly, its nature is non-statistical which suggests that the result from DEA doesn't produce any standard errors. On account of Malmquist Index, it is based on simple calculation as showed by Fare, Grosskopf and Roos (1995). The index can be related to the superlative Tornqvist and Fisher Ideal quantity indexes, under certain conditions as showed by Caves, Christensen and Diewert (1982) and Fare & Grosskopf (1992).

Fare et al (1992) developed the DEA-based Malmquist productivity index as the geometric mean of two Malmquist productivity indexes of Caves et al (1982). Therefore, Malmquist Index can be decomposed into two components, the efficiency change and technical change and the values of these components can be the evidences of the productivity change sources.

Following the Fare et al (1994), the output-oriented Malmquist productivity index between the period t and t+1 can be define as,

$$\boldsymbol{M_0}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}},\boldsymbol{x^t},\boldsymbol{y^t}) = \frac{\boldsymbol{D_o^{t+1}}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}})}{\boldsymbol{D_o^t}\,(\boldsymbol{x^t},\boldsymbol{y^t})} \times \left[\left(\frac{(\boldsymbol{D_o^t}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}})}{\boldsymbol{D_o^{t+1}}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}})}\right)\left(\frac{(\boldsymbol{D_o^t}\,(\boldsymbol{x^t},\boldsymbol{y^t})}{\boldsymbol{D_o^{t+1}}\,(\boldsymbol{x^t},\boldsymbol{y^t})}\right)\right]^{1/2}$$

Where, $\boldsymbol{D_o^t}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}})$ shows the distance from the period t+1 observations to the period t technology.

The first component of an index $\boldsymbol{TEC_o} = \boldsymbol{D_o^{t+1}}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}})/\boldsymbol{D_o^t}\,(\boldsymbol{x^t},\boldsymbol{y^t})$ measures the relative technical efficiency changes at the period t and t+1. The component shows the score of changes in efficiency over the time which reflects catching up effect of DMU to the frontier. The second component $\boldsymbol{FS_o} = \left[\left(\frac{(\boldsymbol{D_o^t}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}})}{\boldsymbol{D_o^{t+1}}\,(\boldsymbol{x^{t+1}},\boldsymbol{y^{t+1}})}\right)\left(\frac{(\boldsymbol{D_o^t}\,(\boldsymbol{x^t},\boldsymbol{y^t})}{\boldsymbol{D_o^{t+1}}\,(\boldsymbol{x^t},\boldsymbol{y^t})}\right)\right]^{1/2}$ measures the shift in technology (frontier) between the time period t and t+1. If the score of FS ***o*** is greater than unity suggests the positive shift in the frontier, less than unity represents the negative shift or technical deterioration and equal to unity indicates that there is no change in the technology frontier (Fare et al 1992, 1994).

The Malmquist index is the product of TEC***o*** and FS***o*** components. The improved productivity performance could be evidence if the score of Malmquist index represents greater than unity, if it comes less than unity which indicates productivity regress.

In order to calculate productivity, we have to solve four different linear programming problems under the constant returns to scale. The efficiency change can be further decomposed into the scale change and pure-efficiency change under the variable returns to scale; therefore it requires calculation of two more additional linear programming (Fare et al 1994).

2. Method

In our methodology, it is assume that there are k=1, …. K number of hi-tech industries which are using n=1….N number to inputs at each time period t=1….T and yield m=1, ….M number of outputs. In our studies, output-oriented approach has been adopted because of firms or industries have goal to maximize outputs at the given level of inputs.

3. Data and Variables

In our study, the panel data of fifteen hi-tech industries have been selected over the period of 2000-2010, which makes the sample of 165 observations. An effort has been incorporated in order to careful selection of variables with respect to hi-tech industry. There are two outputs and three inputs have chosen to measure the productivity changes in hi-tech industry of China (see Table-2).

Table-1

Hi-tech Industry Classifications of China
Chemical Medicine
Traditional Chinese Medicines
Biological & Biochemical Products
Repairing of Airplanes
Spacecrafts
Communication Equipments
Radar and Peripheral Equipments
Broadcast and Television Equipments
Electronic Appliances
Electronic Components
domestic TV sets and Radio Receivers
Entire Computer
Computer Peripheral Equipments
Office Equipment
Manufacturing of Measuring Instruments

4. Results

Table-3 describing the core features of the collected data of inputs and outputs. The low standard deviation figures indicates the pool data points are very close to their mean which could be interpreted that the average variables show some degree of consistency over the number of years.

The DEA applied to measure the result of Malmquist index and its component (table-4). The results obtained by applying the output-oriented with CRS (Constant Returns to Scale) model.

The table-4 shows the annual mean values of the efficiency change, pure efficiency change, scale efficiency change, technical change and total factor productivity change over the period of 2001-2010. The mixed results obtained where hi-tech industry of China mostly enjoyed the productivity gains over the study period. Similarly, it is ambiguous to identify with certainty the major source behind the productivity gains, as in some cases productivity changes caused by technical changes and in some cases by technical efficiency changes. By looking at the on average figures of the study period, it can be concluded that the productivity deterioration is mainly due to the inefficiency of the industry as the technical change progress on average. Furthermore, the technical efficiency change is the product of pure technical efficiency and scale efficiency change therefore; in our case the relative sources of inefficiency are both these indices.

Table-2
Definition & Measurement of Output and Input Variables

Variables	Definition & Measurement
Outputs	
y1: Gross Output (Ln)	Gross Industrial Output (valued at 1995) in 100 Million RMB
y2: Patents	Patents granted for invention, utility model and designs (in units)
Inputs	
x1: R&D Expenditure (Ln)	Perpetual Inventory Method used to measure the R&D input. (valued at 1995) in 10000 RMB
x2: R&D Personnel (Ln)	Sum of full-time persons and the full-time equivalent of part-time persons converted by workload (in persons)
x3: Human Capital	Represented as the ratio of technical persons to labor. (in persons)

Table-3
Descriptive statistics of input and output variables

Statistic	y1	y2	x1	x2	x3
Mean	25.298	50.7654	20.83455	8.764424	0.048545
Median	25.48	50.9654	20.97	8.87	0.04
Maximum	27.72	183	24.14	11.5	0.13
Minimum	21.88	1	16.54	5.22	0
Std. Dev.	1.569071	29.6567	1.516576	1.287128	0.032875
Skewness	-0.485	4.7689	-0.36857	-0.29573	0.929502

Kurtosis	2.297124	3.9876	2.760764	2.663095	2.563749
Sum	4174.17	1023	3437.7	1446.13	8.01
Sum Sq. Dev.	403.7652	102.765	377.2007	271.6987	0.177251
Observations	165	165	165	165	165

Table-4
Annual Means for DEA Model from 2001 to 2010

	EC	**PEC**	**SEC**	**TC**	**MI**
2001	1.025	1.013	1.012	0.964	0.988
2002	0.914	0.982	0.931	1.117	1.021
2003	1.028	1.006	1.022	0.883	0.908
2004	0.973	0.999	0.974	1.058	1.029
2005	1.017	1.006	1.011	0.995	1.012
2006	1.025	1.001	1.024	0.976	1.000
2007	0.978	1.001	0.977	1.050	1.027
2008	0.985	0.994	0.991	1.013	0.998
2009	0.996	0.996	1.000	1.008	1.004
2010	1.000	0.998	1.002	0.975	0.975
Mean	0.9941	0.9996	0.9944	1.0039	0.9962

The table-5 exhibits the mean changes of technical efficiency, technology, pure technical efficiency, scale efficiency and total factor productivity from the period 2000-2010 by industries. The Malmquist index score shows that the all industries enjoyed the productivity gains except the Electronic Components and domestic TV sets and Radio Receivers industries. The inefficiency is the reason behind the productivity regress as in the case of entire computer industry and both inefficiency and technology regress are the reasons behind the productivity deterioration in case of domestic TV sets and Radio Receivers industry. The overall industries are confronting the catching up to the frontier problem but are the good enough to change the frontier.

Table-5
Annual mean change of technical efficiency, technology, pure technical efficiency, scale efficiency, and total factor productivity from 2002 to 2007

DMU	TEC	PEC	SEC	TC	MI
1	0.994	1.001	0.993	1.009	1.003
2	0.993	0.999	0.994	1.01	1.003
3	0.991	0.997	0.994	1.009	1.000
4	0.993	1.001	0.992	1.009	1.002
5	0.994	0.999	0.995	1.009	1.003
6	0.992	1	0.992	1.009	1.001
7	0.991	0.997	0.994	1.009	1.000
8	0.995	1.002	0.993	1.017	1.012
9	0.995	0.999	0.996	0.98	0.975
10	1.002	1	1.002	1.015	1.017
11	0.992	1.002	0.99	1	0.992
12	0.994	1	0.994	1.006	1.000
13	0.993	1	0.993	1.016	1.009

14	1.000	1	1	1.037	1.037
15	0.992	0.998	0.994	1.008	1.000

5. Conclusion

The study conducted to measure the Malmquist Productivity index by DEA approach under the constant returns to scale of hi-tech industries of China. The study concludes that the electronic components and office equipments industries are considered to be the efficient industries among the others. And on average the overall hi-tech industry is struggling to catching-up the frontier.

Secondly, the relative technical efficiency sources are pure efficiency and scale efficiency. The main source of technical efficiency is the pure efficiency.

Thirdly, the Malmquist productivity index exhibits mixed results over the study period but the mean score shows the overall deterioration of the productivity performance of the hi-tech industry. From 2000 to 2010, the Office Equipment enjoyed the productivity gain by 3.7% which is the highest among the other industries, followed by the electronic components industries by 1.7%.

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