

Atlanta Conference on Science and Innovation Policy

Oct. 2-3, 2009

Theme: Roundtables on Methods, Measures, and Data

Analyzing R&D Efficiency in Asia and the OECD: An Application of the Malmquist Productivity Index

V. J. Thomas, Sudhir K. Jain and Seema Sharma

Department of Management Studies, Indian Institute of Technology-Delhi, New Delhi 110016, INDIA
(vjthomas_2001@yahoo.co.in)

Introduction

It is widely acknowledged that R&D is one of the major drivers of the economic progress of nations. With the move from individual R&D to organized research labs in the latter part of the nineteenth century, there was a vast increase in the productivity of research institutions which lead to more efficient use of R&D resources. This organizational improvement was used by the other developed countries of the time to enhance their own technological capabilities. Another significant development was the increasing role of research collaboration through the creation of links between academia, government and industry. As a result of the success of collaboration, and in recognition of the critical role played by R&D in economic growth, there has been a sustained effort by many countries to stimulate and sustain R&D in their countries.

The USA, Japan and members of the European Union have been competing over the years to demonstrate their technological superiority. This has lead to discussions on the decline in British Science in the eighties and nineties, and the more recent identification of the European Paradox (Tijssen and Wijk, 1999; Dosi, Llerena and Labini, 2006). The European paradox highlights the inability of the members of the European Union to capitalize on their leadership in scientific publications, and convert it to a larger number of patents and market leadership. The USA has been the leader in this sphere and is closely followed by Japan.

Lately, the decline in world shares of patents and publications of the USA and members of the European Union has come to the attention of scholars (Leydesdorff and Wagner, online; Hicks, 2005). This decline is mainly attributed to the increasing scientific activity of some Asian nations, mainly China and South Korea. A number of scholars and institutions have commented on the rise of these Asian nations (Glanzel, Debackere and Meyer, 2008; Leydesdorff and Zhou, 2005; NSF, 2007; WIPO, 2008).

Existing studies on R&D efficiency have either failed to use the concept of time lags between inputs and outputs (Rousseau and Rousseau, 1997; Rousseau and Rousseau, 1998) or have compared relative R&D efficiency of countries using CRS or VRS formulations (Lee and Park, 2005; Wang and Huang, 2007; Sharma and Thomas, 2008). This study seeks to contribute to the ongoing discussion on R&D efficiency by comparing some progressive Asian nations with major OECD countries by analyzing trends in their research productivity using the Malmquist Productivity Index (MPI).

Methodology

Data envelopment analysis (DEA) is an important non-parametric analysis technique which deals with measuring the relative efficiency of decision making units in a constant returns to scale (CRS) as well as a variable returns to scale (VRS) framework. Data is collected on the inputs and outputs to a production process for different decision making units (DMUs). The technique is non parametric and helps in the creation of the frontier of efficient performance based on the actual performance of the DMUs. The basic DEA models use CRS and VRS formulations which are at a point in time, hence leading to the criticism that this is a case of comparing statics. This criticism can be ameliorated by using longitudinal data and the Malmquist productivity index (MPI).

The Malmquist productivity index (MPI) measures the productivity changes in a DMU between two time periods. It requires panel data on inputs and outputs, and the analysis provides values for total factor productivity (TFP). The output based Malmquist index is defines as the product of the technical change or "technology (T)" and the technical efficiency (E). The technology (T) can be understood to be shifts in the efficiency frontier, while the technical efficiency (E) can be understood as the movement or catch up of the DMU towards the efficiency frontier in a particular time period.

$$M = T \times E \quad (1)$$

Or Malmquist Productivity Index = Technology change (T) x Technical efficiency change (E)

More formally,

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

where D^t is a Distance Function and measures the efficiency of the conversion of inputs x^t to outputs y^t during the period t. (Cooper, Seiford and Tone, 2007).

Data Sources

The study had to be restricted to 20 OECD countries, the Russian Federation and China for a total of 22 countries, due to lack of data on all the variables under consideration. Gross domestic expenditure on research and development (GERD) measured in Purchasing Power Parity (PPP) Million \$, and the number of Researchers are taken as R&D inputs. The number of researchers is measured in Full Time Equivalent (FTE) per million population of the country. The data on these inputs are taken from UNESCO Institute for Statistics. The patents granted to residents are taken as an output and an indicator of the R&D capabilities of the country and is collected from the World Intellectual Property Organization, WIPO. The data on scientific publications are taken from the Science Citation Index (SCI) as the academic outputs of the R&D process of the country. This data on the number of scientific publications is taken from the ISI Web of Science Online Database taking articles, letters, notes and reviews as publications. The inputs are lagged by 3 years as compared to the outputs. Thus the data on the inputs are for the years 1999, 2001 and 2003 while the data for the outputs are for 2002, 2004 and 2006 respectively.

Results

Several countries show a marked improvement in their performance based on the MPI scores. These countries are Canada, Iceland and the Republic of Korea. We further compare the scientific publication output of the Republic of Korea, Japan, China and the Russian Federation based on data collected from the ISI Web of Science database. It is evident that there is a rapid increase in number of scientific publications emerging from China. The Republic of Korea has shown a massive increase in the number of patents granted to residents, especially during the period 2004-06, which is the primary reason for achieving the highest score in the MPI for that period among the selected countries.

These results confirm the rapid advancement of China and the Republic of Korea, which is leading to reduced world shares of scientific publication and patents granted to residents of major scientific nations like the USA and the UK. This study contributes to the existing literature by assessing R&D efficiency in a longitudinal perspective by using the Malmquist Productivity Index and by identifying that China's performance on the MPI is mainly due to scientific publication output. The Republic of Korea shows sustained increases in patenting among residents mainly due to the progressive policies followed by the Korean government over several decades.

Bibliography

- Cooper, W. W., L. M. Seiford and K. Tone, *Data Envelopment Analysis – A comprehensive text with models, applications, references and DEA-Solver Software*. NY: Springer, 2007.
- Dosi, G., P. Llerena, and M. S. Labini, "The relationships between science, technologies and their industrial exploitation: an illustration through the myths and realities of the so-called 'European Paradox'," *Res. Policy*, vol. 35, pp. 1450-1464, 2006.
- Glanzel, W., W. Debackere, and M. Meyer, "'Triad' or 'Tetrad'? On global changes in a dynamic world," *Scientometrics*, vol. 74, no. 1, pp. 71-88, 2008.
- Hicks, D. "America's innovative edge at risk?," *Res. Tech. Manage.*, Nov.–Dec., pp. 8-12, 2005.
- Lee, H. Y. and Y. T. Park, "An international comparison of R&D efficiency: DEA Approach," *Asian J. Technology Innovation*, vol. 13, no. 2, pp. 207-222, 2005.
- Leydesdorff, L. and C. Wagner, "Is the United States losing ground in science? A global perspective on the world science system," unpublished, [Online]. Available: http://users.fmg.uva.nl/lleydesdorff/us_science/us_science.pdf
- Leydesdorff, L. and P. Zhou, "Are the contributions of China and Korea upsetting the world system of science?," *Scientometrics*, vol. 63, no. 3, pp. 617-630, 2005.
- NSF, "Asia's Rising Science and Technology Strength: Comparative Indicators for Asia, the European Union, and the United States," National Science Foundation, Division of Science Resources Statistics, Arlington, VA. NSF 07-319. May 2007.
- Tijssen, R. J. W. and E. V. Wijk, "In search of the European Paradox: an international comparison of Europe's scientific performance and knowledge flows in information and communication technologies research," *Res. Policy*, vol. 28, pp. 519-543, 1999.
- Rousseau, S. and R. Rousseau, "Data Envelopment Analysis as a Tool for Constructing Scientometric Indicators," *Scientometrics*, vol. 40, no. 1, pp. 45-56, 1997.
- Rousseau, S. and R. Rousseau, "The Scientific Wealth of European Nations: Taking Effectiveness into Account," *Scientometrics*, vol. 42, no. 1, pp. 75-87, 1998.
- Sharma, S. and V. J. Thomas, "Inter-Country R&D Efficiency Analysis: An Application of Data Envelopment Analysis," *Scientometrics*, vol. 76, no. 3, pp. 483-501, Sept. 2008.
- Wang, E. C. and W. Huang, "Relative efficiency of R&D Activities: A cross-country study accounting for environmental factors in the DEA approach," *Res. Policy*, vol. 36, no. 2, pp. 260-273, 2007.
- WIPO, "World Patent Report – A Statistical Review," WIPO, Switzerland, 2008.