World Patent Information 33 (2011) 4–10

Contents lists available at ScienceDirect

World Patent Information

journal homepage: www.elsevier.com/locate/worpatin

Using patents and publications to assess R&D efficiency in the states of the USA ☆

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ARTICLE INFO

Keywords:
Patents
R&D efficiency
American Paradox
USA
BRICS
American states

ABSTRACT

Even with the USA spending the largest amounts in R&D, its share in total patent grants worldwide has been declining. This decline is also evident in its share of world scientific publications. These developments have been termed by some as the "American Paradox". Extant research on R&D efficiency and technological innovation capability has considered the USA as a homogeneous entity and has not focused at the sub-national level. This paper analyses the R&D efficiency of 50 US states and the District of Columbia. R&D efficiency is calculated as the ratio of patents granted and scientific publications to R&D expenditures. Only 14 states out of the 51 regions are found to exhibit positive changes in R&D efficiency between 2004 and 2008. Comparing this performance with that of the BRICS nations over the same period we find that Brazil, India, China and South Korea show significant improvements in R&D efficiency with India taking the lead. This research identifies the states in the US with the highest R&D efficiency and presents benchmarks which can be followed by policy interventions. The paper highlights the importance of conducting analyses of R&D efficiency using patents and publications at the sub-national level for informed policy making.

1. Introduction

It is widely acknowledged that the growth of knowledge based economies is fuelled by research and development (R&D) and technological innovation. With large sums of money being invested in R&D by developed and developing countries, there is a growing interest in measuring scientific productivity and the efficiency of the R&D process.

Initial comparative studies of scientific productivity of nations have focused mainly on developed countries [1–10]. These studies have led to the identification of various declines and paradoxes. The European Paradox [11,12] highlights the excellence of the European Union in scientific publications which does not get translated to innovations and market success. Recently, attention has been drawn to the American Paradox which describes the falling world shares of scientific publications and patents of the USA despite world leading research investment [13–15]. This is generally attributed to the increasing world shares of various Asian nations like China and South Korea [16–22].

2. Data and methods

Patents have generally been accepted as indicators of the innovation and R&D process in the absence of more robust indicators [23]. The reason for using patents as an indicator has been the widespread availability of patent statistics collected over long periods of time across nations and regions. The USA has been able to provide patent statistics with breakdown for its various states. Even though not all inventions are patented and not all patents are useful, they have become the most common indicator of innovative output. Another, albeit an academic indicator of the R&D process, is the number of scientific publications. While publications are a valuable source of information on R&D output, they may suffer from language bias [24,25]. Publications include articles, letters, notes and reviews [26]. As most publications have multiple authors, sometimes from different countries, it becomes difficult to determine the contribution of different authors. Additionally it is also difficult to divide multiple author papers among various countries. Several methods have been developed to resolve both these issues [26,27]. Publication output is also not the only form of scientific output. Project reports, monographs and other gray literature are equally important. However, as data on such outputs are not available, we use scientific publications as an R&D output. This may favor states with high scientific publications. The data on patents is collected from the US Patent and Trademark Office [28] and the data on publications is compiled from the ISI Web of Knowledge Science Citation Index Expanded (v.4.1).

☆ A preliminary draft version of this paper was accepted for presentation at the Eighth Global Conference on Flexible Systems Management, Stevens Institute of Technology, New Jersey, USA (June 14–16, 2008). Although it was eventually not presented, it has been included in the CD of the conference proceedings.

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0172-2190/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.wpi.2010.01.005

Most nations collect data on R&D expenditure. Following convention, nations attempt to provide details of expenditure on basic, applied and developmental research. In large countries like USA which have adopted a federal system of governance, the situation gets further complicated by federal funding of research in academic institutions, in business entities and non-profit organizations. Instead of concentrating on identifying the impact of public R&D on private R&D as has generally been the case, this paper attempts to look at the overall picture of R&D expenditure across the states of USA. The data on US R&D expenditure is collected from the National Science Foundation, Division of Science Resources Statistics.

An issue in the assessment of R&D efficiency is the presence of a time lag between the provision of inputs and the expectation of outputs. Following Goto & Suzuki [29], we take a three year time lag between the input and the output data. The data on patents and publications are taken for the years 2004 and 2008, while the data on total R&D expenditure is taken for the years 2001 and 2005. Data is available for the District of Columbia for all the inputs and outputs, and we observe that it has outputs comparable and exceeding most states. Hence the District of Columbia is also included in our analysis along with the 50 states in the USA taking the total number of geographic entities to 51.

There are some comparative studies of R&D efficiency at the national level [24,30–37] but few studies have looked at the R&D efficiency of regions within a particular country with recent exceptions being Altvater-Mackensen et al. for Germany [38] and Chen et al. for China [39]. Some studies focus on subject areas, institutions, firms, or policy programs [40–46]. One of the earlier works on R&D potential within a country is Muller and Nejedly [47] which studies the regional structure of R&D in erstwhile Czechoslovakia. Their statistical analysis indicates that R&D potential is concentrated in a few localities which are usually centers of state administration, education and cultural life. While cross country studies have their relevance, there is a need to examine R&D efficiency within a nation to identify whether R&D efficiency is homogeneous across the regions of the country under study, or is it concentrated in a few regions. This analysis can help in the identification of the exceptional performers and laggards, and help focus research to understand the reasons for the same. Thus, we would be able to develop policies which can replicate the success of a particular region in other parts of the country as well.

There is no known study on the regional analysis of R&D efficiency in the USA to the best of our knowledge. The United States of America is one of the most prolific nations as far as patents and scientific publications are concerned. In addition, the government in the USA has been proactive in promoting R&D in government as well as private institutions. The recent decline in the performance of the USA following a period of sustained world leadership in patents and scientific publications, the geographic structure of USA with a large number of states and the availability of data on R&D outputs and inputs for these regions has motivated us to study R&D efficiency in the states of USA and provides us with an opportunity to investigate the American Paradox.

3. R&D outputs and inputs in the states of USA

3.1. Patents granted

Patents granted are widely recognized as indicators of R&D performance. Data on patents granted are available from the USPTO by various categories. We take the data for the year 2008 which is the most recent available. As the number of geographical regions for this study is 51, we sort the data and divide it into four groups or quartiles based on their performance. This technique has the advantage of identification of peers as well as the possibility of depicting the variation in values without missing any region. Table 1 shows the quartiles, with the number of patents granted to each state/region in front of their names for easy comparison.

As is evident, the state of California with 22,202 patents granted for the year 2008 leads the rest of the states by a huge margin. The next state is Texas which has one third of the patents granted to California. However, as our initial discussion had envisaged, we are interested not only in the current best performers, but also their performance over time. In order to know whether their performance is improving or diminishing, we take patents granted data for the year 2004 to compare it with the data for 2008 and calculate the percentage growth. The results are presented in the form of quartiles for quick reference in Table 2.

We can see from Table 2 that only 12 of 51 regions of the USA exhibit a positive growth rate in patents granted for the five year period 2004–2008. This indicates a gradual reduction in the actual numbers of patents granted in these states. Even for the 12 states which have a positive growth rate during this period, 5 states which include Virginia, Kansas, Kentucky, California and North Carolina exhibit modest growth below 5%. The states Georgia, North Dakota, Arizona, Oregon, Hawaii and Vermont show a higher growth rate between 6% and 21%. Some of these states such as North Dakota and Hawaii have achieved these growth rates because of low performance in 2004. The case of the state of Washington which exhibits a growth rate of over 70% during this period will be investigated further after looking at the performance of these states in terms of scientific publications.

3.2. Scientific publications

Scientific publications are an indicator of academic productivity and excellence. Data on scientific publications have been compiled from the ISI Web of Science for the states and are presented in Table 3. We can see that the performance of the states with regard to scientific publication output is more homogenous as compared to the patents granted. California still leads the rest of the states but New York and Massachusetts have a chance of reaching California's output at some time in the future.

We further explore the percentage growth rate in scientific publications over 2004–2008 in Table 4. It is to be noted that except for New Mexico, all other states show a positive change in scientific output. The growth for the states is also stable without major variations, but as in the case of patents granted, states like South Dakota, North Dakota and Alaska show higher growth rates because of modest performance in 2004.

3.3. R&D expenditure

R&D expenditure is a major input to the R&D process. We take the data on R&D expenditure for the years 2001 and 2005 to keep a three year time lag between the inputs and outputs. The data on R&D expenditure is for the total R&D performance of the states (in Million $). As data for the year 2001 was not available it was computed as the average of the total R&D performance for the years 2000 and 2002. The results are presented in Table 5. We can see that except for Idaho, all other states have modest to robust increases in R&D expenditure.

4. Analyzing changes in R&D efficiency over time

R&D efficiency has been conceptualized as the ratio of R&D outputs to R&D inputs. The outputs taken are patents granted and scientific publications, while the input taken is R&D expenditure. We add the data on patents and publications for the year 2008 and di-