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Factors Affecting the Efficiency of the BRICSs' National Innovation Systems: A Comparative Study based on DEA and Panel Data Analysis

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Abstract Efficiency scores for the national innovation systems (NISs) in 22 countries including the BRICS and the G7 are calculated using data envelopment analysis (DEA). Factors that may affect the efficiency of the NIS are summarized based on the NIS approach and the new growth theory. Empirical evidence is provided using panel data analysis and principal component analysis. The results of the efficiency calculations and the empirical tests show the following. (1) The BRICS differ greatly in the efficiency of their NISs, with China, India, and Russia ranking fairly high, and Brazil and South Africa ranking low. (2) In accordance with the NIS approach and the new growth theory, there are many factors that affect the NISs including ICT infrastructure, enterprise R&D, market environment, governance, education systems, economic scale, natural endowments, and external dependence. (3) Enterprise innovation is of particular importance for the NISs. To improve the efficiency of innovation systems, efforts should be made to improve the market conditions, governance, and financial structures, and create a sound environment for R&D. (4) ICT infrastructure, economic scale, and openness affect the diffusion of knowledge and technology, and in turn affect NIS efficiency. (5) The BRICS have low governance levels and a high dependency on natural resources, both of which are determined by their stage of development and extensive growth patterns. To avoid the so-called middle-income trap, the BRICS should transform their factor-driven growth patterns into innovation-driven growth patterns. China still needs to improve its ICT infrastructure, its governance systems, and its education system. During its 12th five-year plan, more effort should be devoted to these fields and to improving external conditions for R&D.

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Keywords The BRICS; National Innovation System (NIS); NIS efficiency; Data Envelopment Analysis (DEA); Panel Data Analysis (PDA)

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Introduction

As the representatives of emerging economies, during 2000-2009, Brazil, India, Russia, China and South Africa (BRICS) have gained an average annual growth of 3%, 5.4%, 7.2%, 10.3% and 3.6% respectively, much higher than the OECD average of 1.6% and the World average of 2.6%. However, rapid growth does not enhance the competitiveness of the BRICS correspondingly. According to the ranking of Global Competitiveness Report provided by the World Economic Forum, the competitiveness of Brazil, Russia, India, China, and South Africa rank 31, 52, 37, 44, and 25 in the year 2000. By 2009, their ranking changed to be 58, 63, 49, 29, and 45. All but China get a decrease in competitiveness ranking to certain extent. Even for China, the competitiveness ranking of about 30 does not match with its world highest growth rate and second largest economic size.

The paradox of high growth and low competitiveness for the BRICS can be attributed to their extensive growth patterns. In recent years, the high growth of China and India is largely dependent on their advantages in demographic structure and cheap labor force, while Russia, Brazil and South Africa depend more on the export of mineral resources. As we know, it is a very common chooses for economies in the take-off stage to choose an extensive growth pattern characterized with high-input, high-accumulation and high-output. However, most of the BRICS have stepped over the stage and entered a transition from middle-income to high-income. The growth of these countries will inevitably encounter constraints such as natural resources supply, environmental degradation, etc. To maintain a rapid growth and surpass "Middle-income Trap", it is very urgent for the BRICS to improve the efficiency of National Innovation System (NIS) and enhance their innovation capability. Therefore, efficiency of NIS and the influencing factors behind should be calculated and analyzed before a series of policies and measures were adopted.

As a matter of fact, the NIS of the BRICS has increasingly been studied while their economies are uprising in recent 10 years. Liu and White (2001)[14]put forward an analytical framework for Innovation System including R&D, implementation, end-use, education, and their linkages, being applied to make a comparative study on China's NIS in different periods and development stages. Viotti (2002)[19] proposed a new conceptual and theoretical framework of "National Learning System (NLS)", for developing economies based on the NIS Approach. Viotti (2002) further chose Brazil and South Korea as typical cases, and characterized their NLS as Passive and Active one correspondingly. Feinson (2003)[6] also chose the two as typical cases but proposed that R&D policies, intellectual property, human capital, FDI are all among the elements affecting the NIS besides NLS. The joint research project co-directed by Cassiolato and Lundvall (2010) [2]makes overall comparison for the NIS of BRICS in production, education, finance, politics, regulation, etc.

Tomas et al (2011)[18] analyze R&D efficiency of 51 regions in the United States from 2004 to 2008 with the ratio of patents granted and scientific publications to R&D expenditures, and compared the performance of United States with that of the BRICS.

Most of the existing literatures on NIS of the BRICS are mainly cases study or qualitative description of the innovation patterns, while the quantitative analysis on innovation capability and efficiency of innovation is very limited. To reduce the subjective factors as far as possible and get a more objective and reliable judgment on the NIS of the countries, the Data Envelopment Analysis (DEA) and econometric analysis are adopted in this paper. Here, the NIS is treated as a special production sector in the economy with certain inputs, including human and financial resources to produce some particular outputs such as patents, scientific publications. The NIS of the BRICS as well as other 17 nations including the G7 and some other OECD members are chosen as the Decision Making Units (DMUs). Relative efficiency scores of each DMUs are calculated with DEA method.

Factors influencing NIS efficiency are summarized according to the National Innovation System Approach (NIS Approach) and New Growth Theory. And empirical test is carried out using cross country panel data with the efficiency scores as the explained variable. The NIS efficiency as well as the influencing factors of China and other four countries will be further analyzed based on the previous DEA efficiency scores and the panel data analysis. Section 1 is a brief review on quantitative methods for analysis of NIS. Section 2 is the relative efficiency calculation of NIS for 22 countries including the BRICS. Section 3 will analyzes the factors affecting the NIS efficiency. And in the end some concluding remarks and policy implications are explored in section 4.

1 Quantitative methods for analysis of NIS

When Christopher Freeman, Bengt-Ake Lundvall, Richard Nelson and other innovation economists gave the concept of National Innovation System (NIS) and the NIS Approach in the late 1980s and early 1990s, the research methods in this field are mainly qualitative analysis such as evolutionary analysis and case study. In the mid of 1990s, many innovation economists proposed to adopt more quantitative methods in the study. Patel and Pavitt (1994)[17] might first appeal for quantitative analysis on the input and output characters of NIS [1].With the execution of Community Innovation Survey (CIS) throughout the European Union and its implementation in the annual European Innovation Scoreboard

[1] The quantitative analysis in the field of innovation can be further track to 1950s and 160s, when the Linear Model of Innovation was prevailing.

(EIS)[2],quantitative analysis has been widely used in studying national innovation capacity and innovation system. These quantitative methods can be categorized into 3 approaches: Composite (Innovation) Indicators, DEA Efficiency Calculation, and Modeling/Econometric Approach.

Composite Indicators Approach has been adopted by many institutions in evaluating innovation capacity in national level. The famous EIS/IUS, Competitiveness Ranking of the World Economic Forum, and many other ranking works are all implementation of the Approach. To get a sound and comparable evaluation results under this approach, an inclusive indicator system covering various aspects of NIS is to be established. Normally, the indicator system would include indicators: input, output, procedure of innovation; as well as organization pattern of innovation activities, institutional arrangements, etc. However, here efficiency of innovation system is ignored since the input and output indicators are treated in the same way. As a result, economies with "high innovation inputs and low innovation outputs" may get a score equal to or even higher than those with "low innovation inputs and high innovation outputs".

In contrast to the composite Indicator approach, the DEA Approach focused exactly on input-output efficiency of innovation systems. In this approach, innovation system is treated as a special sector of the economy, and each (country or region) economy is regarded as an independent DMU (Decision Making Unit). After choosing proper innovation input and output indicators, the relative efficiency of each DMU can be calculated. Nasierowski and Arcelus (2003) [15] has applied the DEA to calculate efficiency of innovation system for over 40 countries and regions. Guan Jiancheng et al (2006) [10] also have done a lot of innovation efficiency calculation with DEA in both country and regional levels. An obvious advantage of DEA Approach is the simplification of indicator system since only indicators of innovation inputs and outputs are required. At the same time, the efficiency score calculated from these input/output indicators is a reflection of the capability of transferring innovation inputs into outputs, and can be regarded as a composite capability of the Innovation System as well. Nevertheless, what the efficiency score reflects is only the general capability of the Innovation System, while the information of what influence this capability are not given by the scores.

The Modeling/Econometric Approach is mainly used to analyze the factors influencing the national innovation capacity. The procedure of this approach includes theoretical analysis, mathematical modeling, and econometric test, which is conformed to the research paradigm of mainstream economics. Furman et al (2002, 2004)[9] [8], Hu and Mathews (2005, 2008) [12] [13]also explored the approach. Factors analysis in this approach is supported by both economic theory

[2] In October, 2010, the former EIS was reconstructed and renamed as Innovation Union Scoreboard (IUS).

and the empirical data, with more reliable results. However, in econometric test, one single indicator is chosen as the explained variable, for example, "International Patent Granted" is usually selected as the proxy of innovation capacity. As we know, innovation capacity is far from the patents granted. And such treatment would inevitably lead to a bias.

Obviously, the advantages of above two approaches, are complementary, and can be combined into a deep and overall analysis on efficiency of NIS. Actually, the combination has been applied in the empirical study of other fields. For example, Casu and Molyneux (2003) [3]calculated the relative efficiency scores for 530 European Banks. Taking the efficiency scores as the explained variable, they then analyze the factors affecting the efficiency, with Tobit model. Hoff (2007)[11] named the DEA-based econometric analysis as "Second stage DEA" and compares the estimation results between OLS and Tobit. It is shown that OLS may actually in many cases replace Tobit as a sufficient second stage DEA model.

In the empirical studies of NIS efficiency, few have combined the DEA with econometric analysis. This paper will fill the gap to make such a combination for analyzing NIS efficiency of the BRICS.

2 Measuring the relative efficiency of NIS with DEA

2.1 Optimization model for the efficiency measurement

The DEA method has been used in measuring the relative efficiency for DMUs widely, since it was first proposed by Charnes et al (1978)[4] over 30 years ago. According to Farrell (1957)[5], the measurement of production efficiency can be divided into two categories: Input-Oriented and Output-Oriented. The former fixes outputs to compare the inputs to measure relative efficiency, while the later fixes inputs to compare the outputs. Output-Oriented model is chose in this paper. Besides, efficiency measuring models can be divided into Constant Return to Scale (CRS) and Variable Return to Scale (VRS). More DMUs would be in the production frontier using VRS model compared with using CRS model, which means more DMUs would get an efficiency score of 1. Such a measuring result may lead to a bias in the efficiency scores and in turn affect a succeeding econometric analysis. So, the CRS model is used in the final measurement to reduce the above bias. And the algebraic expression for the chosen Output-Oriented CRS model is as follow.

$$(D_o^t)\begin{cases} [D_o^t(\overrightarrow{x_0}^t, \overrightarrow{y_0}^t)]^{-1} = Max_{\phi,\lambda}\ \phi \\ s.t. \quad -X^t_{m\times n}\overrightarrow{\lambda}_{n\times 1} + \overrightarrow{x_0}^t \geq 0_{m\times 1} \\ \qquad Y^t_{s\times n}\overrightarrow{\lambda}_{n\times 1} + 0_{s\times 1}\phi \geq \phi\overrightarrow{y_0}^t \\ \qquad \phi > 0,\ \lambda_j \geq 0,\ j = 1, 2, \cdots, n \end{cases} \tag{1}$$

In the above equation (1), X, Y are the inputs and outputs matrixes formed by of all DMUs; n, m and s refer to the number of DMU, input indicators and output indicators respectively;While t and ϕ refer to time period and relative efficiency score. What can be calculated from equation (1) is the relative efficiency score of DMU0 in the period of t . And the relative efficiency score ϕ is also the value of distance function to the Frontier for the DMU being measured, which can be expressed as $[D_o^t(\overrightarrow{x_0}^t, \overrightarrow{y_0}^t)]^{-1}$.[3]

2.2 Selection of DMUs and input/output indicators

The efficiency score is highly relevant to the input/output indicators as well as the number of DMUs. If the number of DMUs to be measured is very limited, most DMUs may be in the production frontier constructed by themselves with the corresponding relative efficiency score to be 1. And the ranking based on these efficiency score may become meaningless. To avoid such circumstance, the G7 countries (United States, Japan, Germany, Canada, United Kingdom, France, Italy), 8 European countries (Finland, Sweden, Denmark, Swiss, Netherland, Austria, Belgium), and two OECD countries in the Asia Pacific Region, (South Korea and Australia) are selected as the DMUs, together with the five BRICS countries. The 17 countries are all OECD members, including the world largest developed economies, small European economies famous for their innovation capacity and competitiveness, and South Korea, the typical successful case of catching up with and surpassing. Taking the NIS as a special production sector, the production frontier constructed by the above countries (DMUs) would definitely be a good approximation of the real one.

As a special production sector, the inputs of NIS are mainly the human resources and financial resources allocated in innovation activities, while the outputs are mainly patents granted, scientific publications, and output of high-tech industries. Relevant input-output indicators from 2000 to 2008 are collected from different sources including the World Bank's Open Database (DataBank), the database of UNESCO Institute for Statistics, and the data released in the website of World Intellectual Property Organization (WIPO). Finally, "General Expenditures on R&D (GERD)" and "Total R&D personnel" are chosen as the input indicators, while the output indicators include "WIPO patents granted", "Scientific and technical journal articles", and "High-technology and ICT services exports". Although there is no dimensional limit using DEA for efficiency measurement, the indicators of GERD and "High-technology and ICT exports" are still converted into constant price

[3] The index of technological change for the DMU, that is the Malmquist Index, can be further calculated based on equation (1) via geometric average.

of 2000 U.S. dollar,[4] and the "Total R&D personnel" is converted into full-time equivalent (FTE).

2.3 Measurement results of the NIS efficiency score

Based on the previous measuring model and the data collected, the relative efficiency scores for the NIS of the 22 countries from 2000 to 2008 are calculated with Win4DEAP. See Table 1 and Table 2.

Table 1: Relative efficiency scores for NIS of 22 countries including BRICS

	2000	2001	2002	2003	2004	2005	2006	2007	2008
BR	0.184	0.223	0.233	0.198	0.214	0.219	0.223	0.198	0.213
RU	0.756	0.680	0.773	0.676	0.628	0.756	0.727	0.601	0.748
IN	0.415	0.588	0.680	0.642	0.661	0.675	0.735	0.756	0.913
CN	0.631	0.731	0.849	0.870	0.920	0.926	0.956	0.944	0.999
ZA	0.314	0.343	0.311	0.274	0.264	0.265	0.266	0.250	0.261
US	0.340	0.353	0.352	0.251	0.250	0.254	0.274	0.249	0.264
JP	0.358	0.357	0.385	0.308	0.308	0.320	0.336	0.300	0.310
DE	0.368	0.460	0.523	0.429	0.474	0.467	0.499	0.415	0.448
UK	0.818	0.608	0.748	0.595	0.661	0.688	0.773	0.676	0.593
FR	0.362	0.395	0.414	0.323	0.311	0.316	0.347	0.312	0.357
CA	0.455	0.412	0.390	0.332	0.279	0.294	0.318	0.315	0.344
IT	0.367	0.419	0.417	0.376	0.369	0.362	0.364	0.338	0.357
FI	0.436	0.442	0.487	0.403	0.353	0.423	0.386	0.378	0.546
SE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
DK	0.353	0.395	0.473	0.369	0.361	0.385	0.351	0.296	0.281
CH	0.554	0.697	0.859	0.725	0.738	0.692	0.725	0.686	0.842
NL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
NO	0.235	0.296	0.333	0.230	0.220	0.242	0.279	0.254	0.335
AT	0.446	0.517	0.658	0.526	0.558	0.430	0.454	0.390	0.404
BE	0.511	0.620	0.829	0.680	0.681	0.678	0.639	0.621	0.732
AU	0.226	0.244	0.243	0.214	0.192	0.244	0.178	0.159	0.162
KR	0.832	0.682	0.849	0.702	0.704	0.682	0.989	0.890	0.737
Means	0.498	0.521	0.582	0.506	0.507	0.521	0.537	0.501	0.538

Notes: each country is abbreviated as follow, Brazil- BR, Russia Federation- RU, India- IN, China- CN, South Africa- ZA, United States- US, Japan- JP Germany- DE, United Kingdom- UK, France- FR, Canada- CA, Italy- IT, Finland- FI, Sweden- SE, Denmark- DK, Switzerland- CH, Netherlands- NL, Norway- NO, Austria- AT, Belgium- BE, Australia- AU, Korea- KR.

[4] Converting into constant price of 2000 U.S. dollar is convenient for further calculation of Malmquist Index in this period.

Table 2: Efficiency ranking for NIS of 22 countries including BRICS

	2000	2001	2002	2003	2004	2005	2006	2007	2008
BR	22	22	22	22	21	21	21	21	21
RU	5	6	7	7	9	5	7	9	6
IN	12	9	9	8	7	9	6	5	4
CN	6	3	4	3	3	3	4	3	3
ZA	19	19	20	18	18	18	20	19	20
US	18	18	18	19	19	19	19	20	19
JP	16	17	17	17	16	15	16	16	17
DE	13	11	11	11	11	10	10	10	11
UK	4	8	8	9	8	7	5	7	9
FR	15	15	15	16	15	16	15	15	13
CA	9	14	16	15	17	17	17	14	15
IT	14	13	14	13	12	14	13	13	14
FI	11	12	12	12	14	12	12	12	10
SE	1	1	1	1	1	1	1	1	1
DK	17	16	13	14	13	13	14	17	18
CH	7	4	3	4	4	6	8	6	5
NL	1	1	1	1	1	1	1	1	1
NO	20	20	19	20	20	20	18	18	16
AT	10	10	10	10	10	11	11	11	12
BE	8	7	6	6	6	8	9	8	8
AU	21	21	21	21	22	22	22	22	22
KR	3	5	5	5	5	4	3	4	7
Means	8-9	9-10	10-11	10-11	10-11	9-10	9-10	9-10	10-11

The above measurement results show that the relative efficiency of the NIS of the BRICS during 2000-2008 differs a lot from each other. In general, Russia, India, and China get pretty good scores and rankings with China ranking 3-4 in most of the period. At the same time, the scores and rankings of Brazil and South Africa are far from satisfactory, almost always ranking at the bottom.

The efficiency score and ranking of NIS for G7 countries are not as striking as anticipated, comparing with their leading status in the world economy. Only the United Kingdom gets an efficiency score above mean level for the 9 years. Following the United Kingdom, the efficiency score of Germany is a little bit lower than the mean level for most of the period. In contrast, more small developed European economies get a good efficiency score. Among them, the NIS of Sweden and Netherland are always in the production Frontier with an efficiency score of 1. Swiss, Belgium, and Austria get fairy good scores and high rankings as well. Nevertheless, the efficiency scores of the NIS for the remaining three small economies, Norway, Denmark, and Finland are below the mean level in most of the period. As for two Asia-Pacific OECD countries, always Korea ranks on the top, while Australia at the bottom.

Considering the economic scale, endowments, developing stage and other characters of the 22 selected countries, there seem to be some potential rules behind the NIS efficiency scores and rankings. Firstly, endowments of natural resources seem to have negative impacts on the efficiency of NIS considering the bad rankings of the two countries most influenced by natural resources, Brazil and Australia. Secondly, high score countries such as Netherland, Sweden, South Korea, Belgium, Switzerland, and China, have a good openness with high dependency ratio on foreign trade.[5] Thirdly, GDP per capita may be negatively related to the efficiency of NIS. On one hand, China and India have the lowest GDP per capita among the 22 countries, but their NIS efficiency scores rank fairly high; The GDP per capita of United States and Norway are among the highest in the world, while their NIS efficiency ranks fell behind on the other.[6]

It should be aware that the above are merely intuitive judgments based on ranking results and other rough information. To make further analyses on the root reason influencing the efficiency of NIS, an overall review should be made under the theoretical framework of NIS Approach, and corresponding empirical test should be made as well with econometric analysis.

3 Econometric analyses on factors influencing NIS efficiency

3.1 Potential factors influencing NIS efficiency

In the view of innovation economics and NIS Approach, implementing innovation activities is a systematic engineering involving different entities and various factors including government agencies, enterprises, universities and research institutions; while a NIS is composed of different sub-systems such as economic regime, educational system, financial structure, infrastructure, cultural traditions, and so on. Economic development is regarded as a co-evolutionary process of various sub-systems (Freeman, 2002; Nelson, 2008).[7] [16] The mainstream new growth theory also stressed that innovation is a social process. And "¡the intensity and direction of people's innovative activities are conditioned by the laws, institutions, customs, and regulations that affect their incentive and their ability to appropriate

[5] In the year 2008, the ratio of dependency on foreign trade for Netherland, Sweden, South Korea, Belgium, and Switzerland are 145.04%, 99.66%, 107.2%, 170.53%, and 101.61% respectively. While the ratio for China, United States, and Japan are 62.24%, 30.6%, and 34.89%.

[6] According to the World Bank, the GDP per capita in 2008 for United States, Norway, Netherland, South Korea, China, and India are 71500, 69700, 45200, 42200, 9400, and 4600 in constant price of 2000 USD.

rents from newly created knowledge, to learn from each other's experience, to organize and finance R&D¡"(Aghion and Howitt, 1998, p.1).[1]

It can be inferred from the NIS Approach and New Growth Theory that efficiency of NIS would be affected by factors such as governance, market circumstance, enterprise R&D activities, education system, financial structure, informational infrastructure. Moreover, factors like incentives for innovation, diffusion of knowledge, advantages of late-comer, economic scale, would influence efficiency of NIS.

Besides, incentives for innovation are highly related to endowment of resources, since economy with fluent natural resources may rely on its natural resources and have little motivation for innovation. Diffusion of knowledge in a country is relevant to its degree of openness. Economic scale would affect NIS efficiency through economies of scale. Hence, natural endowments, ratio of dependency on foreign trade, GDP per capita, and economic scale which have been mentioned in the previous section 3 may be important factors affecting NIS efficiency.

3.2 Selection of proxy variables and the unit root tests

To test how the factors mentioned above affect NIS efficiency, corresponding proxy variable should be selected for each factor in advance. Considering availability of cross-country data, proxy variables are chosen from the indicators in the Databank of World Bank and the database of UNESCO Institute for Statistics. Choose "Internet users (per 100 people)", "Mobile cellular subscriptions (per 100 people)", and "Telephone lines (per 100 people)" as the proxy variable for ICT infrastructure, and abbreviate them as ITNET, MOBL, and TEL.

Choose "Domestic credit provided by banking sector (% of GDP)", "Domestic credit to private sector (% of GDP)", and "Market capitalization of listed companies (% of GDP)" as the proxy variables of financial structure, and abbreviate them as CDBBAN, CDTPRV, and CAPLST.

Choose "Researchers (FTE) - Business enterprise %", "GERD - performed by Business enterprise %", and "GERD - financed by Business enterprise %" as the proxy variable of enterprise R&D activities, and abbreviate them as ENTRRE, ENTRPGERD, and ENTRFGERD.

Choose "School enrollment, tertiary (% gross)" and "School enrollment, secondary (% gross)" as the proxy variable of education system, and abbreviate these two indicators as TEENRL and SEENRL.

Choose "Cost of business start-up procedures (% of GNI per capita)", "Total tax rate (% of commercial profits)", "Cost to register property (% of property value)", "Strength of legal rights index (0=weak to 10=strong)", and "Strength of investor protection index (0 to 10)" as the proxy variable of market circumstance for innovation activities, and abbreviated them as BSCOST, TAXRATE, PRCOST, LGRIGHT, and INVPORT respectively.

Choose "Control of Corruption", "Government Effectiveness", "Political Stability and Absence of Violence/Terrorism", "Regulatory Quality", "Rule of Law", and "Voice and Accountability" as the proxy variable of governance, and abbreviated them as CORRUP, GOVEFF, POLSTAB, REGULA, LAW, and VOACCT respectively.

Represent the factors of "Endowments of natural resources", "Dependence on foreign trade', "Relative income level", and "Economic scale" with indicators of "Total natural resources rents (% of GDP)", "Trade (% of GDP)", "GDP per capita to the world average", and "Proportion of GDP in the World total output (%)" respectively, and abbreviate these indicators as NRTGDP, TRTGDP, RGDPPC, and PORGDP.

Besides, the indicator of "Population ages 65 and above (% of total)" is also selected as a potential explanatory variable since the demographic structure, particularly the aging of population is thought to have negative impact on innovation activities. As for the explained variable, the relative efficiency scores calculated in the previous section 3 is chosen as the proxy, and shorted as CRS.

Yearly data from 2000 to 2008 for the above indicators are collected from the above databases. With a series process of pretreatments, a completed data set is generated, which can be used in the following econometric analysis with Balanced Panel Model. To avoid the spurious regression, unit root test is made in advance.[7] And the results of unit root tests for all the potential explanatory variables and explained variable are listed in Table 3.

Table 3: Unit Root Tests for Panel Data

Variables	Model	Prob.1	Prob.2	Prob.3	Variables	Model	Prob.1	Prob.2	Prob.3
CRS	(0, C)	0.000	0.000	0.000	AGE	(0, C)	0.002	0.000	0.000
ITNET	(0, C)	0.000	0.000	0.000	MOBL	(0, T)	0.000	0.009	0.001
TEL	(0, N)	0.000	0.000	0.000	CDBBAN	(0, T)	0.000	0.069	0.008
CDTPRV	(0, T)	0.000	0.942	0.000	CAPLST	(0, N)	0.000	0.016	0.051
ENTRRE	(0, C)	0.000	0.018	0.000	ENTRPGERD	(0, T)	0.000	0.002	0.002
ENTRFGERD	(0, C)	0.000	0.002	0.449	TEENRL	(0, C)	0.000	0.001	0.000
SEENRL	(0, C)	0.000	0.007	0.900	BSCOST	(0, N)	0.000	0.000	0.000
TAXRATE	(0, N)	0.067	0.123	0.021	PRCOST	(0, T)	0.001	0.000	0.000
CORRUP	(0, C)	0.000	0.015	0.303	GOVEFF	(0, T)	0.000	0.009	0.000
POLSTAB	(0, C)	0.000	0.060	0.091	REGULA	(0, T)	0.000	0.002	0.002
LAW	(0, T)	0.000	0.028	0.000	VOACCT	(0, C)	0.000	0.023	0.121
RGDPPC	(0, T)	0.000	0.120	0.005	PORGDP	(0, N)	0.000	0.000	0.000
TRTGDP	(0, T)	0.000	0.001	0.000	NRTGDP	(0, T)	0.000	0.005	0.000

Notes: (1) in the column of "Model", the number in the parentheses refers to the order of integration, and T, C, N corresponding to "intercept and trend", "intercept only", and "no intercept or trend"

[7] The data used in this paper cover only a short period of 9 years. In general, the data would be stable with little fluctuation in such a short time. However, to be more prudent, the relevant tests are still made according to the standard procedure in this paper.

respectively. (2) Prob.1, prob.2, and prob.3 are corresponding to the Statistics value of "Levin-Lin-Chu test", "ADF-Fisher test", and "PP-Fisher test". (3) The null hypotheses of all the three tests are "have unit root", and the prob. is the probability of a TYPE I error (rejecting a true null hypothesis). (4) A variable is regarded as stable here in this paper if more than two tests for this variable show a character of stability.

From the results, we conclude that all the explanatory variables and explained variable are stable. Thus a simple OLS econometric regression can be made directly.

3.3 Panel data analysis with original indicators as the explanatory variables

Based on Hendry's general-to-specific modeling rule, all the proxy variables above are treated as explanatory variables at the first round of regression with the relative efficiency score CRS as the explained variable. To examine the robustness of the regression results, the weighted cross section fixed effects, cross section fixed effects, period and cross section fixed effects, and non fixed effects are all tested. And the testing results are listed in Table 4.

Table 4: Panel regression results including all the proxy variables

Explanatory Variables	weighted cross section fixed effects	Cross section fixed effect	Period and Cross section fixed effect	Non-fixed effects
C	-0.115(0.650)	-0.071(0.871)	0.374(0.411)	–
AGE?	-0.001(0.901)	-0.007(0.682)	-0.012(0.427)	-0.007(0.373)
ITNET?	0.001(0.185)	0.001(0.471)	-0.002(0.018)	0.005(0.000)
MOBL?	0.000(0.783)	0.001(0.244)	-0.001(0.242)	0.000(0.960)
TEL?	0.004(0.000)	0.004(0.032)	0.005(0.006)	0.010(0.000)
CDBBAN?	0.000(0.687)	0.000(0.938)	-0.001(0.208)	-0.003(0.000)
CDTPRV?	-0.001(0.231)	-0.001(0.406)	0.000(0.766)	0.004(0.001)
CAPLST?	-0.001(0.000)	-0.001(0.000)	-0.001(0.006)	0.000(0.031)
ENTRRE?	0.000(0.690)	0.000(0.807)	0.000(0.893)	-0.007(0.000)
ENTRPGERD?	-0.001(0.490)	-0.001(0.805)	-0.001(0.663)	0.012(0.001)
ENTRFGERD?	0.002(0.116)	0.003(0.290)	0.001(0.559)	-0.002(0.395)
TEENRL?	0.001(0.171)	0.001(0.765)	0.000(0.951)	-0.003(0.011)
SEENRL?	0.000(0.874)	0.000(0.934)	-0.001(0.652)	0.010(0.000)
BSCOST?	0.002(0.369)	0.004(0.111)	0.002(0.399)	0.020(0.000)
TAXRATE?	0.005(0.070)	0.003(0.515)	0.002(0.684)	-0.008(0.000)
PRCOST?	0.002(0.688)	0.001(0.894)	0.018(0.068)	0.024(0.001)
LGRIGHT?	0.002(0.777)	0.010(0.482)	0.012(0.434)	-0.099(0.000)
INVPORT?	0.003(0.771)	0.008(0.808)	-0.017(0.596)	0.015(0.199)
CORRUP?	-0.019(0.416)	0.004(0.924)	0.003(0.944)	0.273(0.000)
GOVEFF?	0.048(0.155)	0.107(0.056)	0.114(0.030)	0.053(0.506)
POLSTAB?	-0.097(0.000)	-0.123(0.019)	-0.095(0.052)	-0.077(0.311)
REGULA?	0.046(0.002)	0.031(0.267)	0.029(0.289)	0.024(0.632)
LAW?	0.050(0.203)	0.005(0.952)	0.034(0.640)	0.017(0.829)
VOACCT?	-0.083(0.004)	-0.066(0.233)	-0.014(0.818)	-0.267(0.000)
RGDPPC?	-0.056(0.142)	-0.045(0.439)	0.004(0.939)	-0.137(0.000)
PORGDP?	0.054(0.000)	0.057(0.024)	0.040(0.084)	0.018(0.000)
TRTGDP?	0.003(0.000)	0.003(0.012)	0.002(0.105)	0.001(0.059)
NRTGDP?	-0.001(0.718)	0.002(0.529)	0.005(0.110)	0.003(0.262)
R-Sq	0.994	0.961	0.971	0.811
Adjusted R-Sq	0.992	0.949	0.959	0.782
D.W.	1.673	1.683	1.605	0.789
Cross section F	79.063(0.000)	26.255(0.000)	29.619(0.000)	–
Cross section Chi-Sq.	–	306.435(0.000)	334.323(0.000)	–
Period F	–	–	5.613(0.000)	–
Period Chi-Sq.	–	–	54.742(0.000)	–

Notes: (1) all the models are balanced panel regression. (2) the value outside the parentheses are the coefficients of for the explanatory variables, while the value inside the parentheses are their corresponding probabilities. (3) The coefficients of the fixed effects are not listed in this table.

The regression results in this table show that most of the variables exhibit good robustness in the circumstances of "Weighted cross-section fixed effects", "Cross-section fixed effects", and "non fixed effects". However, coefficients of 9 variables change the direction when the period fixed effects were taken into accounts. Therefore, abandoning the period fixed effects would get a more reliable regression results.[8] To improve the significance and robustness of the regression model, the insignificant variables would be eliminated gradually based on the weighted cross-section fixed effect model in Table 4, in accordance to the general-to-specific rule. And the robustness of the regression results would be analyzed as well by comparing the coefficients in different models. Some regression results are revealed in Table 5.

Table 5: Weighted cross-section fixed effect models from general to specific

Explanatory	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
C	-0.131(0.552)	-0.141(0.482)	-0.113(0.568)	-0.061(0.758)	-0.073(0.676)	-0.044(0.794)
AGE?	–	–	–	–	–	–
ITNET?	0.001(0.210)	0.001(0.160)	0.001(0.153)	0.001(0.056)	0.001(0.009)	0.001(0.004)
MOBL?	0.000(0.797)	–	–	–	–	–
TEL?	0.004(0.000)	0.005(0.000)	0.005(0.000)	0.005(0.000)	0.005(0.000)	0.004(0.000)
CDBBAN?	0.000(0.744)	0.000(0.681)	0.000(0.687)	–	–	–
CDTPRV?	-0.001(0.235)	-0.001(0.211)	-0.001(0.207)	0.000(0.015)	0.000(0.027)	0.000(0.030)
CAPLST?	-0.001(0.000)	-0.001(0.000)	0.000(0.000)	0.000(0.000)	-0.001(0.000)	0.000(0.000)
ENTRRE?	0.000(0.766)	-0.001(0.374)	-0.001(0.465)	0.000(0.755)	–	–
ENTRPGERD?	-0.002(0.431)	-0.001(0.578)	-0.001(0.479)	-0.001(0.501)	–	–
ENTRFGERD?	0.002(0.088)	0.002(0.131)	0.002(0.124)	0.002(0.124)	0.001(0.098)	0.001(0.158)
TEENRL?	0.001(0.171)	0.002(0.072)	0.001(0.100)	0.001(0.135)	0.001(0.156)	0.001(0.262)
SEENRL?	0.000(0.869)	–	–	–	–	–
BSCOST?	0.002(0.360)	0.002(0.337)	0.002(0.334)	0.002(0.308)	–	–
TAXRATE?	0.005(0.062)	0.005(0.077)	0.005(0.077)	0.005(0.051)	0.006(0.003)	0.006(0.004)
PRCOST?	0.002(0.654)	0.002(0.571)	0.003(0.446)	0.003(0.425)	–	–
LGRIGHT?	0.002(0.766)	0.004(0.595)	0.003(0.619)	0.001(0.857)	–	–
INVPORT?	0.003(0.771)	0.005(0.601)	0.004(0.675)	–	–	–
CORRUP?	-0.020(0.389)	-0.021(0.337)	-0.022(0.318)	-0.018(0.418)	–	–
GOVEFF?	0.047(0.140)	0.050(0.105)	0.050(0.099)	0.049(0.105)	0.033(0.223)	0.043(0.096)
POLSTAB?	-0.096(0.000)	-0.095(0.000)	-0.093(0.000)	-0.095(0.000)	-0.099(0.000)	-0.096(0.000)
REGULA?	0.046(0.002)	0.047(0.001)	0.047(0.001)	0.046(0.001)	0.042(0.000)	0.041(0.001)
LAW?	0.050 (0.191)	0.057(0.135)	0.054(0.152)	0.046(0.218)	0.039(0.245)	–
VOACCT?	-0.083(0.004)	-0.083(0.002)	-0.085(0.001)	-0.092(0.001)	-0.086(0.001)	-0.089(0.000)
RGDPPC?	-0.056(0.137)	-0.054(0.136)	-0.054(0.128)	-0.060(0.090)	-0.062(0.040)	-0.051(0.080)
PORGDP?	0.054(0.000)	0.052(0.000)	0.052(0.000)	0.054(0.000)	0.051(0.000)	0.051(0.000)
TRTGDP?	0.003(0.000)	0.003(0.000)	0.003(0.000)	0.003(0.000)	0.003(0.000)	0.003(0.000)
NRTGDP?	-0.001(0.726)	-0.001(0.810)	–	–	–	–
R-Sq	0.994	0.995	0.995	0.994	0.994	0.994
Adjusted R-Sq	0.992	0.994	0.994	0.993	0.993	0.993
D.W.	1.679	1.685	1.67	1.666	1.673	1.682
Cross section F	83.01(0.000)	91.31(0.000)	93.49(0.000)	108. 8(0.000)	209.1(0.000)	219.4(0.000)

The regression results here shows that NIS efficiency is affected by ICT infrastructure, financial structure, enterprise innovation activity, education system, market circumstance, governance, economic scale, dependency on foreign trade, and income level. For each of these factors, at least one of the corresponding proxy variables is statistically significant. And most of the explanatory variables show good robustness in different models with stable coefficient values.

[8] In the empirical study with panel data analysis, the period fixed effect is seldom taken into accounts, although the period F statistics and period Chi-sq. statistics may be significant. As for this paper, the time span is only 9 years and the data used in the regression are all stable, hence, the regression results would be more robust without time fixed effects.

However, there still are some exceptions. The coefficients of CDTPRV and CAPLST change across different models, and the coefficient sign of POLSTAB and VOACCT is not conformed to the economic intuition in spite of their robustness.[9]

3.4 Panel data analysis with some variables constructed by principal factor analysis

A possible explanation for the above exceptions is that there exists multi-collinearity due to the correlation among the proxy variables representing the same influencing factor. To eliminate the correlation among proxy variables, principal factor analysis may be applied to generate few independent principal factors or just the first principal factor, which contain most of the information carried by the relevant proxy variables. Replacing the proxy variables corresponding to the same influencing factor with their first principal factor, the multi-collinearity among explanatory variables would be eliminated. Next, panel data analysis would be further applied to the efficiency of NIS with some constructed first principal factors as explanatory variables. How the first principal factors were constructed is listed in Table 6.

Table 6: Construction of first principal factors for relevant factors

First Principal factors (F. P. F.)	Constructing equations	Cumulative proportion
Infrap1(Infrastructure)	Infrap1=0.62ITNET+0.56 MOBL+0.55 TEL	0.75
Finp1 (financial structure)	Finp1=0.64CDBBAN+0.66 CDTPRV+0.40 CAPLST	0.71
Entp1 (enterprises innovation)	Entp1=0.55ENTRRE+ 0.60ENTRPGERD+0.57 ENTRFGERD	0.78
Edup1 (education system)	Edup1=0.71 TEENRL+0.71 SEENRL	0.89
Markp1(Market circumstance)	Markp1=-0.38 BSCOST-0.60 TAXRATE+0.03 PRCOST+ 0.60 LGRIGHT+0.36 INVPORT	0.41
Govp1 (governance)	Govp1=0.42CORRUP+0.42GOVEFF+0.39POLSTAB+ 0.41REGULA+0.41 LAW+ 0.39VOACCT	0.92

The six first principal factors contained most of the information carried by the corresponding proxy variables for ICT infrastructure, financial structure, enterprise innovation activities, education system, market circumstance, and governance. Panel data analysis might be made once again with the above principal factors and some of the retained indicators, NRTGDP, TRTGDP, RGDPPC, and PORGDP as the explanatory variables. And the regression will also be made under the rule of "General-to-specific" with the insignificant variables being eliminated gradually. The regression results with principal factors as explanatory variables are listed in Table 7.

[9] For example, a stable political situation forms a good social environment for innovation, and should enhance the efficiency of the NIS. However, the POLSTAB is negatively related to NIS efficiency according to the regression results in table 5.

Table 7: Regressions with First Principal Factors as Explanatory Variables

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
C	-0.083(0.600)	-0.081(0.554)	-0.083(0.541)	-0.038(0.755)	0.010(0.924)
INFRAP1?	0.000(0.134)	0.000(0.029)	0.001(0.013)	0.001(0.018)	0.001(0.013)
FINP1?	-0.001(0.000)	-0.001(0.000)	-0.001(0.000)	-0.001(0.000)	-0.001(0.000)
ENTP1?	0.000(0.517)	0.000(0.516)	0.000(0.526)	–	–
EDUP1?	0.000(0.978)	–	–	–	–
MARKP1?	-0.005(0.037)	-0.005(0.032)	-0.005(0.037)	-0.005(0.028)	-0.006(0.012)
GOVP1?	-0.007(0.603)	-0.007(0.587)	–	–	–
RGDPPC?	0.028(0.283)	0.028(0.269)	0.024(0.287)	0.019(0.403)	–
PORGDP?	0.068(0.000)	0.068(0.000)	0.069(0.000)	0.072(0.000)	0.078(0.000)
TRTGDP?	0.002(0.000)	0.002(0.000)	0.002(0.000)	0.002(0.000)	0.002(0.000)
NRTGDP?	-0.002(0.377)	-0.002(0.372)	-0.002(0.423)	-0.003(0.201)	-0.003(0.153)
R-Sq	0.99	0.99	0.991	0.991	0.991
Adjusted R-Sq	0.989	0.989	0.989	0.99	0.99
D.W.	1.62	1.62	1.608	1.611	1.615
Cross section F	185.19(0.000)	188.29(0.000)	196.64(0.000)	314.51(0.000)	315.78(0.000)

It can be seen from Table 7 that the three constructed first principal factors, INFRAP1, FINP1, and MARKP1, are statistically significant. The coefficients of these variables show good robustness in different models, and the sign of the coefficients are conformed to economic intuitions on the whole.

The rest 3 principal factors, ENTP1, EDUP1 and GOVP1 were eliminated step by step since their regression coefficients are insignificant, which means these three first principal factors are not suitable to be used as their proxies. However, at least one of the proxies corresponding to "enterprise innovation activities", "education system" and "governance" is statistically significant according to the regression models in Table 5. These proxy variables include ENTRFGERD, TEENRL, POLSTAB, and REGULA. Hence, it may be better to substitute the 3 principal factors, ENTP1, EDUP1 and GOVP1 with these proxies.

As for the proxy variables of relative income level, economic scale, dependency on foreign trade, and the natural endowments, the regression coefficients of PORGDP and TRTGDP are very robust in all the 5 models of Table 7, and are conformed to that in Table 5. Nevertheless, the regression results for RGDPPC and NRTGDP are different from that in Table 5. The regression results of RGDPPC in Table 5 are significant and robust, while those in Table 7 are insignificant. On the contrary, the regression coefficients of NRTGDP are totally insignificant in Table 5, while those in Table 7 shows fairly good significance, particularly in model 4 and model 5.

To further improve the regression results of the panel data analysis, the proxies with good significance in the regression models in Table 5 together with 3 constructed first principal factors, INFRAP1, FINP1 and MARKP1, are selected as the explanatory variables. See Table 8.

Table 8: Regression with principal factor and original proxy as explanatory

Explanatory	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
C	0.025(0.883)	-0.046(0.717)	-0.144(0.443)	-0.153(0.288)	-0.294(0.049)	-0.230(0.118)
INFRAP1?	0.001(0.001)	0.001(0.000)	0.001(0.004)	0.001(0.002)	0.001(0.007)	0.001(0.014)
FINP1?	-0.001(0.000)	-0.001(0.000)	-0.001(0.000)	-0.001(0.000)	-0.001(0.000)	-0.001(0.000)
ENTRFGERD?	0.002(0.024)	0.002(0.015)	0.002(0.019)	0.002(0.015)	0.002(0.024)	0.002(0.048)
TEENRL?	-0.001(0.324)	-0.001(0.420)	–	–	–	–
SEENRL?	–	–	0.001(0.310)	0.001(0.244)	0.003(0.039)	0.001(0.205)
MARKP1?	-0.009(0.001)	-0.009(0.001)	-0.008(0.003)	-0.009(0.001)	-0.008(0.002)	-0.007(0.006)
GOVEFF?	0.019(0.482)	–	0.011(0.670)	–	–	–
POLSTAB?	0.042(0.000)	0.043(0.000)	0.046(0.000)	0.048(0.000)	0.046(0.000)	0.037(0.002)
REGULA?	-0.081(0.002)	-0.070(0.000)	-0.070(0.007)	-0.063(0.002)	–	–
VOACCT?	-0.050(0.058)	-0.042(0.063)	-0.055(0.040)	-0.055(0.019)	-0.059(0.015)	
RGDPPC?	-0.016(0.616)	–	0.001(0.983)	–	–	–
PORGDP?	0.068(0.000)	0.068(0.000)	0.064(0.000)	0.066(0.000)	0.068(0.000)	0.072(0.000)
TRTGDP?	0.002(0.000)	0.002(0.000)	0.002(0.000)	0.002(0.000)	0.002(0.000)	0.002(0.000)
NRTGDP?	-0.003(0.105)	-0.003(0.129)	-0.004(0.089)	-0.004(0.081)	-0.003(0.227)	-0.003(0.200)
R-Sq	0.988	0.99	0.988	0.99	0.99	0.989
Adjusted R-Sq	0.985	0.988	0.985	0.988	0.988	0.987
D.W.	1.607	1.616	1.626	1.644	1.664	1.645
Cross section F	181.76(0.000)	212.26(0.000)	185.88(0.000)	217.37(0.000)	222.18(0.000)	223.07(0.000)

In the 6 regression models in Table 8, the three principal factors, INFRAP1, FINP1, and MARKP1, still show good significance. And the coefficients are very robust across all the 11 models listed in Table 7 and Table 8. Regression coefficients of PORGDP, TRTGDP, and NRTGDP also show good robustness among all the 11 models. The coefficients of ENTRFGERD are significant and robust in the 12 regression models listed in Table 5 and Table 8. While the regression results of the two proxy variables for education system, SEENRL and TEENRL are very different from that in Table 5. The regression results for proxies of governance in Table 8 are much different from that in Table 5 as well with POLSTAB and REGUL changing their signs across the two tables.

3.5 Further analysis on the regression results

Factors affecting NIS efficiency and their mechanisms

Based on all the regression results in Table5, 7 and 8, it is clear how the NIS efficiency is affected by relevant influencing factors. And the affecting mechanisms behind can be further figured out with the guidance of innovation economic theory, NIS approach, and the new growth theory.

Firstly, NIS efficiency is positively related to ICT infrastructure. Country with higher coverage of ICT infrastructure would have a better score. As a matter of fact, the diffusion of knowledge and information is highly dependent on ICT infrastructure. And the diffusion of knowledge and information is of great importance to innovation. After all, innovation is inherently a sort of knowledge-based activity.

Secondly, the NIS efficiency of a country is affected by R&D and innovation activities of corporate sector. Proportion of enterprises in total R&D expenditure is positively related to efficiency score. From the view of innovation economics, enterprise is the most active and important element in an innovation system. The more enterprises were involved in innovation activities, the more efficient would the NIS be.

Thirdly, larger economic scale and higher degree of openness would be helpful to form a more efficient NIS. Larger economic scale and higher dependent ratio means a bigger domestic and international market, and would facilitate the diffusion of knowledge and technology in a larger scope. It would be easier for innovative activities to gain the benefit of economy of scale and economy of scope in such a circumstance.

Fourthly, the factors of financial structure, market circumstance, and governance are all relevant to NIS efficiency. However, the coefficients of the proxy variables are not very robust. As too many proxy variables were selected for these factors, the correlation among the proxies would affect the regression results more or less. Another reason is that the functioning mechanisms of these factors on NIS are not very direct. Good financial structure, market circumstance, and governance would only form a favorable external environment for innovation activities by reducing various kinds of transaction costs.

Fifthly, the regression results for proxies of education system, natural endowments, and income level are not robust with the corresponding coefficients being significant in some models and insignificant in other models. In fact, these factors are only effective for NIS efficiency of some countries, and their impacts on NIS are not very direct. Education system would affect NIS efficiency through accumulation in human capital, which could be regarded as the source of innovativeness. And an economy highly dependent on natural resources might be short of incentives for innovation activities, which would in turn reduce its NIS efficiency. As for the income level, only a very limited number of countries can grasp the so called later comer advantages and step into a developed stage, which would be a positive impact on NIS efficiency.

Further analyses on NIS efficiency for each country of BRICS

Based on the previous econometric and mechanisms analyses, factors affecting NIS efficiency of each BRICS country can be further inferred with some basic data in Table 9. Many as the factors relevant to NIS efficiency, the decisive factors for each BRICS country are very different.

For China, the high efficiency score and good ranking are mainly due to its huge economic scale, high proportion of enterprise R&D, and high dependency on foreign trade. In the year 2008, the GDP takes a proportion of 6.64% of the world total output, and the R&D financed by enterprises reaches to 72%, both much higher than those of the other BRICS countries. China also has a high dependency ratio on foreign trade of 66%, ranking the second among the BRICS countries. Moreover, China is still in a take-off stage according to income level per capita, and the industrialization is far from fulfilled. Thus, there are some later comer advantages for improving the innovation capacity. Nevertheless, China still has much room for progress in the fields of ICT infrastructure, education system, market circumstance and governance. Besides, China's dependency ratio on natural endowments is still quite high comparing with other countries selected in this paper. All these elements would suppress micro-level innovation activities in the long run, and in turn impact NIS efficiency negatively.

The fairly good efficiency score and ranking of India mainly comes from the huge later-comer advantages due to its backward developing stage. And the big economic scale is another element positively contributing to its NIS efficiency. As for the other relevant factors, the performance of India is very poor.

Russia has great advantages in ICT infrastructure and education system among the BRICS countries, which is even comparable to that of most developed nations. However, Russia is highly dependent on its natural resources in recent years. And Russia government does not govern in a satisfactory manner.

The badly ranking of Brazil can be attributed to its low proportion of enterprise R&D, low dependency on foreign trade, high dependency on natural resources, and the unsatisfying governance. Yet, Brazil still has relative advantages in ICT infrastructure and economic scale.

As for the South Africa, the low efficiency of NIS is mainly due to the low coverage of ICT infrastructure, low participation of enterprises in R&D. Besides, South Africa has no advantages in economic scale and education system as well. However, the market circumstance, the governance, and the dependency ratio on foreign trade of South Africa are obviously better than those of the other BRICS countries.

Table 9: Some of the data in 2008 for factors influencing NIS efficiency

	BR	RU	IN	CN	ZA	US	JP	DE	UK	FR	CA
ITNET	37.5	32	4.5	22.5	8.6	75.8	75.2	78.1	78.2	70.4	75.3
TEL	21.5	31.6	3.3	25.7	9.1	50.8	37.9	62.2	54.1	56.2	54.8
ENTRRE	37	50	37	69	31	80	75	60	34	57	60
ENTRPGERD	40	63	34	73	58	73	78	69	62	63	54
ENTRFGERD	44	29	34	72	43	67	78	67	45	51	48
PORGDP	2.1	1.1	2	6.6	0.5	28.8	12.7	5.2	4.4	3.7	2.1
TRTGDP	27	53	52	62	74	31	35	89	61	56	69
NRTGDP	7.2	31	5.8	3.8	5.9	2.2	0.1	0.2	2.4	0.1	8
RGDPPC	1.6	2.4	0.5	0.9	1.6	7.2	5.2	5.6	5.6	5.1	5.9
TEENRL	34	77	13	23	32	83	58	60	57	55	70
SEENRL	82	85	60	76	73	88	98	92	93	98	91
TAXRATE	69	48	69	80	34	47	55	51	35	65	45
GOVEFF	0.1	-0.3	0	0.2	0.7	1.5	1.4	1.4	1.6	1.5	1.8
POLSTAB	-0.1	-0.6	-0.9	-0.4	0.2	0.5	0.9	1	0.5	0.6	1
REGULA	0.1	-0.5	-0.3	-0.1	0.5	1.5	1.1	1.4	1.7	1.2	1.6
	IT	FI	SE	DK	CH	NL	NO	AT	BE	AU	KR
ITNET	44.4	83.5	89	84.5	70.8	80.2	68.9	87.9	90.5	72.9	70.5
TEL	35.5	31.1	57.7	45.3	43.7	43.9	63.1	44.5	39.8	39.4	41.6
ENTRRE	38	59	69	66	29	77	41	49	51	63	47
ENTRPGERD	53	74	74	70	61	75	74	50	54	71	68
ENTRFGERD	45	70	61	61	61	73	68	49	46	46	61
PORGDP	2.9	0.4	0.8	0.4	1.3	1.9	0.7	1.1	0.5	0.6	0.7
TRTGDP	58	90	100	107	41	107	102	145	77	113	171
NRTGDP	0.3	0.9	1.1	3.6	8.6	0	0	2.7	21.8	0.5	0
RGDPPC	4.7	5.6	5.7	5.6	5.7	4.2	6.3	4.5	7	4.5	4.1
TEENRL	67	94	71	78	77	98	49	61	73	55	63
SEENRL	95	96	99	90	88	95	85	88	96	99	86
TAXRATE	73	48	55	30	50	34	29	39	42	55	58
GOVEFF	0.4	2	1.9	2.1	1.8	1.1	1.9	1.7	1.8	1.6	1.2
POLSTAB	0.6	1.4	1.1	1	1	0.4	1.2	0.9	1.3	1.3	0.7
REGULA	0.9	1.6	1.6	1.9	1.7	0.7	1.6	1.7	1.4	1.6	1.3

4 Concluding remarks

The previous parts of this paper calculate the relative efficiency of NIS for 22 countries including the BRICS from 2000 to 2008 considering the national level innovation inputs and outputs with DEA method. Taking the efficiency scores as the explained variable, factors affecting NIS efficiency are further analyzed with econometric and statistical tools. The efficiency calculation and the empirical test results can be summarized:

(1) The BRICS are very different in their relative efficiency of NIS. Russia, India and China have relatively high efficiency score and good ranking, while

Brazil and South Africa are not, ranking at the bottom among the 22 selected countries.

(2) Influencing factors of NIS efficiency involve a lot of elements, including the ICT infrastructure, enterprise R&D activities, economic scale, economic openness, financial structure, market circumstance, governance, education system, natural endowments. This is conformed to the relevant arguments of NIS Approach and the New Growth Theory.

(3) Enterprise is the most active and important actor for innovation and enterprises innovation activities are of key importance to the NIS. The more enterprises involved in R&D activities, the higher would the NIS efficiency be. Elements including financial structure, market circumstance, and governance level form the external environments for innovation activities, which would affect NIS efficiency indirectly.

(4) ICT infrastructure, economic scale, and openness decide diffusion speed and scope of knowledge, and in turn affect NIS efficiency. Furthermore, economic scale and degree of openness decide the scale of domestic and international market for enterprises. The economy of scale and economy of scope are much easier to be realized in a bigger market, which would influence the NIS efficiency indirectly as well.

(5) The decisive factors for NIS efficiency of each BRICS are very different. However, the BRICS still have some characters in common, particularly the low governance and fairly high dependency on natural resources, which was decided by their developing stage and extensive developing patterns.

In modern history, only very few economies, e.g. Japan and South Korea, have caught up with and leaped into developed nations successfully. In the coming future, the BRICS should endeavor a transition from factors-driven to innovation-driven pattern in order to improve their competitiveness substantially and avoid "middle-income trap". Governments of each country should improve its governance and create a sound external environment for enterprise innovation.

China is implementing its "12th Five Year Planning" for national economy and social development from 2011 to 2015. To accelerate the process of constructing innovative nation, and transform the economic pattern essentially, governments in different levels should dedicate to improve capability in social administration, enhance the expenses on infrastructure and education, and create a more comfortable market circumstance.

References

[1] P. Aghion and P. Howitt. *Endogenous Growth Theory*. The MIT Press, Cambridge, Massachusetts., 1998.

[2] José Cassiolato and Bengt-Aake Lundvall. Brics project: Comparative and summary report on brics national innovation system. Research project report, Jointly by IDRC, CRDI, RedeSist, Globelics and UFRJ, Brazil, 2010.

[3] Barbara Casu and Philip Molyneux. A comparative study of efficiency in european banking. *Applied Economics*, 35:1865–1876, 2003.

[4] A. Charnes, W.W. Cooper, and E. Rhodes. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2:429–444, 1978.

[5] M. J. Farrell. The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, 120(3):253–290, 1957.

[6] Stephen Feinson. National innovation systems overview and country cases. Research project report, Jointly by IDRC, CRDI, RedeSist, Globelics and UFRJ, 2003.

[7] Chris Freeman. Continental, national and sub-national innovation systems-complementarity and economic growth. *Research Policy*, 31:191–211, 2002.

[8] Jeffery L. Furman and Richard Hayes. Catching up or standing still? national innovative productivity among 'follower' ountries, 1978-1999. *Research Policy*, 33:1329–1354, 2004.

[9] Jeffery L. Furman, Michael E. Porter, and Scott Stern. The determinants of national innovative capacity. *Research Policy*, 31:899–933, 2002.

[10] Jian-Cheng Guan, Richard C.M. Yam, C K Mok, and Ning Ma. A study of the relationship between competitiveness and technological innovation capability based on dea models. *European Journal of Operational Research*, 170:971–986, 2006.

[11] Ayoe Hoff. Second stage dea: Comparison of approaches for modeling the dea score. *European Journal of Operational Research*, 181:425–435, 2007.

[12] Mei-Chih Hu and John A. Mathews. National innovative capacity in east asia. *Research Policy*, 34:1322–1349, 2005.

[13] Mei-Chih Hu and John A. Mathews. China's national innovative capacity. *Research Policy*, 37:1465–1479, 2008.

[14] X. Liu and S. White. Comparing innovation systems: a framework and application to china's transitional context. *Research Policy*, 30:1091–1114, 2001.

[15] W. Nasierowski and F. J. Arcelus. On the efficiency of national innovation systems. *Socio-Economic Planning Sciences*, 37:215–234, 2003.

[16] Richard Nelson. Economic development from the perspective of evolutionary economic theory. *Oxford Development Studies*, 36:9–21, 2008.

[17] P. Patel and K. Pavitt. National innovation systems: why they are important, and how they might be measured and compared. *Economics of Innovation and New Technology*, 3(1):77–95, 1994.

[18] V.J. Tomas, Seema Sharma, and Sudhir K. Jain. Using patents and publications to assess r&d efficiency in the states of the usa. *World Patent Information*, 33:4–10, 2011.

[19] Eduardo B. Viotti. National learning systems: A new approach on technological change in late industrializing economies and evidences from the cases of brazil and south korea. *Technological Forecasting & Social Change*, 69:653–680, 2002.

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