# Factors Affecting the Efficiency of the BRICSs' National Innovation System: A Comparative Study based on the Two-Stage Semi-Parametric DEA Method

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#### **Abstract**

The two-stage semi-parametric DEA method is applied in this paper to calculate NIS efficiency performance and analyze the potential influencing factors for 22 countries including the BRICS and G7. In the first stage, the ordinary DEA and the bootstrapping method are implemented to generate bias-corrected NIS efficiency scores for the 22 countries. A censored panel regression model is adopted in the second stage with the bias-corrected efficiency scores as the explanatory variable. Potential factors that may affect the innovation system efficiency are analyzed based on NIS Approach, New Growth Theory and relevant theories before the econometric test. The results of efficiency calculation and empirical test show that: (1) Each of the BRICS differs greatly in NIS efficiency, with China, India and Russia performing pretty good, while Brazil and South Africa ranking at the bottom; (2)In accordance with the NIS approach and the new growth theory, there are many factors that affect the NISs including age structure of population, ICT infrastructure, firm-level R&D and innovation activities, economic and market size, trade openness, reliance on natural resources, financial structure, market

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circumstance, and governance level; (3) Firm-level innovation activities are vital to the NIS efficiency. And the age structure of population affects the NIS efficiency as well, since young people are more creative than the old. (4) ICT infrastructure, economic scale and openness affect the diffusion of knowledge and application of new technology, and in turn influence the 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, governance level and education system. During its 12th five-year plan, more effort should be devoted to these fields and to improving external conditions for R&D and innovation.

Keywords: The BRICS, National Innovation System (NIS), NIS efficiency, Two-Stage Semi-Parametric DEA, Censored Panel Regression. Journal of Economic Literature Classification: O30,O57,P52.



## Introduction

As the world leading emerging economies, the BRICS countries, i.e. Brazil, India, Russia, China, and South Africa, have all encountered a fast economic growing in recent years with an average annual growth rate of 3%, 5.4%, 7.2%, 10.3% and 3.6% respectively during 2000-2009. In contrast, the annual growth rate of the world economy is only 2.6% in the same period, while the OECD countries get an even lower level of 1.6%. However, rapid growth does not enhance the competitiveness of the BRICS proportionally. According to the Global Competitiveness Report of 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 rankings changed to be 58, 63, 49, 29, and 45. All but China get a lower competitiveness ranking. Even for China, the competitiveness ranking of about 30 does not match with its world highest growth rate and world 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 take-off 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 its 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)[27]put forward an analytical framework for Innovation System including R&D, implementation, end-use, education, and their linkages, and make a comparative study on China's NIS in different periods and development stages. Viotti (2002)[42] 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 respectively. Feinson (2003)[15] also chose these two countries 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) [5]makes overall comparison for the NIS of BRICS in production, education, finance, politics, regulation, etc. Tomas et al (2011)[41] 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 make objective and reliable judgments on the NIS of the countries, the two-stage DEA method is adopted in this paper to calculate the NIS efficiency of the BRICS and analyze the potential environmental factors. In the first stage, 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 as well as bootstrapping methods. In the second stage, potential influencing factors are summarized first according to the National Innovation System Approach (NIS Approach), the New Growth Theory, and etc. Then, 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 econometric analysis.

The remaining of this paper is to be arranged as follow. 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 National Innovation Capacity and NIS efficiency

# 1.1 Review on the quantitative analysis of National Innovation Capacity and 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)[33] might first appeal for quantitative analysis on the input and output characters of NIS <sup>1</sup>. With the execution of Community Innovation Survey (CIS) throughout the European Union and its implementation in the annual European Innovation Scoreboard (EIS)<sup>2</sup>, quantitative analysis has been widely used in studying national innovation capacity and innovation system. These quantitative methods might 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 this Approach (Archibugi and Coco, 2005)[3]. 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 of input, output, procedure of innovation as well as organization pattern of innovation activities, institutional arrangements, etc. However, efficiency of innovation system is ignored since the input and output indicators are merely different aspects of the innovation capacity in this approach. 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 Efficiency 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. Similar measurement of efficiency can be traced early to Farrell (1957)[14], which first proposed the concept of technical efficiency, price (allocative) efficiency, overall (economic) efficiency, and the efficient production function (production frontier). The notions of efficiency and production frontier can be further traced up to Koopman (1951)[26] and Debreu (1951)[11]. To

<sup>&</sup>lt;sup>1</sup> The quantitative analysis in the field of innovation can be further track to 1950s and 1960s, when the Linear Model of Innovation was prevailing.

<sup>&</sup>lt;sup>2</sup> In October, 2010, the former EIS was reconstructed and renamed as Innovation Union Scoreboard (IUS).

<sup>&</sup>lt;sup>3</sup> Efficiency is always connected with productivity. However, Lovell (1993)and Coelli (1995) pointed out that they are not the same thing. Productivity means the ratio of outputs to inputs, while efficiency involves the comparison between observed unit and the optimal unit. The productivity of a unit can be measured with a single index, such as the productivity of labor, or by calculation of TFP based on a common production function.



date, there are two primary methods to measure efficiency/inefficiency through frontier estimation. One is DEA, and the other is the Stochastic Frontier Analysis (SFA), which are organized around mathematical programming and econometric analysis respectively (Coelli,1995[8]; Lovell, 1993[28]). The DEA method has more advantages in coping with multi-output situation. While in SFA, it is difficult to construct an aggregate output, particularly when the data of price is not available. Obviously, the output of NIS can not be measured by a single indicator, which may explain why the SFA is seldom chosen to measuring the efficiency of NIS in practice. In practice, Nasierowski and Arcelus (2003) [30] has applied the DEA to calculate efficiency of innovation system for over 40 countries and regions. Guan Jiancheng et al (2006) [19] have done a lot of innovation efficiency calculation with DEA in both national and regional levels. And Cullmann et al (2010)[10] apply the DEA method to assess the relative efficiency of knowledge production (R&D efficiency) for OECD countries. 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. The empitical works of Furman et al (2002, 2004)[18] [17], Hu and Mathews (2005, 2008) [24] [25] are all application of this approach. As the factors analysis in this approach is supported by both economic theory and the empirical data, the quantitative results seems more reliable. However, in econometric test, only one single indicator can be chosen as the explained variable. For instance, "International Patent Granted" is usually selected as the proxy of innovation capacity. Obviously, innovation capacity is far from the patents granted. And such treatment would inevitably lead to a bias.

# 1.2 The Two-Stage DEA method – a combination of DEA and Modeling/Econometric approaches

It can be seen that the advantages of DEA efficiency calculation and the the Modelling/Econometric Approach are complementary. Combining these two approaches would help to make a deep and overall analysis on efficiency of NIS. Such a combination is named as "the Two-Stage DEA Method" or "the Two-Stage



Semi-Parametric DEA Method", and has been applied in the empirical study of many fields. For example, Casu and Molyneux (2003) [6]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)[22] compares the estimation results between OLS and Tobit in the second stage, and chooses the Danish fishery as a case study. In the field of innovation, such an implementation is not very common. A recent paper of Cullmann et al (2010) has assessed the relative efficiency of knowledge production in the OECD using this two-stage DEA method.

Although the two-stage DEA method has been widely used in many papers, most of the implementations has some defects (Simar and Wilson, 2007; 2011)[39] [40]. Simar and Wilson (2007) point out that most of the existing literatures have not provided a coherent description of the underlying DGP (Data Generation Process) for the efficiency scores in the first stage, which would make the second stage regression more sensible. And the conventionally calculated efficiency scores would cause serial correlation in the second stage in case of finite samples. Simar and Wilson (2007, 2011) further provide bootstrap methods for the DGP of efficiency scores, which is necessary to get feasible means for inference (or consistent and asymptotic estimation) in the second stage regression. Besides, Simar and Wilson (2007, 2011) prove that ML (Maximum Likelihood) estimator with truncated(or censored) regression in the second stage can provide a consistent estimation results, while the OLS estimation is consistent only under very unusual assumptions.

This paper will attempt to analyze NIS efficiency of the BRICS and the relevant influencing factors with the above two-stage semi-parametric DEA method, which has seldom been applied in innovation study. The technical details of the two-stage DEA will be conducted in conformed to the rules proposed by Simar and Wilson (2007, 2011).

# 2 Measuring the relative efficiency of NIS with DEA

## 2.1 Understanding the NIS efficiency

According to the different but similar definition given by various innovation economists, the concept of NIS refers to a system or network of institutions and entities inside the borders of a nation, which interact with each other to influence or promote the innovation process of the nation (Freeman, 2002; Nelson, 2008; Sharif, 2006[35]; Feinson, 2003). Complex and huge as the NIS may be, it has many similarities to an ordinary micro-level firm. If the nation-wide innovative process and activities were treated as a special kind of production, then the NIS is



the special manufacturing factory with R&D efforts as its inputs. More concretely, the inputs are mainly the R&D expenditures and human resources allocated to R&D activities, while the outputs can be attributed to the outcomes R&D activities such as patents, academic papers, and new products. The efficiency of NIS is related to the ratio of the above special inputs and outputs. Such an efficiency of NIS can be interpreted as the national R&D efficiency as well. As a matter of fact, similar understanding of the NIS efficiency can be found in Nasierowski and Arcelus (2003)<sup>4</sup>.

It should be noted that the improvement of NIS efficiency would contribute to the innovativeness and competitiveness of an economy, and in turn contributes to the performance of the whole economy. Thus, two types of efficiency/performance are involved here: NIS (or R&D) efficiency and economic efficiency (or productivity). The former focus on the input/output ratio of R&D activities, while the latter refers to the indirect contribution of R&D efforts to the national economy. We might also defined them as "narrow NIS efficiency" and "generalized NIS efficiency" respectively, and the NIS efficiency in this paper refer to the narrow one.<sup>5</sup>

## 2.2 Selection of input/output indicators and DMUs

The DEA method has been widely used in measuring the relative efficiency for DMUs ever since it was first proposed by Charnes et al (1978)[7] over 30 years ago. As the NIS efficiency in this paper is confined to the national R&D efficiency, it is appropriate to treat the NIS (or the R&D related activities) as a special production sector of the national economy and apply DEA to compare the relative efficiency of NIS for each BRICS countries. The inputs of NIS (or the R&D related activities) 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 cross-country data for these input-output indicators from 2000 to 2008 are collected from 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). Considering the availability and relatedness, "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

<sup>&</sup>lt;sup>4</sup> p.216:NISs are formed in order to foster development, application, and diffusion of technology, thereby improving productivity. As a result, investment in technology can be considered as one of the inputs of a sector of an economy. Within this context, efficiency relates to an NIS's ability to transform R&D inputs into R&D outputs.

<sup>&</sup>lt;sup>5</sup> Most of the existing literatures on NIS (or R&D) efficiency refer to the narrow one, including Nasierowski and Arcelus (2003), Cullmann et al (2010)[10], Sharma and Thomas (2008)[36], Wang and Huang (2007)[43], and etc. As for the generalized one, the performance of the NIS might be measured by TFP of the economy.



"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 of 2000 U.S. dollar,<sup>6</sup> and the "Total R&D personnel" is converted into full-time equivalent (FTE).

As for the DMUs, the five BRICS countries are definitely included. But it is still far from enough. The efficiency scores calculated with DEA are not based on the true production frontier but the observed frontier constructing by the available DMUs. The more DMUs involved in the calculation, the more the observed frontier would approximate the true one. If the number of DMUs is very limited, there would be a large (positive) bias for the calculated efficiency scores. Particularly, the calculated scores would lose their basic function of efficiency comparison, because most of the DMUs may be on the observed frontier formed by themselves with their corresponding calculated efficiency scores all to be 1. And the ranking based on these efficiency score may become meaningless. To avoid such scenario, the G7 countries (United States, Japan, Germany, Canada, United Kingdom, France, Italy), 8 European countries (Finland, Sweden, Denmark, Swiss, Netherland, Austria, Belgium), and 2 OECD countries in the Asia Pacific Region (South Korea and Australia), are selected as the DMUs together with the five BRICS countries. These 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 typical for catching up with and surpassing successfully. 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.

## 2.3 Optimization model for the efficiency measurement

According to Farrell (1957)[14], the measurement of production efficiency can be divided into two categories: Input-Oriented and Output-Oriented. The former fixes outputs and compares the inputs to measure relative efficiency, while the later fixes inputs and compares the outputs. Although the output- and input-orientated measurement will only provide equivalent calculation results of technical efficiency when constant returns to scale exist(Färe and Lovell, 1978) [13], the choice of orientation will have only minor influences upon the scores obtained(Coelli, 1996)[9]. And here in this paper, the output-Oriented model is chosen for efficiency measurement.

Moreover, efficiency measuring models can be divided into Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). In order to choose the proper

<sup>&</sup>lt;sup>6</sup> Converting into constant price of 2000 U.S. dollar is convenient for further calculation of Malmquist Index in this period.



model, returns to scale is tested first using the DEA efficiency estimates and the bootstrapping process proposed by Simar and Wilson(2002).[38] The efficiency scores for both CRS and VRS can be calculated with the following two output-oriented models.

$$(D_{o}^{t} - CRS) \begin{cases} [D_{o}^{t}(\overrightarrow{x_{0}}^{t}, \overrightarrow{y_{0}}^{t})]^{-1} = Max_{\varphi, \lambda} \phi \\ s.t. \quad -X_{m \times n}^{t} \overrightarrow{\lambda}_{n \times 1} + \overrightarrow{x_{0}}^{t} \ge 0_{m \times 1} \\ Y_{s \times n}^{t} \overrightarrow{\lambda}_{n \times 1} + 0_{s \times 1} \phi \ge \phi \overrightarrow{y_{0}}^{t} \\ \phi > 0, \ \lambda_{j} \ge 0, \ j = 1, 2, \dots, n \end{cases}$$

$$(1)$$

$$(D_{o}^{t} - VRS) \begin{cases} [D_{o}^{t}(\overrightarrow{x_{0}}^{t}, \overrightarrow{y_{0}}^{t})]^{-1} = Max_{\phi, \lambda} \varphi \\ s.t. \quad -X_{m \times n}^{t} \overrightarrow{\lambda}_{n \times 1} + \overrightarrow{x_{0}}^{t} \ge 0_{m \times 1} \\ Y_{s \times n}^{t} \overrightarrow{\lambda}_{n \times 1}^{t} + 0_{s \times 1} \varphi \ge \varphi \overrightarrow{y_{0}}^{t} \\ \sum_{j=1}^{n} \lambda_{j} = 1 \\ \phi > 0, \quad \lambda_{j} \ge 0, \quad j = 1, 2, \dots, n \end{cases}$$

$$(2)$$

In the above equation (1) and (2), 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  $\phi$  refer to time period and relative efficiency score. The CRS and VRS relative efficiency scores of DMU0 in the period of t can be calculated respectively with these two equations. And the relative efficiency score  $\phi$  is also the value of distance function to the Frontier for the DMU being measured, which can be expressed as  $[D_o^t(\overline{x_0}^t, \overline{y_0}^t)]^{-1}$ .

Simar and Wilson (2002) has proposed 6 test statistics for testing hypotheses regarding returns to scale. Two of the six statistics are selected in this paper as constructed by the following equation.

$$\begin{cases} \hat{S}_{1n}^{crs} = n^{-1} \sum_{i=1}^{n} \hat{D}_{n}^{crs}(x_{i}, y_{i}) / \hat{D}_{n}^{vrs}(x_{i}, y_{i}) \\ \hat{S}_{2n}^{crs} = \sum_{i=1}^{n} \hat{D}_{n}^{crs}(x_{i}, y_{i}) / \sum_{i=1}^{n} \hat{D}_{n}^{vrs}(x_{i}, y_{i}) \end{cases}$$
(3)

Based on equation (1) to (3), the observed estimate of  $\hat{S}_{1n}^{crs}$  and  $\hat{S}_{2n}^{crs}$  can be calculated first with the available 22 DMUs. Then, the bootstrap estimate of the two statistics  $\hat{S}_{1nb}^{crs*}$  and  $\hat{S}_{2nb}^{crs*}$  can be calculated by generating B pseudo samples  $\zeta_{bn}^*$ ,  $b=1,\dots,B$ , each with n observations.

$$\begin{cases} \hat{S}_{1nb}^{crs*} = n^{-1} \sum_{i=1}^{n} \hat{D}_{nb}^{crs*}(x_{i}, y_{i}) / \hat{D}_{nb}^{vrs*}(x_{i}, y_{i}) \\ \hat{S}_{2nb}^{crs*} = \sum_{i=1}^{n} \hat{D}_{nb}^{crs*}(x_{i}, y_{i}) / \sum_{i=1}^{n} \hat{D}_{nb}^{vrs*}(x_{i}, y_{i}) \end{cases}$$
(4)

<sup>&</sup>lt;sup>7</sup> The index of technological change for the DMU, i.e. the Malmquist Index, can be further calculated based on equation (1) via geometric average.

# **Economics** Discussion Paper

In this paper, B is set to be 1000. And for convenience, the two observed estimators may be represented by  $\hat{\omega}_{obs}$ , and the two bootstrap estimators by  $\hat{\omega}^*$ . The observed estimator values and the 5% and 10% critical values of the bootstrap estimators are listed in the following table 1.

Table 1: Observed and bootstrap estimators for testing the returns to scale

	$\hat{S}_{1n}^{crs}$	$\hat{S}_{1n}^{crs*}(5\%)$	$\hat{S}_{1n}^{crs*}(10\%)$	$\hat{S}_{2n}^{crs}$	$\hat{S}_{2n}^{crs*}(5\%)$	$\hat{S}_{2n}^{crs*}(10\%)$
2000	0.6959	0.6225	0.6464	0.6624	0.6010	0.6205
2001	0.6989	0.6408	0.6582	0.6678	0.6208	0.6387
2002	0.7214	0.6695	0.6924	0.6973	0.6518	0.6732
2003	0.6743	0.6091	0.6321	0.6418	0.5843	0.6083
2004	0.6725	0.6165	0.6408	0.6369	0.5903	0.6117
2005	0.6845	0.6341	0.6579	0.6526	0.6058	0.6329
2006	0.7076	0.6497	0.6736	0.6795	0.6278	0.6511
2007	0.6842	0.6301	0.6489	0.6548	0.6028	0.6263
2008	0.7080	0.6481	0.6718	0.6758	0.6241	0.6415

Notes: (1)the percentage of 5% (or 10%) in the first row means only 5% (or 10%) of all the bootstrap estimated values are less than the value in the corresponding column, which can be regarded as the critical value for nominal size of 5% (or 10%). (2)The calculations are conducted by coding with the software package FEAR in R environment (Wilson, 2008, 2010a, 2010b).[44] [46] [45]

The null hypothesis  $H_0$  is "the production frontier exhibit constant returns to scale". Under  $H_0$  and the original sample  $\zeta_n$ , a probability statement can be given for the bootstrap estimators.

$$\hat{p} = \Pr(\hat{\omega}^* \le \hat{\omega}_{obs} | H_0, \zeta_n) \tag{5}$$

 $\hat{p}$  means the probability that the value of bootstrap estimator is less than that of the observed estimator. If  $\alpha$  is the nominal size of this test, for instance 5% or 10%, then the null hypothesis  $H_0$  would be rejected when  $\hat{p} \leq \alpha$  (Simar and Wilson, 2002, p.122). In another words, if the critical value of the bootstrap estimator corresponding to the nominal size  $\alpha$  is greater than the value of observed estimator, the null hypothesis  $H_0$  would be rejected. Otherwise, the observed frontier can be regarded as exhibiting constant returns to scale. It is shown in table 1 that values of two observed estimators are greater than the 10% critical values of the corresponding bootstrap estimators for all the 9 years. Thus, the hypothesis of constant returns to scale can not be rejected.

# 2.4 Calculation of the NIS efficiency scores

Based on the previous output-oriented constant returns to scale model, the relative efficiency scores as well as the efficiency ranking for the NIS of the 22 countries



from 2000 to 2008 can be calculated by coding with FEAR in R. See Table 2 and Table 3.

Table 2: Relative efficiency scores for NIS of 22 countries including BRICS

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	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	0.757	0.679	0.773	0.674	0.627	0.755	0.727	0.600	0.750
IN	0.416	0.588	0.680	0.642	0.662	0.675	0.735	0.756	0.913
CN	0.631	0.731	0.849	0.870	0.919	0.926	0.956	0.945	0.999
ZA	0.313	0.343	0.313	0.273	0.264	0.264	0.265	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	0.411	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	0.435	0.441	0.487	0.403	0.353	0.423	0.385	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	0.336
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	0.622	0.732
AU	0.226	0.244	0.243	0.214	0.192	0.172	0.178	0.159	0.162
KR	0.831	0.682	0.849	0.702	0.704	0.819	0.989	0.890	0.737
means	0.498	0.521	0.582	0.505	0.506	0.517	0.537	0.501	0.539

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.



Table 3: 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	16	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	15	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

As has discussed in the previous section, the efficiency scores calculated with conventional DEA method represent not the efficiency relative to the true frontier but to the observed frontier constructed by the available DMUs. The bias of the observed efficiency scores would lead to an inconsistent estimating results if they were used as the dependent variable in the second stage of regression. The most ideal solution to eliminate such bias is to enumerate all the samples of existing DMUs and construct the real frontier. However, it is usually impossible in practice. Alternatively, Simar and Wilson (1998, 2007)[37] propose a bootstrapping method that pseudo samples of large scale can be generated by replicating the data generation process (DGP) of the original observed sample (DMUs). With the bootstrapping pseudo sample, a new frontier can be constructed to generate new efficiency scores, which would have their bias eliminated to a large extent. We may define the new efficiency scores as the bias-corrected efficiency scores. It is further proved in Simar and Wilson (2007, 2011) that consistent and asymptotic



estimation can be obtained in the second stage regression using the bias-corrected efficiency scores.

Defining the original sample as  $\zeta_n$ , B pseudo samples  $\zeta_{bn}^*$ ,  $b=1,\cdots,B$  can be generated, each with n observations. In our case, the original observed sample  $\zeta_n$  is just the selected countries with n to be 22 and the bootstrapping times B is set to be 999. Again coding with the FEAR software package in R environment, bias-corrected efficiency scores for all the selected 22 countries from 2000-2008 can be calculated.

Table 4: Bias-corrected efficiency scores for NIS of 22 countries including BRICS

				DKI	CD				
	2000	2001	2002	2003	2004	2005	2006	2007	2008
BR	0.150	0.184	0.194	0.157	0.171	0.178	0.181	0.157	0.173
RU	0.545	0.496	0.584	0.484	0.448	0.541	0.530	0.427	0.544
IN	0.335	0.496	0.583	0.538	0.552	0.565	0.612	0.621	0.759
CN	0.517	0.599	0.693	0.698	0.725	0.737	0.754	0.741	0.803
ZA	0.242	0.269	0.252	0.213	0.210	0.213	0.213	0.197	0.208
US	0.271	0.285	0.290	0.193	0.190	0.193	0.210	0.186	0.200
JP	0.269	0.273	0.302	0.230	0.228	0.235	0.252	0.216	0.225
DE	0.297	0.377	0.443	0.345	0.385	0.377	0.406	0.331	0.364
UK	0.689	0.506	0.638	0.486	0.539	0.539	0.589	0.497	0.449
FR	0.287	0.318	0.343	0.251	0.240	0.246	0.271	0.242	0.279
CA	0.366	0.333	0.319	0.269	0.225	0.237	0.256	0.251	0.278
IT	0.291	0.342	0.344	0.303	0.300	0.295	0.296	0.266	0.281
FI	0.345	0.352	0.397	0.320	0.275	0.334	0.302	0.296	0.445
SE	0.660	0.671	0.686	0.654	0.654	0.656	0.668	0.650	0.659
DK	0.286	0.325	0.402	0.298	0.291	0.309	0.281	0.230	0.225
CH	0.455	0.587	0.755	0.605	0.612	0.572	0.599	0.559	0.699
NL	0.777	0.780	0.796	0.773	0.765	0.771	0.763	0.761	0.776
NO	0.184	0.237	0.280	0.179	0.169	0.187	0.219	0.195	0.268
AT	0.369	0.434	0.572	0.434	0.458	0.350	0.371	0.315	0.332
BE	0.410	0.503	0.695	0.535	0.541	0.533	0.504	0.482	0.581
AU	0.164	0.182	0.188	0.157	0.140	0.125	0.131	0.113	0.117
KR	0.646	0.527	0.670	0.540	0.538	0.616	0.748	0.670	0.571
means	0.389	0.413	0.474	0.394	0.393	0.400	0.416	0.382	0.420

Notes: the statistical size of the confidence intervals  $\alpha$  is set to be 5%, and the number of bootstrapping replication is set to be 999.



Table 5: Bias-corrected efficiency ranking for NIS of 22 countries including RRICS

				BRIC	<i>/</i> U				
	2000	2001	2002	2003	2004	2005	2006	2007	2008
BR	22	21	21	21	20	21	21	21	21
RU	5	8	8	9	10	7	8	9	8
IN	12	9	9	6	5	6	5	5	3
CN	6	3	4	2	2	2	2	2	1
ZA	19	19	20	18	18	18	19	18	19
US	17	17	18	19	19	19	20	20	20
JP	18	18	17	17	16	17	17	17	17
DE	13	11	11	11	11	10	10	10	11
UK	2	6	7	8	7	8	7	7	9
FR	15	16	15	16	15	15	15	15	14
CA	10	14	16	15	17	16	16	14	15
IT	14	13	14	13	12	14	13	13	13
FI	11	12	13	12	14	12	12	12	10
SE	3	2	5	3	3	3	4	4	5
DK	16	15	12	14	13	13	14	16	18
CH	7	4	2	4	4	5	6	6	4
NL	1	1	1	1	1	1	1	1	2
NO	20	20	19	20	21	20	18	19	16
AT	9	10	10	10	9	11	11	11	12
BE	8	7	3	7	6	9	9	8	6
AU	21	22	22	22	22	22	22	22	22
KR	4	5	6	5	8	4	3	3	7
means	8–9	10–11	10–11	10–11	10–11	9–10	9–10	9–10	10–11

It can be seen that the bias-corrected efficiency scores listed in table 4 are all less than their corresponding original observed efficiency scores in table 2. Such a result is quite reasonable since the frontier constructed by bootstrapping pseudo samples are expected to be closer to the real frontier than frontier constructed by the original observed samples. As for the efficiency ranking, only a few countries got a slightly change for 1 or 2 rankings in certain years, while the general situation of NIS efficiency for the 22 countries is basically unchanged.

The calculation results in table 2-5 show that the relative NIS efficiency of the BRICS countries differs a lot from each other in the period of 2000-2008. In general, Russia, India, and China get pretty good scores and rankings with China ranking 2-4 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 of all the selected countries.



The efficiency score and ranking of NIS for G7 countries are not so striking as anticipated, comparing with their leading status in the world economy. Only the United Kingdom gets efficiency scores above mean level for all the 9 years. The second best one among the G7 countries is Germany, whose efficiency scores are only a little bit lower than the mean level for most of the period. While the two biggest economic giants United States and Japan only rank around 17-20, which is not very conformed to expectation. In contrast, some small-sized European economies get good NIS efficiency scores. Netherland almost always rank on the top of all the 22 countries. Sweden ranks among the top 3 for most of the period. Besides, 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 years. As for two Asia-Pacific OECD countries, always Korea ranks on the top, while Australia at the bottom.

# 3 Econometric analysis on factors influencing NIS efficiency

In the previous section 2, the efficiency scores of NIS for 22 countries are calculated with conventional DEA method and the corresponding bootstrapping process. These measurement results can provide information about the NIS (relative) efficiency of the selected 22 countries. However, the factors influencing the NIS efficiency seems to be are of more concern for policymakers. And this section will try to make a further analysis, i.e.,the second stage regression, on the influencing factors of the NIS efficiency.

## 3.1 Potential factors influencing NIS efficiency

It is shown in table 2 and 4 that the NIS efficiency performance of the selected 17 Western countries appeared to be quite different. For instance, Netherland achieves efficiency scores around 0.77, while the United States only around 0.2. At the same time, these Western economies are considered to be technologically similar. Such a paradox means technology is not the only determinant for NIS efficiency. The potential influencing factors may involve many other social-economic elements. As a matter of fact, if the economic characters, such as the economic scale, endowments, developing stage, and etc., of the selected 22 countries were taken into account together with their NIS efficiency performance, we may find some potential connections behind them. Firstly, endowments of natural resources seem to have negative impacts on the NIS efficiency considering the bad rankings of Brazil and Australia, both of which are endowed with abundant natural resources. Secondly, many of the selected countries with high NIS efficiency performance,



such as Netherland, Sweden, South Korea, Belgium, Switzerland, and China, exhibit good openness, which can be inferred from their high dependency ratio on foreign trade.<sup>8</sup> Thirdly, GDP per capita seems to be negatively related to the NIS efficiency performance to some extent. On the one hand, countries with the lowest GDP per capita, like China and India, have quite good NIS efficiency scores and rankings; While on the other hand, some countries with world highest GDP per capita, such as United States and Norway, did not get a good NIS efficiency performance as expected.<sup>9</sup>

It should be aware that the above are merely rough judgements out of intuition. To seek out the possible potential influencing factors systematically and get more convincing judgments, we should rely on the NIS Approach, the New Growth Theory and other innovation relevant theories, and provide a theocratical support for further econometric analysis.

According to the view of NIS Approach and the innovation economics alike, promoting innovation is a systematic engineering, which involves various socialeconomic entities including government agencies, firms, universities and research institutions and etc. The National Innovation System of a country is actually composed of different sub-systems ranging from economic regime, financial structure, infrastructure to educational system, cultural traditions, and so on. And economic development is regarded as the inter-action and co-evolutionary process of these sub-systems (Freeman, 2002; Nelson, 2008).[16] [31] 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 rents from newly created knowledge, to learn from each other's experience, to organize and finance R&D ... "(Aghion and Howitt, 1998, p.1).[2] Therefore, It can be inferred from these arguments that efficiency of NIS would be affected by factors such as governance, market circumstance, firm-level R&D activities, education system, financial structure, informational infrastructure.

Moreover, market size, openness, natural endowments and the development stage of an economy would affect its firm-level innovation activities, and influence the NIS efficiency as well. The transmission mechanisms of how these factors acting on innovation has been studied in many existing literatures. Acemoglu and Linn (2004)[1] argue that greater market size for a particular product implies greater profitability from sales, which would spur a faster innovation. Desmet and

<sup>&</sup>lt;sup>8</sup> 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. And the ratio for China, United States, and Japan are 62.24%, 30.6%, and 34.89%.

<sup>&</sup>lt;sup>9</sup> 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.



Parente (2010)[12] propose a novel mechanism that larger markets would change the price elasticity of demand and lead to more competition, which in turn facilitates the adoption of more advanced technologies. Accordingly, Desmet and Parente (2010) further argue that greater trade openness would promote innovation through this mechanism. Nevertheless, Roper and Love (2010)[34] attribute the benefits in innovation from openness to the improved knowledge diffusion. Papyrakis and Gerlagh (2005)[32] investigate the connection between natural resources and innovation, and argue that an increase in resource income would induce a small proportion of labor force to engage in innovation, which may partly explain the so called "Resources Curse". Bas and Kunc (2009)[4] seem to support this argument with a proof of Chile's copper industry. It is found that Chile contributes 36% of the total copper production in the world but with low expenditure on R&D and almost no patents originated in Chile registered in the USPTO. Such is not a special case for latecomer nations in Latin America. Although the latecomer nations are in an inferior position in innovation compared with the first movers, they also have their own advantages. The lead countries have to maintain their lead through "new-to-the-world" innovation, while the latecomer countries only need focus on technology transfer and diffusion or "new-to-the-country" innovation (Hu and Mathews, 2005; Mathews, 2001[29]). Besides, the aging of population is thought to have negative impact on innovation activities since young people are usually more creative than the old.

#### 3.2 Indicators for influencing factors and pretreatment of data

To test how the potential factors mentioned above may influence NIS efficiency, indicators should be selected as the proxy variable for each factor in advance. Considering the availability of cross-country data, proxy variables are chosen from the indicators in the Data-bank of World Bank and the database of UNESCO Institute for Statistics. See table 6 for details.

Yearly data from 2000 to 2008 for the selected proxy indicators are collected from the previously mentioned two databases. Since the time periods covers only 9 years, there is no need to apply the panel unit root test (Hsiao, 2003, p.298)[23] <sup>10</sup>However, these rough data may not be proper to be used as explanatory variables directly. On the one hand, the number of the listed proxy indicators reaches 25, while the number of the cross-sections is only 22 and less than the number of explanatory variables, which is not allowed in random effect model. On the other hand, some of the available indicators are obviously correlated, which would lead to serial correlation and inconsistent estimation. To reduce the number of explanatory

 $<sup>^{10}</sup>$  As Hsiao (2003) pointed out that panel unit-root test statistics are suggested when N and T are large. Here in this paper, T is fairly small covering only 9 years. Normally, the data would be stable with little fluctuation in such a short period.



variables and eliminate the possible serial correlation, principal factor analysis may be applied to generate fewer independent principal factors substituting the relevant indicators.

Table 6: Potential influencing factors for NIS efficiency and their proxy

indicators									
Influencing factors	Proxy Indicators	Abbreviation							
Demographic structure/aging	Population ages 65 and above (% of total)	AGE							
ICT infrastructure	Internet users (per 100 people)	ITNET							
	Mobile cellular subscriptions (per 100 people)	MOBL							
	Telephone lines (per 100 people)	TEL							
Financial structure	Domestic credit provided by banking sector (% of GDP)	CDBBAN							
	Domestic credit to private sector (% of GDP)	CDTPRV							
	Market capitalization of listed companies (% of GDP)	CAPLST							
Invovlment of firms in R&D	Researchers (FTE) - Business enterprise %	ENTRRE							
	GERD - performed by Business enterprise %	ENTRPGERD							
	GERD - financed by Business enterprise %	ENTRFGERD							
Education	School enrollment, tertiary (% gross)	TEENRL							
	School enrollment, secondary (% gross)	SEENRL							
Market circumstance	Cost of business start-up procedures (% of GNI per capita)	BSCOST							
	Total tax rate (% of commercial profits)	TAXRATE							
	Cost to register property (% of property value)	PRCOST							
Governance	Control of Corruption	CORRUP							
	Government Effectiveness	GOVEFF							
	Political Stability and Absence of Violence/Terrorism	POLSTAB							
	Regulatory Quality	REGULA							
	Rule of Law	LAW							
	Voice and Accountability	VOACCT							
Market size	Proportion of GDP in the World total output (%)	PORGDP							
Openness	Trade (% of GDP)	TRTGDP							
Natural resource endowments	Total natural resources rents (% of GDP)	NRTGDP							
Development phase	GDP per capita to the world average	RGDPPC							

Correlations between relevant indicators are test before the construction of principal factors. And most of the testing results listed in the following tables.

Table 7: Correlations between some of the relevant proxy indicators

	ITNET	MOBL	TEL		CDBBAN	CDTPRV	CAPLST
ITNET	1.0000			CDBBAN	1.0000		
MOBL	0.7098	1.0000		CDTPRV	0.9174	1.0000	
TEL	0.6735	0.4599	1.0000	CAPLST	0.3027	0.3909	1.0000
	ENTRRE	ENTRPGERD	ENTRFGERD		BSCOST	TAXRATE	PRCOST
ENTRRE	1.0000			BSCOST	1.0000		
ENTRPGERD	0.6905	1.0000		TAXRATE	0.3988	1.0000	
ENTRFGERD	0.5739	0.7576	1.0000	PRCOST	0.2699	0.1492	1.0000

**Table 8: Correlations between the proxy indicators of governance** 

	CORRUP	GOVEFF	POLSTAB	REGULA	LAW	VOACCT
CORRUP	1.0000					
GOVEFF	0.9747	1.0000				
POLSTAB	0.9095	0.8950	1.0000			
REGULA	0.9603	0.9593	0.8725	1.0000		
LAW	0.9613	0.9653	0.8672	0.9451	1.0000	
VOACCT	0.8778	0.8667	0.7946	0.8853	0.8777	1.0000

Besides the above two tables, the correlation coefficient between TEENRL and SEENRL are calculated to be 0.7779. It can be inferred from the testing results



that some of the proxy indicators are significantly correlated with each other. And based on the correlation test results, principal components can be constructed for relevant proxy indicators.

**Table 9: Construction of principal components** 

Principal	Constructing equations	Cumulative
components		proportion
commp1	0.6210ITNET+0.5610MOBL+0.5476TEL	0.745
credp1	0.7071CDBBAN+0.7071CDTPRV	0.959
frdp1	0.5527ENTRRE+0.6044ENTRPGERD+0.5738ENTRPFGERD	0.784
edp1	0.7071TEENRL+0.7071SEENRL	0.889
mkp1	0.6519BSCOST+0.5922TAXRATE+0.4735PRCOST	0.519
mkp2	0.8414PRCOST-0.1360BSCOST-0.5230TAXRATE	0.807
govp1	0.42CORRUP+0.42GOVEFF+0.39POLSTAB+0.41REGULA+0.41LAW+0.39VOACCT	0.924

With the principal components constructed above, further panel analysis can be made as the second stage of the semi-parametric DEA method.

#### 3.3 Censored Panel data analysis

The second stage econometric analysis is something particular. As the dependent variable ranges between 0 and 1, it may be better to cope with censored regression. At the same time, the censored regression involves panel data other than the cross section data in ordinary textbooks. Henningsen (2012a)[20] specifies the censored regression model for panel data with individual specific effects as follow.

$$y_{it}^* = x_{it}'\beta + \varepsilon_{it} = x_{it}'\beta + \mu_i + \nu_{it}$$
 (6)

$$y_{it} = \begin{cases} a & y_{it}^* \le a \\ y_{it}^* & a < y_{it}^* < b \\ b & y_{it}^* \ge b \end{cases}$$
 (7)

Here in this paper, the subscript  $i = 1, \dots, N$  represents the individual country, while subscript  $t = 1, \dots, T_i$  indicates the time period,  $T_i$  is the time period for the ith individual,  $\mu_i$  is time-invariant individual specific effect, and  $v_{it}$  the remaining disturbance.

Based on equation (6) and (7), censored regression for panel data can be made through maximum likelihood estimation. Coding with the software package *censReg* developed by Hennigsen (2012a,2012b)[21] in *R* environment, random-effects regression are made using the Gauss-Hermite quadrature. Following the general-to-specific modeling rule proposed by Hendry, all the potential factors are involved in the regression with proper proxy indicators or the principal components constructed. And different regression models are tried to examine the robustness of the regression results. The testing results are exhibited in table 10.



**Table 10: Censored Regression for Panel Data** 

$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Tabl	e 10: Censore	a Regression	ior Panei Data	a
$\begin{array}{c} {\rm age} & \begin{array}{c} (0.049530) \\ -0.02826[***] \\ -0.0355[***] \\ (0.002623) \\ (0.002480) \\ (0.002654) \\ (0.002654) \\ (0.0002654) \\ (0.0003073] \\ (0.000447) \\ (0.000437) \\ (0.000748) \\ (0.000657) \\ (0.000633) \\ (0.000657) \\ (0.000633) \\ (0.000657) \\ (0.0000633) \\ (0.000102) \\ (0.000103) \\ (0.000103) \\ (0.000105) \\ (0.000105) \\ (0.000099) \\ (0.000114) \\ (0.00099) \\ (0.000114) \\ (0.00099) \\ (0.000114) \\ (0.000991) \\ (0.000114) \\ (0.000276) \\ (0.000278) \\ (0.000297) \\ (0.001265) \\ - \\ (0.001265)$		Model 1	Model 2	Model 3	Model 4
$\begin{array}{c} {\rm age} \\ {\rm commp1} \\ {\rm (0.002623)} \\ {\rm (0.002480)} \\ {\rm (0.002648)} \\ {\rm (0.002654)} \\ {\rm (0.00303)} \\ {\rm (0.000303)} \\ {\rm (0.000437)} \\ {\rm (0.000125[***]} \\ {\rm (0.000125[***]} \\ {\rm (0.000125[***]} \\ {\rm (0.000125[***]} \\ {\rm (0.000102)} \\ {\rm (0.000103)} \\ {\rm (0.000103)} \\ {\rm (0.000103)} \\ {\rm (0.000105)} \\ {\rm (0.000099)} \\ {\rm (0.000102)} \\ {\rm (0.000103)} \\ {\rm (0.000099)} \\ {\rm (0.000114)} \\ {\rm (0.000276)} \\ {\rm (0.000278)} \\ {\rm (0.000297)} \\ {\rm (0.00138[]} \\ {\rm -} \\ {\rm -} \\ {\rm (0.000138[]} \\ {\rm -} \\ {\rm -} \\ {\rm (0.000138[]} \\ {\rm (0.00125]} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.0001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.0001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.000125]} \\ {\rm (0.000125]} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.000125]} \\ {\rm (0.00$	(Intercept)	0.31190[***]	0.20240[***]	0.27840[***]	0.19140[***]
$\begin{array}{c} \text{commp1} & (0.002623) & (0.002480) & (0.002654) & (0.003003) \\ 0.00115[**] & 0.00130[!] & 0.00082[] & 0.00073[] \\ (0.000437) & (0.000738) & (0.000657) & (0.00063] \\ \text{credp1} & -0.00125[***] & -0.00126[***] & -0.00107[***] & -0.00105[***] \\ (0.000090) & (0.000102) & (0.000103) & (0.000105) \\ \text{caplst} & -0.00046[***] & -0.00060[***] & -0.00039[***] & -0.00035[***] \\ (0.000099) & (0.000114) & (0.00096) & (0.000094) \\ \text{frdp1} & 0.00510[***] & 0.00595[***] & 0.00365[***] & 0.00345[***] \\ (0.000276) & (0.000278) & (0.000297) & (0.000297) \\ \text{edp1} & -0.00174[***] & - & - & - \\ (0.000363) & - & - & - \\ \text{cenrl} & - & - & (0.00138[] & - \\ - & & (0.000551) & - & - \\ \text{seenrl} & - & - & (0.00138[] & - \\ - & & (0.000551) & - & - \\ \text{seenrl} & - & - & (0.001265) & - \\ \text{mkp1} & -0.00057[] & (0.00630) & (0.00084) & (0.000929) \\ \text{mkp2} & -0.00413[**] & (0.00165[**] & -0.00050[] & -0.0020[] \\ (0.000759) & (0.000630) & (0.000884) & (0.000929) \\ \text{mkp2} & -0.00413[**] & (0.001231) & (0.001356) & (0.001287) \\ \text{govp1} & 0.00373[] & -0.03059[***] & -0.03197[*] & -0.0357[***] \\ (0.007955) & (0.007135) & (0.013480) & (0.009475) \\ \text{rgdpc} & 0.01936[**] & 0.04549[***] & (0.013480) & (0.009475) \\ \text{rgdpp} & 0.00516[.] & 0.00141[] & 0.00231[.] & 0.00240[!] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0052[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0055[**] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \text{trtgdp} & 0.0055[**] & 0.00053[**] & 0.000404) & (0.000391) \\ \text{trtgdp} & 0.0055[**] & 0.00056[**] & 0.00077[**] & 0.00843[**] \\ \text{trtgdp} & 0.0056[**] & 0.00056[**]$		(0.049530)	(0.052380)	(0.073640)	(0.038270)
$\begin{array}{c} \text{commp1} & \begin{array}{c} (0.002623) & (0.002480) & (0.002654) & (0.003003) \\ 0.00115[**] & 0.00130[!] & 0.00082[] & 0.00073[] \\ (0.000437) & (0.000748) & (0.000657) & (0.000633) \\ \text{credp1} & \begin{array}{c} -0.00125[***] & -0.00126[***] & -0.00107[***] & -0.00105[***] \\ (0.000090) & (0.000102) & (0.000103) & (0.000105) \\ \text{caplst} & \begin{array}{c} -0.0046[***] & -0.0060[***] & -0.00039[***] & -0.00035[***] \\ (0.000099) & (0.000114) & (0.00096) & (0.000094) \\ \text{frdp1} & \begin{array}{c} 0.00510[***] & 0.00595[***] & 0.00365[***] & 0.00345[***] \\ (0.000276) & (0.000278) & (0.000297) & (0.000297) \\ \text{edp1} & \begin{array}{c} -0.00174[***] & - & - & - \\ -0.00174[***] & - & - & - \\ \end{array} \\ \text{eenrl} & \begin{array}{c} - & 0.00041[] & - & - \\ - & (0.000551) & - & - \\ \end{array} \\ \text{seenrl} & \begin{array}{c} - & - & 0.00138[] & - \\ - & 0.000551] & - & - \\ \end{array} \\ \text{seenrl} & \begin{array}{c} - & 0.00165[**] & 0.00165[**] & -0.00020[] \\ \end{array} \\ \text{mkp1} & \begin{array}{c} -0.00057[] & 0.00165[**] & -0.00138[] & - \\ - & 0.00057[] & 0.00165[**] & -0.00050[] & -0.00020[] \\ \end{array} \\ \text{govp1} & \begin{array}{c} 0.00057[] & 0.00165[**] & -0.00050[] & -0.00020[] \\ \end{array} \\ \begin{array}{c} 0.000759) & (0.000630) & (0.000884) & (0.000929) \\ \end{array} \\ \text{govp1} & \begin{array}{c} 0.0037[] & -0.03059[***] & -0.03197[**] & -0.03357[***] \\ \end{array} \\ \begin{array}{c} 0.00373[] & -0.03059[***] & 0.001386) & (0.001287) \\ \end{array} \\ \text{rgdpc} & \begin{array}{c} 0.0136[**] & 0.004549[***] & 0.04475[***] & 0.04519[***] \\ \end{array} \\ \begin{array}{c} 0.006227) & (0.008539) & (0.008482) & (0.007117) \\ \end{array} \\ \text{porgdp} & \begin{array}{c} 0.0051[] & 0.00141[] & 0.0023[] & 0.00240[] & 0.00240[] \\ \end{array} \\ \begin{array}{c} 0.00025(**) & 0.00447[**] & 0.00177[***] & 0.00183[**] \\ \end{array} \\ \begin{array}{c} 0.0022[] & 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[**] \\ \end{array} \\ \begin{array}{c} 0.0022[] & 0.00052[**] & 0.00147[**] & 0.00177[***] \\ 0.00023(*) & 0.0003674 & (0.001499) & (0.00136) \\ \end{array} \\ \begin{array}{c} 0.0052[**] & 0.0044[**] & 0.00177[***] & 0.00183[**] \\ \end{array} \\ \begin{array}{c} 0.052[**] & 0.0044[**] & -0.0045[!] & -0.00423[*] & -0.00423[*] \\ \end{array} \\ \begin{array}{c} 0.052[**] & 0.0044[***] & -0.0045[!] & -0.00423[*] \\ \end{array} \\ \begin{array}{c} 0.052[**] & 0.0044[***] & -0.0045[!] & -0.00423[*] \\ \end{array} \\ \begin{array}{c} 0.0052[**] & 0.00632) & (0.007775) & (0.06985) \\ \end{array} \\ \begin{array}{c} 0.052$	age	-0.02826[***]	-0.03555[***]	-0.02358[***]	-0.02513[***]
$\begin{array}{c} \text{credp1} & \begin{array}{c} (0.000437) \\ -0.00125[***] \\ -0.00126[***] \\ 0.000090) \\ (0.000102) \\ (0.000103) \\ (0.000103) \\ (0.000105) \\ (0.000105) \\ (0.000105) \\ (0.00035[***] \\ (0.000099) \\ (0.000114) \\ (0.000096) \\ (0.000276) \\ (0.000278) \\ (0.000297) \\ (0.0001265) \\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -$		(0.002623)	(0.002480)	(0.002654)	(0.003003)
$\begin{array}{c} {\rm credp1} & -0.00125[***] \\ {\rm (0.000090)} \\ {\rm (0.000102)} \\ {\rm (0.000103)} \\ {\rm (0.000103)} \\ {\rm (0.000105)} \\ {\rm (0.000099)} \\ {\rm (0.000102)} \\ {\rm (0.000099)} \\ {\rm (0.000014)} \\ {\rm (0.000096)} \\ {\rm (0.000096)} \\ {\rm (0.000096)} \\ {\rm (0.000096)} \\ {\rm (0.0000276)} \\ {\rm (0.000278)} \\ {\rm (0.000278)} \\ {\rm (0.000297)} \\ {\rm (0.000185]} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {\rm -} \\ {\rm -} \\ {\rm -} \\ {\rm (0.001265)} \\ {\rm -} \\ {$	commp1	0.00115[**]	0.00130[!]	0.00082[]	0.00073[]
$\begin{array}{c} {\rm caplst} & (0.000090) \\ {\rm caplst} & -0.00046[***] \\ {\rm c} -0.00046[***] \\ {\rm c} -0.00060[***] \\ {\rm c} -0.00039[***] \\ {\rm c} -0.00039[***] \\ {\rm c} -0.00039[***] \\ {\rm c} -0.00035[***] \\ {\rm c} -0.00035[***] \\ {\rm c} -0.00036[***] \\ {\rm c} -0.00365[***] \\ {\rm c} -0.00365[***] \\ {\rm c} -0.00365[***] \\ {\rm c} -0.00276) \\ {\rm c} -0.000278) \\ {\rm c} -0.000297) \\ {\rm c} -0.00297) \\ {\rm c}$		(0.000437)	(0.000748)	(0.000657)	(0.000633)
$\begin{array}{c} {\rm caplst} & \begin{array}{c} -0.00046[***] \\ (0.000099) \\ (0.000114) \\ (0.000096) \\ (0.000096) \\ (0.000096) \\ (0.0000976) \\ (0.000276) \\ (0.000278) \\ (0.000277) \\ (0.000297) \\ (0.000138[] \\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -$	credp1	-0.00125[***]	-0.00126[***]	-0.00107[***]	-0.00105[***]
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		(0.000090)	(0.000102)	(0.000103)	(0.000105)
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	caplst	-0.00046[***]	-0.00060[***]	-0.00039[***]	-0.00035[***]
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		(0.000099)	(0.000114)	(0.000096)	(0.000094)
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	frdp1	0.00510[***]	0.00595[***]	0.00365[***]	0.00345[***]
teenrl $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		(0.000276)	(0.000278)	(0.000297)	(0.000297)
teenrl $ -0.00041[]$ $         -$	edp1	-0.00174[***]	_	_	_
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		(0.000363)	_	_	_
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	teenrl	_	-0.00041[]	_	_
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		_	(0.000551)	_	_
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	seenrl	_	_	-0.00138[]	_
$\begin{array}{c} \text{mkp2} & \begin{array}{c} (0.000759) & (0.000630) & (0.000884) & (0.000929) \\ -0.00413[**] & 0.00006[] & -0.00592[***] & -0.00576[***] \\ (0.001431) & (0.001231) & (0.001356) & (0.001287) \\ 0.00373[] & -0.03059[***] & -0.03197[*] & -0.03357[***] \\ (0.007955) & (0.007135) & (0.013480) & (0.009475) \\ \text{rgdppc} & 0.01936[**] & 0.04549[***] & 0.04475[***] & 0.04519[***] \\ (0.006227) & (0.008539) & (0.008482) & (0.007117) \\ \text{porgdp} & 0.00516[.] & 0.00141[] & 0.00231[.] & 0.00240[!] \\ (0.003280) & (0.003674) & (0.001499) & (0.001376) \\ \text{trtgdp} & 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[***] \\ (0.000257) & (0.000543) & (0.000404) & (0.000391) \\ \text{nrtgdp} & -0.00040 & -0.00348[**] & -0.00405[!] & -0.00423[*] \\ (0.000957) & (0.001123) & (0.002338) & (0.001926) \\ \hline \\ \log \Sigma \nu & -2.876[***] & -2.882[***] & -2.886[***] & -2.879[***] \\ (0.05507) & (0.09632) & (0.07275) & (0.06985) \\ \hline \\ \text{Log-likelihood} & 261.5701 & 262.8887 & 263.2175 & 258.1071 \\ \hline \end{array}$		_	_	(0.001265)	_
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	mkp1	-0.00057[]	0.00165[**]	-0.00050[]	-0.00020[]
$\begin{array}{c} \text{govp1} & (0.001431) & (0.001231) & (0.001356) & (0.001287) \\ 0.00373[] & -0.03059[***] & -0.03197[*] & -0.03357[***] \\ (0.007955) & (0.007135) & (0.013480) & (0.009475) \\ \text{rgdppc} & 0.01936[**] & 0.04549[***] & 0.04475[***] & 0.04519[***] \\ (0.006227) & (0.008539) & (0.008482) & (0.007117) \\ \text{porgdp} & 0.00516[.] & 0.00141[] & 0.00231[.] & 0.00240[!] \\ (0.003280) & (0.003674) & (0.001499) & (0.001376) \\ \text{trtgdp} & 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[***] \\ (0.000257) & (0.000543) & (0.000404) & (0.000391) \\ \text{nrtgdp} & -0.00040 & -0.00348[**] & -0.00405[!] & -0.00423[*] \\ (0.000957) & (0.001123) & (0.002338) & (0.001926) \\ \hline \log \sum \mu & -1.644[***] & -1.656[***] & -1.691[***] & -1.694[***] \\ (0.03170) & (0.03091) & (0.02949) & (0.03450) \\ \log \sum \nu & -2.876[***] & -2.882[***] & -2.886[***] & -2.879[***] \\ (0.05507) & (0.09632) & (0.07275) & (0.06985) \\ \hline \text{Log-likelihood} & 261.5701 & 262.8887 & 263.2175 & 258.1071 \\ \hline \end{array}$		(0.000759)	(0.000630)	(0.000884)	(0.000929)
$\begin{array}{c} \text{govp1} & \begin{array}{c} (0.001431) & (0.001231) & (0.001356) & (0.001287) \\ 0.00373[ ] & -0.03059[***] & -0.03197[*] & -0.03357[***] \\ (0.007955) & (0.007135) & (0.013480) & (0.009475) \\ \end{array} \\ \text{rgdppc} & \begin{array}{c} 0.01936[**] & 0.04549[***] & 0.04475[***] & 0.04519[***] \\ (0.006227) & (0.008539) & (0.008482) & (0.007117) \\ \end{array} \\ \text{porgdp} & \begin{array}{c} 0.00516[ \ . \ ] & 0.00141[ \ ] & 0.00231[ \ . \ ] & 0.00240[ \ ! \ ] \\ (0.003280) & (0.003674) & (0.001499) & (0.001376) \\ \end{array} \\ \text{trtgdp} & \begin{array}{c} 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[***] \\ (0.000257) & (0.000543) & (0.000404) & (0.000391) \\ \end{array} \\ \text{nrtgdp} & \begin{array}{c} -0.00040 & -0.00348[**] & -0.00405[ \ ! \ ] & -0.00423[ \ *] \\ (0.000957) & (0.001123) & (0.002338) & (0.001926) \\ \end{array} \\ \hline \\ \log \sum \mu & \begin{array}{c} -1.644[***] & -1.656[***] & -1.691[***] & -1.694[***] \\ (0.03170) & (0.03091) & (0.02949) & (0.03450) \\ \end{array} \\ \log \sum \nu & \begin{array}{c} -2.876[***] & -2.882[***] & -2.886[***] & -2.879[***] \\ (0.05507) & (0.09632) & (0.07275) & (0.06985) \\ \end{array} \\ \text{Log-likelihood} & \begin{array}{c} 261.5701 & 262.8887 & 263.2175 & 258.1071 \\ \end{array} $	mkp2	-0.00413[**]	0.00006[]	-0.00592[***]	-0.00576[***]
$\begin{array}{c} \text{rgdppc} & (0.007955) & (0.007135) & (0.013480) & (0.009475) \\ 0.01936[**] & 0.04549[***] & 0.04475[***] & 0.04519[***] \\ (0.006227) & (0.008539) & (0.008482) & (0.007117) \\ \text{porgdp} & 0.00516[.] & 0.00141[] & 0.00231[.] & 0.00240[!] \\ (0.003280) & (0.003674) & (0.001499) & (0.001376) \\ \text{trtgdp} & 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[***] \\ (0.000257) & (0.000543) & (0.000404) & (0.000391) \\ \text{nrtgdp} & -0.00040 & -0.00348[**] & -0.00405[!] & -0.00423[*] \\ (0.000957) & (0.001123) & (0.002338) & (0.001926) \\ \\ \log \Sigma \mu & -1.644[***] & -1.656[***] & -1.691[***] & -1.694[***] \\ (0.03170) & (0.03091) & (0.02949) & (0.03450) \\ \\ \log \Sigma \nu & -2.876[***] & -2.882[***] & -2.886[***] & -2.879[***] \\ (0.05507) & (0.09632) & (0.07275) & (0.06985) \\ \\ \text{Log-likelihood} & 261.5701 & 262.8887 & 263.2175 & 258.1071 \\ \end{array}$		(0.001431)	(0.001231)	(0.001356)	(0.001287)
$\begin{array}{c} \text{rgdppc} & \begin{array}{c} (0.007955) & (0.007135) & (0.013480) & (0.009475) \\ 0.01936[**] & 0.04549[***] & 0.04475[***] & 0.04519[***] \\ (0.006227) & (0.008539) & (0.008482) & (0.007117) \\ \text{porgdp} & \begin{array}{c} 0.00516[.] & 0.00141[] & 0.00231[.] & 0.00240[!] \\ (0.003280) & (0.003674) & (0.001499) & (0.001376) \\ \text{trtgdp} & \begin{array}{c} 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[***] \\ (0.000257) & (0.000543) & (0.000404) & (0.000391) \\ \text{nrtgdp} & \begin{array}{c} -0.00040 & -0.00348[**] & -0.00405[!] & -0.00423[*] \\ (0.000957) & (0.001123) & (0.002338) & (0.001926) \\ \end{array} \\ \log \sum \mu & \begin{array}{c} -1.644[***] & -1.656[***] & -1.691[***] & -1.694[***] \\ (0.03170) & (0.03091) & (0.02949) & (0.03450) \\ \log \sum \nu & \begin{array}{c} -2.876[***] & -2.882[***] & -2.886[***] & -2.879[***] \\ (0.05507) & (0.09632) & (0.07275) & (0.06985) \\ \end{array} \\ \text{Log-likelihood} & \begin{array}{c} 261.5701 & 262.8887 & 263.2175 & 258.1071 \\ \end{array} $	govp1	0.00373[]	-0.03059[***]	-0.03197[ * ]	-0.03357[***]
$\begin{array}{c} \text{porgdp} & (0.006227) & (0.008539) & (0.008482) & (0.007117) \\ 0.00516[\ .\ ] & 0.00141[\ ] & 0.00231[\ .\ ] & 0.00240[\ !\ ] \\ (0.003280) & (0.003674) & (0.001499) & (0.001376) \\ \text{trtgdp} & 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[***] \\ (0.000257) & (0.000543) & (0.000404) & (0.000391) \\ \text{nrtgdp} & -0.00040 & -0.00348[**] & -0.00405[\ !\ ] & -0.00423[\ *\ ] \\ (0.000957) & (0.001123) & (0.002338) & (0.001926) \\ \hline log \sum \mu & -1.644[***] & -1.656[***] & -1.691[***] & -1.694[***] \\ (0.03170) & (0.03091) & (0.02949) & (0.03450) \\ log \sum v & -2.876[***] & -2.882[***] & -2.886[***] & -2.879[***] \\ (0.05507) & (0.09632) & (0.07275) & (0.06985) \\ Log-likelihood & 261.5701 & 262.8887 & 263.2175 & 258.1071 \\ \hline \end{array}$		(0.007955)	(0.007135)	(0.013480)	(0.009475)
$\begin{array}{c} \text{porgdp} & \begin{array}{c} (0.006227) & (0.008539) & (0.008482) & (0.007117) \\ 0.00516[\ .\ ] & 0.00141[\ ] & 0.00231[\ .\ ] & 0.00240[\ !\ ] \\ (0.003280) & (0.003674) & (0.001499) & (0.001376) \\ \text{trtgdp} & \begin{array}{c} 0.00152[***] & 0.00147[**] & 0.00177[***] & 0.00183[***] \\ (0.000257) & (0.000543) & (0.000404) & (0.000391) \\ \text{nrtgdp} & \begin{array}{c} -0.00040 & -0.00348[**] & -0.00405[\ !\ ] & -0.00423[\ *\ ] \\ (0.000957) & (0.001123) & (0.002338) & (0.001926) \\ \hline \\ \log \sum \mu & \begin{array}{c} -1.644[***] & -1.656[***] & -1.691[***] & -1.694[***] \\ (0.03170) & (0.03091) & (0.02949) & (0.03450) \\ \log \sum \nu & -2.876[***] & -2.882[***] & -2.886[***] & -2.879[***] \\ (0.05507) & (0.09632) & (0.07275) & (0.06985) \\ \hline \\ \text{Log-likelihood} & 261.5701 & 262.8887 & 263.2175 & 258.1071 \\ \hline \end{array}$	rgdppc	0.01936[**]	0.04549[***]	0.04475[***]	0.04519[***]
$\begin{array}{c} \text{trtgdp} & (0.003280) \\ \text{0.00152[***]} \\ 0.00152[***] \\ (0.000257) \\ \text{intgdp} \\ \end{array} \begin{array}{c} 0.00147[**] \\ 0.0004040 \\ -0.00348[**] \\ (0.0002338) \\ \end{array} \begin{array}{c} 0.00147[**] \\ 0.000405[!] \\ -0.00405[!] \\ -0.00405[!] \\ -0.00423[*] \\ \end{array} \\ \begin{array}{c} 0.00183[***] \\ 0.000391) \\ \end{array} \\ \begin{array}{c} 0.002338) \\ \text{log} \Sigma \mu \\ \end{array} \begin{array}{c} -1.644[***] \\ (0.03170) \\ \text{log} \Sigma \nu \\ -2.876[***] \\ -2.882[***] \\ \end{array} \begin{array}{c} -2.886[***] \\ -2.886[***] \\ (0.07275) \\ \end{array} \begin{array}{c} -2.879[***] \\ (0.06985) \\ \end{array} \\ \text{Log-likelihood} \end{array} \begin{array}{c} 261.5701 \\ \end{array} \begin{array}{c} 262.8887 \\ \end{array} \begin{array}{c} 263.2175 \\ \end{array} \begin{array}{c} 258.1071 \\ \end{array} \end{array}$		(0.006227)	(0.008539)	(0.008482)	(0.007117)
$\begin{array}{c} \text{trtgdp} & \begin{array}{c} (0.003280) \\ 0.00152[***] \\ 0.00147[**] \\ 0.00147[**] \\ 0.00177[***] \\ 0.00177[***] \\ 0.000401 \\ 0.000957) \\ \hline \\ (0.000957) \\ \hline \\ (0.001123) \\ \hline \\ (0.002338) \\ \hline \\ (0.001926) \\ \hline \\ (0.001926) \\ \hline \\ (0.03170) \\ \hline \\ (0.03170) \\ \hline \\ (0.05507) \\ \hline \\ (0.09632) \\ \hline \\ (0.09632) \\ \hline \\ (0.07275) \\ \hline \\ (0.07275) \\ \hline \\ (0.07275) \\ \hline \\ (0.06985) \\ \hline \\ (0.06187) \\ (0.000391) \\ (0.002338) \\ (0.001926) \\ \hline \\ (0.03450) \\ (0.03450) \\ -2.876[***] \\ (0.05507) \\ (0.09632) \\ \hline \\ (0.07275) \\ (0.06985) \\ \hline \\ 258.1071 \\ \hline \end{array}$	porgdp	0.00516[.]	0.00141[]	0.00231[.]	0.00240[!]
$\begin{array}{cccccccccccccccccccccccccccccccccccc$		(0.003280)	(0.003674)	(0.001499)	(0.001376)
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	trtgdp	0.00152[***]	0.00147[**]	0.00177[***]	0.00183[***]
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		(0.000257)		(0.000404)	(0.000391)
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	nrtgdp	-0.00040	-0.00348[**]	-0.00405[!]	-0.00423[ * ]
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		(0.000957)	(0.001123)	(0.002338)	(0.001926)
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\log \sum \mu$	-1.644[***]	-1.656[***]	-1.691[***]	-1.694[***]
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$					
Log-likelihood     (0.05507)     (0.09632)     (0.07275)     (0.06985)       262.8887     263.2175     258.1071	$\log \sum v$				
Log-likelihood 261.5701 262.8887 263.2175 258.1071	<del>_</del>				
	Log-likelihood				
		16	16	16	15

Notes:(1)'\*\*\*', '\*\*', '\*', '!' and '.' in the bracket represent the significance of 0.0001, 0.001, 0.01, 0.1 and 0.15 respectively; (2) numbers in the parentheses are the standard errors for corresponding estimations.

The regression results in this table show that the explanatory variables exhibit good robustness with stable regression coefficients. Most of the proxy variables (including constructed principal components) has significant impacts on the NIS efficiency performance in at least one regression model. And the regression results



of some proxy explanatory variables like "age", "commp1", "frdp1", "rgdppc", "trtgdp", and etc are particulary satisfactory. Most of these variables show good significance and robustness across different models, and the corresponding regression coefficient sign are conformed to our expectation as well. These provides empirical supports for the previous theoretical analysis and arguments in section 2.

Firstly, demographic structure would influence the NIS efficiency performance with the bias-corrected efficiency score negatively affected by the proxy indicator of aging. This confirms the hypothesis that young people are more creative than the old.

Secondly, NIS efficiency is significantly influenced by the ICT infrastructure. Country with higher coverage of ICT infrastructure would have a better NIS efficiency 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.

Thirdly, the NIS efficiency performance is affected by R&D and innovation activities of firms. The regression results show that the proxy variable "frdp1" would bring positively impacts on the bias-corrected efficiency score. From the view of innovation economics, firm is the most active and important element in an innovation system. The more firms were involved in innovation activities, the more efficient should the NIS be.

Fourthly, the explanatory variables of "trtgdp" and "porgdp" get significant and positive regression coefficients, which confirms the argument that larger economic size and higher degree of openness would be helpful to form a more efficient NIS. As has been discussed, larger economic size and higher dependent ratio means a bigger domestic and international market and greater potential profits, which would be a spur for innovation. Besides, large potential market would facilitate the commercialization of new technology. It would be easier for innovative activities to gain the benefit of economy of scale and economy of scope in such a circumstance.

Fifthly, the explanatory variable of "nrtgdp" gets significant but negative regression coefficients. As a matter of fact, an economy highly dependent on natural resources might be short of incentives for innovation activities, which would in turn reduce its NIS efficiency. And this may act as a possible explanation for the so called "Resources Curse".

The estimating results of proxy variables for factors like development stage, financial structure, market circumstance, and governance are only partly consistent with our previous theoretical inferences.

It has been discussed that the latecomer economies may have some advantages in innovation as they only need to focus on technology "new-to-the-country", while the leading economies have to endeavor on technology "new-to-the-world" which is far more difficult and may sacrifice the efficiency. And the NIS performances

# **Economics** Discussion Paper

of China, India, U.S, and Japan seem to support this judgement. However, the estimating coefficient for the proxy variable "rgdppc" is positive, opposite to expectation. This may be explained from two facets. On the one hand, the leading countries have first mover advantage as well, which may offset the advantages of latecomers to some extent. On the other hand, the proxy variable "rgdppc" is also connected with market size. For a given amount of population, highly developed economies with higher GDP per capita would generate greater demand than less developed one.

Both of the two proxy variables for financial structure get a negative estimating coefficient with high significance. The constructed principal component "credp1" stands for the proportion of banking credit in the economy, which is not a favorite financing channel for innovation activities. And the corresponding regression result is quite reasonable. However, it seem to counter the intuition for the proxy variable of "cap1st" to have negative impacts on NIS efficiency since it represents the maturity of capital market. And a well operated capital market is a prerequisite for the development of venture capital, which is vital for the financing of innovation. A possible explanation is the exist channel of venture capital is mainly the Growth Enterprise Market (or the Second Board Market) for small and medium sized high-tech companies. Only the market capitalization in Second Board Market would positively affect the NIS efficiency.

The estimating coefficients of the proxy variables for market circumstance and governance are not always significant, and their robustness is not very ideal either. This may be attributed to the nature of the corresponding proxy variables. The original indicators for market circumstance got invariant value for several consecutive years, while that for governance are themselves composite index evaluated from various aspects. Nevertheless, it may still support the arguments that the market circumstance and governance of a country would influence the NIS efficiency.

Education is the only potential factor that is statistically unrelated to the NIS efficiency. Different proxy variables as had been tried, none of them exhibits a significant estimating result. As we know education system would affect NIS efficiency through accumulation in human capital, which could be regarded as the source of creativeness and innovation. A possible explanation is the secondary and tertiary enrollment rate of the selected countries are all at a fairly high level, particularly for the 17 OECD member countries (see table 11).



Table 11: School enrollment rate for 22 countries

IUDI	2007		2008	Countries
		CEELIDI		GEELID!
	TEENRL	SEENRL	TEENRL	SEENRL
BR	30.01	81.54	34.44	81.54
RU	75.04	83.98	77.19	84.81
IN	13.48	57.03	13.48	60.02
CN	22.05	73.99	22.69	76.09
SA	30.76	71.43	31.88	73.05
US	81.62	88.23	82.92	88.31
JP	57.87	97.97	58.03	98.26
DE	59.06	91.34	59.58	92.15
UK	58.99	91.33	57.42	93.23
FR	54.66	98.31	54.58	98.49
CA	69.47	91.13	70.27	91.49
IT	67.11	92.42	67.20	94.65
FI	93.79	96.84	94.44	96.45
SE	74.53	99.13	71.05	99.21
DK	80.30	89.59	78.05	89.91
CH	47.19	84.70	49.40	84.73
NL	60.09	88.57	60.60	88.34
NO	75.95	96.55	73.19	95.82
AT	50.32	98.91	54.71	98.54
BE	62.10	86.43	62.97	86.49
AU	75.02	87.51	77.00	87.97
KR	96.08	96.45	98.09	95.46

# 3.4 Further analysis on NIS efficiency for each BRICS countries

Although most of the potential factors exhibit significant influence on the NIS efficiency statistically, the most decisive factors for each country are quite different. Here, based on the previous regression results and the data for some of original indicators (see table 12), further analysis is to be made on how individual factor affects the NIS efficiency of each BRICS country in detail.

For China, the high efficiency score and good ranking are mainly due to its huge economic size, high trade openness, and the active participation of firms in R&D and innovation activities. In the year 2008, the GDP of China is 6.64% of the world total output, much higher than those of the other BRICS countries. At the same time, China also has a fairly high trade openness with the dependency ratio on foreign trade to be 66%, ranking the second among the BRICS countries. As for the firm-level R&D and innovation activities, the three proxy indicators, the "ENTRRE", "ENTRPGERD" and "ENTRFGERD", reach 69%, 73% and 72%



respectively, much higher than the other BRICS countries. Moreover, China is still in a take-off stage according to the income level per capita, and its industrialization process is far from fulfilled. Thus, there are some late comer advantages for China to improve the innovation capacity. Nevertheless, China still has much room for progress in the fields of ICT infrastructure, education system, market circumstance and governance. And its dependency ratio on natural endowments is in a quite high level comparing with other countries selected in this paper. Moreover, China is stepping into the aging society, and its demographic structure is no longer young. 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 may be attributed to the young demographic structure and its huge late-comer advantages since India seems still in the early stage of take-off. Besides, the big economic size is another important element that contributes positively to its NIS efficiency. As for the other relevant factors, India still has much too be improved.

Russia has great advantages in ICT infrastructure and national educational level among the BRICS countries, which are even comparable to those of the world most developed nations. However, Russia is highly dependent on its natural resources in recent years. The governance level of Russia government is far from satisfactory. And the aging of population is very serious.

The badly ranking of Brazil can be ascribed 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, economic size, and the still young demographic structure.

As for the South Africa, the low efficiency of NIS is mainly due to the low coverage of ICT infrastructure and the low participation of enterprises in R&D. Besides, South Africa has no advantages in economic size and education system as well. However, the market circumstance, the governance level, and the dependency ratio on foreign trade of South Africa are obviously better than those of the other BRICS countries. Besides, South Africa has the youngest demographic structure among all the 22 selected countries.



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

Tuble 71 bo	THE OI	tile a	uu III	_000	ioi iu			101115	TID CI		c j
	BR	RU	IN	CN	ZA	US	JP	DE	UK	FR	CA
AGE	6.6	13.3	4.8	7.9	4.4	12.6	21.4	20.0	16.3	16.6	13.6
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	2.0	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	0.5	0.6	1.0
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
AGE	20.1	16.5	17.7	15.9	16.7	14.7	14.7	17.0	17.2	13.4	10.4
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	7.0	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	1.0	1.0	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

In the previous sections of this paper, the two-stage semi-parametric DEA method is applied to calculate NIS efficiency scores and analyze the potential influencing factors for 22 countries including the five BRICS countries. The time period covers from 2000 to 2008. In the first stage, a constant returns to scale DEA model is chosen to calculate the relative NIS efficiency scores with the observed data of innovation inputs and outputs in national level. A bootstrapping process is further adopted to generate the bias-corrected NIS efficiency scores considering the



corresponding data generation process (DGP). A censored panel regression model is implemented in the second stage to analyze factors affecting NIS efficiency with the bias-corrected efficiency scores as the dependent variable. The efficiency calculation and the empirical test results can be summarized as follow:

- (1) The BRICS are very different in their NIS efficiency performance. China, India and Russia have relatively high efficiency score and good ranking, while Brazil and South Africa perform badly, ranking almost at the bottom among the 22 selected countries.
- (2) Influencing factors of NIS efficiency involve a lot of elements, including demographic structure, ICT infrastructure, firm-level R&D and innovation activities, economic and market size, trade openness, reliance on natural resources, financial structure, market circumstance, and governance level. This is conformed to the relevant arguments of NIS Approach and the New Growth Theory.
- (3) Firm is the most active and important actor in the process of innovation, and firm-level innovation activities are vital to the NIS efficiency. The more firms are involved in R&D and innovation activities, the better would the NIS efficiency be. The age structure of population affects the NIS efficiency as well, since young people are thought to be more creative than the old.
- (4) ICT infrastructure and trade openness would affect the speed and scope of knowledge diffusion, and in turn affect NIS efficiency. Furthermore, economic size and degree of openness determine the scale of domestic and international market for firms. The economy of scale and economy of scope are much easier to be achieved in a bigger market, and in turn influence the NIS efficiency indirectly. Moreover, overdependence on nature resources would reduce the innovation capacity and NIS efficiency.
- (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 level 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 the "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.



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