National Innovation Systems (NIS): Theories, Practices and Empirical Investigation with Non-Parametric Partial Frontier Analysis

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Abstract

The main goal of this paper is to investigate national innovation systems' (NIS) input-output components and model a robust efficiency measurement using the partial frontier order-α technique. We evaluate the innovation performance of 20 emerging and developed countries from the point of view of technical efficiency. Given that the innovation process is one of the main drivers for knowledge-based economic growth, it is clear that we need innovation policies based on rigorous quantitative analysis. Most of the previous NIS studies are descriptive and little emphasis is given to complex analysis. This study makes an important contribution using the partial frontier order-α technique whereby we rank the countries based on outliers-corrected estimation rather than only conventional DEA/FDH efficiency which often causes a dimensionality problem. The efficiency scores obtained from this technique demonstrate outliers-free results of benchmark countries. We suggest some key NIS policy implications that can be learned from the innovation leaders the study identifies.

Keywords: National innovation systems, order-α, partial frontier, outliers, NIS policies, Non-parametric

1. Introduction

The National Innovation System (NIS) concept has recently become one of the most powerful policy tools for designing innovation driven development strategies. The National Innovation System (NIS) of a country is composed of different sub-systems ranging from economic regime, financial structure and physical infrastructure to the education system, cultural traditions and so on. Thus, economic development is regarded as the interaction and co-evolutionary process of these sub-systems (Freeman, 1987; Nelson, 1993).

Lundvall (1992, p.36) defines "the NIS as the elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge and are either located within or rooted inside the borders of a nation state. In other words, the "innovation system is defined as the network of agents and set of policies and institutions that affect the introduction of technology that is new to the economy".

NISs have been used as frameworks for clustering strategies in the context of encouraging existing networked industries to foster innovation for competitive growth (Porter, 1990). The NIS approach is fundamentally rooted in two branches of economic theory; namely evolutionary theory and

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neo-institutional theory (Cai, 2011). In both these theories it is argued that innovation and technological change is an endogenous process, which means that new ideas are derived within the economic system rather than being introduced exogenously. Recently, many researchers have argued there are certain shortcomings in the empirical application of NIS theories into practice.

This is because most of the NIS studies are theoretical and descriptive while other studies use small samples of countries to understand innovation policy trends in cross-country comparisons (Balzat and Hanusch, 2004). This provides a motivation for current research to extend traditional NIS studies by the use of robust parametric or non-parametric techniques to understand the application of NIS theories into reality.

Furman et al. (2002) investigated NIS using formal empirical analysis termed 'national innovative capacity'. This empirical analysis is based on three NIS theories, namely endogenous growth theory (see e.g. Romer, 1990), Porter's theory of international competitiveness (Porter, 1990), and the national systems of innovation introduced by Lundvall (1992). Furman's national innovative capacity illustrated a country's innovation ability to produce and commercialize new ideas over a long period of time. He also argued that innovation culture depends on the strength of a nation's common innovation infrastructure, industrial clusters, and the strength of linkages between these two. A number of variables were used to quantify these three components of innovation in the empirical analysis (Cai, 2011). However, this approach has been criticized for its small variable and sample size in the empirical analysis. Nevertheless after this study, considerable progress has been made in the empirical study of NIS (Balzat and Hanusch, 2004). However, according to appendix 1 and the above discussion, recent trends in the literature reflect that there is still much room for further improvement in NIS approach using robust empirical methods. A consent to accept NIS as a national development model seems to have been reached after the above discussion. The question is how to set benchmarking strategy for the follower countries. Which model or policy should follower regions follow: Silicon Valley model, one of the western European success model, model of Asian tigers for instance Singapore, Korea or hybrid Japanese model? A more fundamental question is whether NIS polices are a panacea for a nation or a region?

In order to fill the gap in the empirical study of NIS, this study applies a robust nonparametric partial frontier order-α analysis to measure the innovation performance of twenty selected emerging and developed economies. The objective of this method is to measure the comparative efficiency of a set of potential innovation input-output variables (see Afzal and Lawrey 2012d).

DEA (Data Envelopment Analysis)/FDH (Free Disposal Hull)/Partial frontier analyses are non-parametric methods and do not require a pre-specified functional form to analyze the efficiency of a particular Decision Making Unit (DMU), here the countries. Moreover, the Partial frontier order-α technique, in particular, improves the DEA/FDH analysis by correcting bias and outliers in the data. Therefore we consider this new method for rigorous analysis. Our approach can be used to rank the best practice countries using potential influencing NIS input-output factors and we believe in order to follow a successful innovation policy, there is need to benchmark best practice innovation systems from cross-country comparison. This paper has six sections; following introduction a theoretical review of NIS is presented in Section 2, research design and methodology in Section 3, data and variables in Section 4, results and discussion in Section 5 and finally Section 6 draws some conclusions and policy implications.

2. Theories Behind the NIS Approach

In last two decades, concepts like the knowledge-based economy (KBE), national/regional innovation systems, information economy, digital economy or new economy have appeared that have significantly influenced science and technology policies. The OECD (1996), World Bank (2002) and APEC (2000) have identified the existence of the knowledge-based economy and yet the question remains to what extent these concepts have any solid theoretical base (Afzal and Lawrey, 2012a, 2012b, 2012c. 2012d; Godin, 2006).

An economy of ideas or innovation was in existence long before the first industrial revolution and had been contributing to the intellectual, spiritual and economic wealth of communities since the dawn of civilization. However, much knowledge was poorly distributed and inaccessible to the vast majority of people (Rooney et al, 2003; Dolfsma, 2001; Lundvall, 1992; Nelson, 1993; Godin, 2006; Boettke, 2002; OECD, 1996; WBI, 2002; APEC, 2000). Suitable and adequate institutions to advance and diffuse knowledge were not sufficiently developed to facilitate large scale networking of knowledge as is the case now in the form of national or regional innovation systems (Lundvall, 1992; Nelson, 1993). Knowledge as something that exists within and between people (tacit and codified) and that is dependent on meaning through interpretation by individuals and groups distinctively differs from data and information.

In recent years, economists have tried to articulate the theories of the knowledge-based economy and innovation policies under two schools of thought, namely new growth theories and evolutionary economic theories. Evolutionary economic theories (also referred to as system theories) explain fundamentally the national and regional innovation systems of a country. The underlying assertions of evolutionary economic theories are the perception that innovation and technological and organizational changes are key drivers of long-run economic growth (ABS, 2002). Rather than viewing the market as in a static condition, this school specifically acknowledges that the market is constantly changing and firms need to innovate in order to adapt to the changing environment.

The core idea of evolutionary or national/regional innovation system theories is that knowledge flows within the whole system by interacting with different micro and macroeconomic agents, for instance research institutes, government, universities, venture capitalists etc. The innovation does not follow a linear path; rather it tracks a non-linear route from the non-commercial sector (such as research institutes, universities) to the commercial sector. The concept of evolutionary economics was given full recognition by the Austrian school in the early twentieth century (Metcalfe, 1995). The Austrian school stated that knowledge and innovation systems play a central role in the evolutionary economic model and are also a crucial part of a competitive market environment. Joseph A. Schumpeter (1883-1950) was the prominent contributor to evolutionary economics (ABS, 2002) and developed the concept of innovation-based competition in modern KBEs. The new growth theory, endogenous technological change and growth, and long run sustainable development by increasing returns to capital are the offspring of Schumpeter's theories of economic development.

The concept of an innovation driven economy is also derived from the endogenous growth model established by Paul Romer (1990, 1986, 1994) and developed by W. Schultz, Gary Becker, Robert Lucas (1988), Helpman (1991), Aghion and Howitt (1992) which showed that technological advancement can be the most important determinant for sustainable economic growth. These modern growth economists argued that there are increasing returns to scale to capital investment (rather than constant returns) because of the externality created by the stock of knowledge and innovation.

3. Research Design and Methodology for Empirical Analysis

In this particular study, we apply a conditional partial order-α (alpha) frontier approach because of the non-linear, interactive nature of innovation system. Non-parametric approaches generally have a clear advantage as the estimated functions can take almost any form. Additionally, real world observations are often difficult to be described in a single dimension or dependent variable as the core definition of NIS has suggested innovation is not a linear phenomenon, but a combination of institutions and their variables. Hence, one of the strengths of the non-parametric technique is that it allows for easy handling of multiple input factors as well as multiple innovativeness outcomes or output factors. In contrast, the consideration of innovativeness measures as multiple dependent variables is particularly difficult to achieve relying on conventional regression techniques (Broekel, 2008; Sanders, Lamoen and Bos, 2011).

3.1 Order-α Partial Frontier Approach

In contrast to the FDH or DEA approach (refer to Charnes, Cooper and Rhodes, 1978; Banker, Charnes and Cooper, 1984; Afzal and Lawrey, 2012b, 2012c, 2012d), the order-α partial frontier approach follows the mechanism of FDH/DEA methods, but rather than using minimum input consumption among the available peers as the benchmark, order-α uses the (100-α) percentile. For α = 100 order-α coincides with FDH, while for α < 100 some DMUs will be classified as 'super-efficient' and these super-efficient DMUs are not be enveloped by the estimated production possibility frontier. That is, just like m for an order-m efficiency estimate, α can be regarded as a modified parameter that determines the number of super-efficient DMUs. Since calculating order-α efficiency scores does not involve a re-sampling procedure like order-m, this method is much faster and smoother (see Aragon et al, 2005; Daouia and Simar, 2007; Simar and Wilson, 2000).

The advantages of order-α non-parametric efficiency analysis are:

1. Sensitivity to outliers is reduced by allowing for super-efficient DMUs
2. Super-efficient DMUs are located beyond the production-possibility frontier
3. Super-efficiency: (input-oriented) efficiency score > 1 (in our case)
4. Increasing the value of α reduces the number of DMUs classified as “super-efficient”
5. In the absence of outliers: the share of super-efficient DMUs should decrease smoothly

Because the partial frontier (e.g. order-α) is not enveloping all observations, it is less sensitive to outliers and noise in the data and solves the well-known problem of ‘curse of dimensionality[3]’ that often plagues non-parametric estimators (Wheelock and Wilson, 2008). Mathematically a two efficiency estimate looks like;

Order-alpha input-oriented efficiency:

$$\hat{\theta}_i^{Ainput} = P_{\substack{100-\alpha \\ j=1,\dots,N \mid yIj \geq yIi \forall I}} \{\max_{m=1,\dots M} \{\frac{X_{mj}}{X_{mi}}\}\} \quad (1)$$

Order-alpha output-oriented efficiency:

$$\hat{\theta}_i^{Aoutput} = P_{\alpha\, j=1,\dots,N \mid X_{mj} \leq X_{mi \forall m}} \{\min_{i=1,\dots L} \{\frac{Y_{Ij}}{Y_{Ii}}\}\} \quad (2)$$

3 Distance usually relates to all the attributes and assumes all of them have the same effects on distance. Wrong classification due to presence of many irrelevant attributes is often termed as the curse of dimensionality.

4. Data and Variables

The influencing factors of NIS efficiency (Table 1) involve many elements, including demographic structure, ICT infrastructure, firm-level and government R&D and innovation activities, economic and market size, trade openness, reliance on natural resources, financial structure, market circumstances and government level. This conforms to the relevant arguments of the NIS approach and the New Growth Theory (Balzat and Hanusch, 2004). The firm is the most active and important factor in the process of commercialization of innovation which is represented by the output variable high-tech exports as a percentage of total manufacturing exports. The more firms that are involved in R&D and innovation activities, the better would be the NIS efficiency. This is according to the arguments of the Austrian school and Lundvall (1992) who argued that the free interaction of knowledge can create and disseminate economically useful knowledge that develops the wealth of nations (Afzal and Lawrey, 2012a). Schumpeter named this process the creative destruction of innovation process.

Table 1. Potential influencing factors for NIS efficiency and their proxy input-output indicators for year 2012

Input factors	Proxy Indicators	Abbreviation	Source of variable
Demographic structure	Population ages 15 to 65 (% of total) as labor force	Lab	World Development Indicators (WDI) 2012
ICT infrastructure	Computer users per 1000	CU	World Development Indicators (WDI) 2012
Financial structure	Domestic credit provided by banking sector (% of GDP)	DCP	World Development Indicators (WDI) 2012
Research and Development	R&D expenditure % GDP	RDE	World Development Indicators (WDI) 2012
Education	School enrollment, secondary (% gross)	SE	World Development Indicators (WDI) 2012
Market circumstance	Cost of business start-up procedure (% of GNI per capita)	CBS	World Development Indicators (WDI) 2012
Governance	Regulatory quality	RQ	World Competitiveness Yearbook (WCY) 2012
Openness	Trade (% of GDP)	TO	Penn Table version 0.7
Natural Resources endowments	Total natural resources rents (% of GDP)	TNR	World Development Indicators (WDI) 2012
Output indicator			
Economically valuable knowledge creation	High-tech export as % total manufacturing exports	HTE	World Development Indicators (WDI) 2012

The age structure of the population affects NIS efficiency, because young people are thought to be more creative than the old people. 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 markets for firms. Economies of scale and economies of scope are much easier to be achieved in a bigger market, and in turn influence NIS efficiency indirectly (Balzat and Hanusch, 2004). Moreover, overdependence on natural resources would reduce innovation capacity and NIS efficiency.

Recent studies indicate that generally patent activity, publications per thousand population and high-tech export variables are considered as output factors of NIS (Kotsemir, 2013). However, the core idea of evolutionary or national/regional innovation system theories is that knowledge flows within the system between research institutes, government, universities, and venture capitalists in a non-linear direction from the non-commercial sector to the commercial sector (ABS, 2002; Lundvall, 1992). Accordingly, in this study we consider high-tech export as a percentage of total manufacturing exports as an NIS output indicator to represent commercialization or economically value-added knowledge in line with Lundvall (1992) NIS definition.

Variables such as property rights, transparent government, political stability, a dependable legal and regulatory system, and competitive and open markets drive the generation of technological knowledge in best-practice countries. This is a very important issue in terms of creation of new ideas to generate greater wealth of nations (Hailin, Xiaohui and Wang, 2012; Marion and Grazia, 2007; Cowen and Tabarrok, 2009).

In this paper, we chose 20 countries for international comparisons, and divided them into three types: emerging South East Asian nations, Emerging Next Eleven and Scandinavian innovation driven economies. Our sample of 20 emerging knowledge-based countries have moderately common characteristics of dependable regulatory quality and a high degree of trade openness. This raises the issue of how efficiency scores vary among the countries that have a moderate regulatory quality and high trade openness in NIS systems. Table 2 shows the descriptive statistics of our sample year 2012 (cross-section sample). In previous studies (Afzal and Humayara, 2013; Afzal and Lawrey, 2012c) we have applied DEA time series analyses with similar types of variables. Moreover, our recent study have addressed the time lag issue in detail while analyzing the knowledge economy variables (Afzal and Lawrey, 2014).

Due to the availability of most recent data of all the countries, we have preferred to use 2012 as our reference year in this study.

Table 2. Descriptive statistics of the input-output variables

	TO	TNR	SE	RQ	RDE	LAB	HTE	DCP	CU	CBS
Mean	116.0	3.4644	88.63	5.38	1.98	67.30	21.71	130.78	565.73	9.2950
Median	88.720	2.343	92.23	5.02	1.97	67.0	16.09	132.8	798.91	3.300
Maximum	409.2	13.14	103.2	7.89	3.96	73.58	67.82	325.9	937.8	56.50
Minimum	29.31	0.0000	63.21	2.90	0.08	60.9	1.9	36.4	39.7	0.0
Std. Dev.	106	3.9	11.9	1.6	1.2	3.2	16.2	66.8	372.4	13.4
Observations	20	20	20	20	20	20	20	20	20	20

5. Results and Discussion

The results presented in Table 3 are generated by the software program FEAR (Frontier Efficiency Analysis with R) that implements the conditional and unconditional order-α partial frontier analysis developed by Simar and Wilson (1998) and Wilson (2008). The efficiency scores are estimated using an input oriented order-α with nine inputs and one output. The decision making units (DMU) with efficiency scores > 1 are 'super- efficient' while DMUs with scores less than that are inefficient.

Table 3. Efficiency scores and ranking (FEAR software results)

α = 0.85			α = 0.90		
Ranking/ Benchmarks	Country	Order-α= 0.85	Ranking/ Benchmarks	Country	Order-α= 0.90
1	Singapore	1.12	1	S. Korea	1.03
2	China Mainland	1.004	2	Hong Kong	1.00
3	S. Korea	1.002	2	Japan	1.00
4	Malaysia	1.00	2	China Mainland	1.00
4	Philippines	1.00	2	Malaysia	1.00
4	Switzerland	1.00	2	Philippines	1.00
7	Sweden	0.75	2	Singapore	1.00
8	Norway	0.70	2	Taiwan	1.00
9	Finland	0.67	2	Switzerland	1.00
10	Hong Kong	0.66	10	Thailand	0.82
11	New Zealand	0.55	11	Sweden	0.75
12	Australia	0.46	12	Finland	0.71
12	India	0.46	13	Norway	0.70
14	Taiwan	0.38	14	India	0.68
15	Brazil	0.34	15	New Zealand	0.57
16	Japan	0.32	16	Indonesia	0.52
17	Thailand	0.31	17	Australia	0.50
18	Indonesia	0.27	18	Brazil	0.43
19	Turkey	0.17	19	Turkey	0.18
20	Denmark	0.001	20	Denmark	0.0012

Generally speaking, the choice of α depends on [100- α]th (αth) percentile with 0 ≤ α ≤ 100 rather as minimum (maximum) as efficiency benchmark. Increasing the value of α reduces number of DMUs classified as “super-efficient”. In the absence of outliers: share of super-efficient DMUs should decrease smoothly. Therefore this research applied 0.85 and 0.90 as order of α which is close to maximum i.e. 1. DMUs still classified “super-efficient” for α≥αdisc (point of discontinuity) most likely outliers (Tauchmann, 2011). Therefore, theoretically if we increase the value of α, it reduces number of DMUs classified as “super-efficient” (Daouia and Simar, 2007). Eventually we have selected α=0.85 and 0.90 respectively in order to observe the theoretical relevance in our sample countries. In the α=0.85 case, the number of super-efficient countries is three, namely Singapore, China and South Korea, while in the case of α=0.90, the number reduces and South Korea stands as the sole super-efficient DMU/country. The three least efficient countries when α=0.85 are Indonesia, Turkey and Denmark while Brazil, Turkey and Denmark are the bottom three when α=0.90. This is an interesting empirical findings where efficiency scores and rankings are not only changed for the top or bottom three countries, but also for other countries in the sample, significantly when α=0.90. Hence, we rank the countries with α=0.90 because it appears to be less sensitive to outliers.

This is an important finding for national innovation policy analysis using robust empirical analysis. We need a robust empirical study because if innovation follower countries improve their efficiency, they need to know how they are positioned in NIS performance. Moreover, in order to improve NIS efficiency, followers can pursue the innovation policies of the frontier countries or innovation leaders by efficiently using NIS input-output variables. In future studies, this new non-parametric order-α application can be used with larger samples to see how efficiency varies among countries.

5.1 NIS Policy Practice

In the section we investigate some notable NIS policies taken by our best practice/benchmark countries using the potential NIS input-output variables. For instance, Japan at its initial stage of NIS focused on three major components e.g. education expenditure and enrollment, reverse engineering and joint ventures with western companies. They created a group of business clusters named Keiretsu that government deliberately favored with subsidies, bank loans and infrastructure facilities. These business clusters are called the successor of the pre-war Zaibatsu regime. South Korea followed a similar strategy as the Japanese at the initial stage of its development during the 1960-70 periods when the Koreans formed a cluster of large firms called Chaebol which were strongly supported by the government. Chaebol is a group of business associations that are controlled by the large family-oriented businesses which have strong ties to the government. They enjoy easy access to domestic and foreign loans, investment and special treatment by the government.

Unlike Japan and South Korea, China and Taiwan rely on SMEs which have also been supported by the government. The Government of China formed a strong relationship with R&D institutions such as universities and high-tech export firms to develop their NIS. Japan, South Korea and China all followed a form of government guided capitalism at their initial stage of NIS development making the best use of NIS input-output variables (Rosenberg, 2013). From this evidence it does not appear to be critical to what extent the government is involved in the economy as such. Hence, this discussion indicates that all best practice countries from our calculation have bought into theories from economic geography, evolutionary economics and cluster approach that innovation does matter in regional or national development context. In other words, NIS and clusters are one of the panaceas for a national development. These countries are following policy prescription to develop strong regional and national innovation systems by giving emphasize on Techno parks, high-tech clusters. We believe the efficient use of NIS input-output variables that we have highlighted in our study can lead to overall economic development by creating employment opportunities, increasing skilled human resources, widening the market for high-tech products by a high degree of trade openness, maintaining a good financial structure and spurring ICT-driven growth. Initially our best practice countries, for instance South Korea and Singapore, followed the policies of frontier regions in NIS e.g. Silicon Valley, Route 128 or Japanese Keiretsu cluster models to build a similar strategy in their respective countries. Hence, our methodology and policy discussion also indicates that there is a need for frontier analysis for successful NIS policy implementation in the follower nations.

6. Concluding Remarks and Policy Implications

It is important for policy makers to be able to see how their countries are positioned in NIS input-output efficiency in relation to other countries. Thus we have used a most recent nonparametric technique of order-α partial frontier efficiency scores that explain which are the most efficient countries in NIS combinations from our data sample of 2012. We have also highlighted some strategies taken by innovation leaders, or efficient countries, while developing their national innovation systems. Inefficient countries could study these strategies and the policies of the most efficient countries in order to improve their ability to transform NIS innovation inputs into NIS outputs. Policy measures should be directed to the efficiency performance of NIS activities in the transformation of knowledge economies. If innovation resources are underutilized, further investment in innovation input factors may offset efficient economic progress. In order to maintain and sustain a national innovation system, emerging knowledge economies can follow some additional policies.

First, countries looking to develop as knowledge-based economies should emphasize that in order to create economic growth; the potential factors of a national innovation system should be created and organized efficiently. Second, government involvement through the provision of appropriate incentives is the key to developing national and regional innovation systems. For instance, in the case of Japan, South Korea, China, Singapore and Taiwan, the business culture and institutions are good at connecting innovators with business people and venture capitalists. In our best practice countries, potential innovators know that if their developments have a good chance of making it to the market. The incentive to discover new ideas is correspondingly strong (Cowen and Tabarrok, 2009). Government of follower countries can follow these examples and support the innovation culture in their society.

Third, market size is important for high-tech goods. Larger markets mean increased incentives to invest in research and development and as India, China, and other large markets including the United States grow, companies in South Korea, Taiwan and Singapore increases their worldwide R&D investments and sales.

Finally, according to Grossman and Helpman (1991) and Aghion and Howitt (1992), products improve along with quality ladders. Every new product is highly substitutable for a similar product of lower quality, but less substitutable for other products. Hence, the future challenges for developed and emerging knowledge economies depend on their quality management of innovative high-tech products. If they can win in the quality improvement battle, the economy will continue grow and create wealth for society.

It is hoped that the contributions of this research are to give an overview of the current trend of national innovation system research, use a robust non-parametric order-α partial frontier approach to identify best practice nations in NIS context and make policy suggestions for the less than efficient countries. It was argued that a partial frontier such as order-α approach is more applicable for analyzing a national innovation system framework than the traditional FDH (Free Disposal Hull) approach due to the advantage of overcoming outliers or extreme points from the sample. We apply a cross-section approach and use the latest dataset from World Development Indicators-2012, World Competitiveness Yearbook-2012 and Penn world table for our analysis. We believe that due to the application of the new non-parametric technique the results of our study are reliable and that this could be taken into account for future policy formation to enhance the development of national innovation systems. In general the small size of country samples is the main limitation of this research along with all reviewed studies. Such limitation highlights the problems with international database availability for authors or with the set of variables 'very high requirements' (data on these variables are available for a very small sample of countries).

In future research, we recommend conditional order-m and α (alpha) frontier analysis to observe the comparison of our sample regions with regions adopting similar values in an external factor z, e.g. the externality variable. In order to achieve this (conditional order-α analysis), the alpha observations are not drawn randomly but are instead conditional on the external factors. We believe it is worth looking into how results vary when we put condition on the selection of in order- α frontier analysis. Besides future work could also attempt with order-m or hyperbolic order-frontier estimation and a large sample of countries to examine how efficiency differs among countries and the effect on the reduction of outliers and extreme points in the data while doing empirical studies on national innovation systems.

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Appendix 1. Key literature on NISs using non-parametric analysis

Authors	Countries studied	Inputs and outputs used in NIS model	Key results	Shortcomings
Cai, Y (2011)	Brazil, Russia, India, China and South Africa along with 17 countries	Input: R&D expenditure as % of GDP, total R&D personnel; Output: Patents per 1000 population, scientific articles per 1000 pop. and high-tech exports as % of total manufacturing exports	Russia, China and India have relatively high efficiency scores while Brazil and South Africa rank at the bottom	Use DEA and panel regression model without correcting the bias or outlier problem in the sample.
Pires, O.J., Garcia, F (2012)	75 countries	SFA productivity analysis	Productivity of nations depends on allocation and scale efficiency	SFA is a parametric model and often require specific probability distribution and functional form, DEA does not require any of these
Sanders, L.J.W.M; Lamoen, V.R.C.R; Bos, B.W.J (2011)	Netherlands	SFA method, R&D input and output at firm level analysis	Innovation follows Schumpeter mark II hypothesis and scale efficiency	SFA cannot take multiple dependent variables while DEA can. No macro level analysis in the study as NIS is highly depend on central government policy
Freeman, C (1987)	Theoretical perspective	Theory and history of NIS concept	NIS definition	No empirical analysis to support the current trends of NIS
Mathews, A.J.; Hu, C.M. (2005)	Selected East Asian countries	Descriptive and regression analysis, R&D expenditure as major input and patents considered as major output of innovation	Late comer countries have advantages to catch up with the developed countries	Parametric analysis often depend on specific functional form and need specific sample distribution, in contrast non parametric such as DEA does not require those
Tangchitpiboon, T; Chairatana, A.P.; Intarakumnerd, P. (2001)	Thailand	Descriptive analysis	Thailand should focus on factors contributing to the long-running perpetuation of weak and fragmented NIS	No robust empirical analysis
Monroe, T (2006)	Singapore and Malaysia	Descriptive analysis	Connect with creative talent wherever it resides and build relationships that enable all parties to innovate more rapidly and to get better faster by working with each other	No robust empirical analysis
T.-W. Pan, S.-W. Hung & W.-M. Lu (2010)	33 Asian and European countries	DEA, bilateral DEA model	The overall technical inefficiencies of the NIS activities in these countries are primarily due to the pure technical inefficiencies rather than the scale inefficiencies	There is no correction of bias or outliers in the sample.