

PERFORMANCE OF NATIONAL INNOVATION SYSTEMS
DURING THE GLOBAL CRISIS: A CROSS-COUNTRY ANALYSIS

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Thesis Abstract

Gözde Nur Kazazoğlu, “Performance of National Innovation Systems during the Global Crisis: A Cross-Country Analysis”

After the 2007 financial crisis and with the rise of information and communication technologies, the main driver of sustainable growth shifted from capital accumulation to innovation driven and knowledge based economy. This focus on knowledge and innovation driven countries and regions to constitute innovation strategies and plans in order to use scarce resources efficiently and maximize the value added by innovation to economic and social welfare.

In this study, two alternative models with two different approaches of Data Envelopment Analysis (DEA) under two different specifications (*input-oriented* and *output-oriented*) are utilized to trace innovation performance across 58 countries during the global crisis from 2007 to 2012.

The empirical evidence reveals that the negative effects of 2008 crisis are reflected on innovation efficiencies of countries in 2008 in the base model and 2009 in the lag model. In addition, grouping countries according to their GDP and GDP per capita and implementing two different models show that there could be differences in the innovation efficiency results since the DEA model shows the innovation efficiency in comparison with the other countries' efficiency. Lastly, with the data it is proven that higher GDP or higher GDP per capita do not lead to high innovation efficiency.

Tez Özeti

Gözde Nur Kazazoğlu,

“Küresel Kriz Döneminde Ulusal Inovasyon Sistemlerinin Performansı:

Ülke Karşılaştırmaları”

2007 krizi sonrası, bilgi ve iletişim teknolojilerinin de yaygınlaşmasıyla beraber sürdürülebilir büyümenin ana faktörü sermaye birikiminde inovasyona ve bilgi odaklı ekonomi olmaya kaymıştır. Bilgi ve inovasyon üzerindeki bu odaklanma, ülkeleri ve bölgeleri ulusal ve bölgesel inovasyon stratejileri ve planları yaparak kısıtlı kaynakları verimli kullanmaya ve inovasyonun ekonomik ve sosyal refah üzerindeki katma değerini artırmaya yönlendirmiştir.

Bu çalışmanın amacı girdi odaklı sabit getirili ve girdi odaklı değişken getirili veri zarflama tekniği ve iki ayrı model ile 58 ülkenin global kriz dönemi olan 2007-2012 yılları arasındaki ulusal inovasyon verimliliğini ölçümlemektedir.

Yapılan ampirik çalışmalar göstermektedir ki 2007 finansal krizinin etkileri temel modeled 2008 yılında, zaman gecikmesinin olduğu modelde de 2009 yılında ortaya çıkmaktadır. Buna ek olarak, ülkeleri GSMH ve kişi başına düşen milli gelire göre gruplandırarak yaptığımız çalışmalar inovasyon verimliliği sonuçlarında farklılıklar göstermiştir. Bu bulgu veri zarflama analizinin karşılaştırmalı sonuçlar verdiğini kanıtlamaktadır. Son olarak, bu çalışma gayri safi milli hasılanın ya da kişi başına düşen gelirin büyüklüğü beraberinde inovasyon verimliliğini getirmediğini göstermiştir.

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ACRONYMS/ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
BCC	Banker, Charner and Cooper
BERD	Business Expenditure on Research and Development
BRICS	Brazil-Russia-India-China-South Africa
BRIICS	Brazil-Russia-India-Indonesia-China-South Africa
CCR	Charnes, Cooper and Rhodes
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EPO	European Patent Office
EU	European Union
EUROSTAT	European Union Statistical Office
FDI	Foreign Direct Investment
G7	Canada, USA, Japan, UK, Germany, France, Italy
GCI	Global Competitiveness Index
GCR	Global Competitiveness Report
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GII	Global Innovation Index
GOVERD	Government Intramural Expenditure on Research and Development
HERD	Higher Education Expenditure on Research and Development
ICT	Information and Communication Technology
IER	Innovation Efficiency Ratio

IT	Information Technology
IT-CI	Information Technology Industry Competitiveness Index
ITU	International Telecommunication Union
IUS	European Innovation Union Scorecard
KBE	Knowledge Based Economy
MAVINS	Mexico-Australia-Vietnam-Indonesia-Nigeria-South Africa
MIS	Measuring Information Society
NAFTA	North America Free Trade Area
NIS	National Innovation System
NRI	Network Readiness Index
OECD	Organization for Economic Cooperation and Development
R&D	Research and Development
SCI	Science Citation Index
SJR	Scientific Journal Rankings
SME	Small and Medium Size Enterprise
STI	Science, Technology and Industry Scoreboard
TAI	Technology Achievement Index
TSI	Turkish Statistical Institute
UK	United Kingdom
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSTAT	United Nations Statistics
USA	United States of America
VRS	Variable Return to Scale
WB	World Bank

CHAPTER ONE

INTRODUCTION

After the recent financial turmoil, the world, with an average economic growth of 2.08% between 2007 and 2012, takes the notion of innovation as the basis of the growth and development. The slowdown in the growth and mass production caused by the crisis needed to be stimulated by research and development, which, it was hoped, would lead to innovation and sustainable growth.

In order to increase productivity, developed countries started to give more importance to a knowledge-based economy and to innovation, while developing countries started to aim at deepening their ICT infrastructure and skills and increasing their research and development expenditures to increase foreign direct investment inflow and to maintain the high growth rates which they had achieved during the crisis period.

In that context, this study underlines the role and the definition of a knowledge-based economy, its relationship to innovation and national innovation efficiency by analyzing the inputs used and outputs created after the 2007 financial crisis.

In the second chapter, various definitions and characteristics of knowledge and knowledge-based economies will first be explained in detail. Definitions of innovation and its evolution will be explained and the importance of national innovation systems will be shown.

In the third chapter, reasons to measure knowledge and various methods of measuring knowledge and innovation efficiency will be discussed by giving examples from globally used indices.

In the fourth chapter, a review of the existing literature on measuring innovation efficiency will be provided. The fifth chapter discusses the methodology and the data used in the study. The sixth chapter introduces the DEA model for measuring the innovation efficiency ratios of 58 countries after the crisis by using different assumptions and models. The final chapter presents policy recommendations and the conclusion.

This study provides an overview of the impacts of crisis on innovation efficiency of countries and may serve as a course of action for policymakers by giving room for comparison with other countries included in the study.

CHAPTER TWO

KNOWLEDGE-BASED ECONOMY

In this introductory chapter, an overview of the knowledge-based economy (KBE) is discussed by explaining the evolution towards the knowledge-based economy from classical production functions, the various definitions of KBE and its characteristics. Then the definitions of innovation and evolution of innovation are discussed. The chapter concludes with detailed information and a definition of national innovation system.

Classical Production Functions to Knowledge Based Economy

With the rise of the use of information and communication technologies (ICT) and with the 2009 world financial crisis, rather than orthodox production and consumption economy, a new type of economy gained importance, one which is based on diffusion of know-how and technology. Based on economic and social welfare augmentation through the pillars of human capital, entrepreneurship, innovation, creation and diffusion of technology, knowledge based economy brings a breath of fresh air to the existing exogenous growth theories.

The world economy has been in a period referred to as the ‘information age’ with the diffusion of ICT technologies. The shift from the traditional industry that started with the Industrial Revolution during the late 18th century has changed the

appearance of the economic order. Rather than the lasting Fordist production lines which aim at mass production with an automation process of workers, in the so-called information age, the rise of information-intensive industries and high technology engender a great need for competitiveness. From individuals to countries, from the private sector to the public sector, all actors acknowledged that competitiveness is the key to success, and in order to maintain sustainable growth rates and to survive in the market, one should not just adapt and adopt new technologies but should also create innovation and human capital.

This increasing significance of innovation and technology may be considered under the rise of post-Fordism in the late 20th century. Rather than workers working on a simple and automated production line to realize the mass consumption habits of the society, post-Fordism depends on the idea of small batch production, flexible specialization and the advantages of the information technologies. In addition, flexibility and skill in labor gained importance while sectorial clustering and industrial districts started to compose.

According to the Kondratiev (1925), global economic history and its future consists of business cycles that are long cycles of fifty or more years. These cycles, also called as Kondratiev waves, were first accounted for on the basis of capital investment dynamics that later turned into technological innovations.

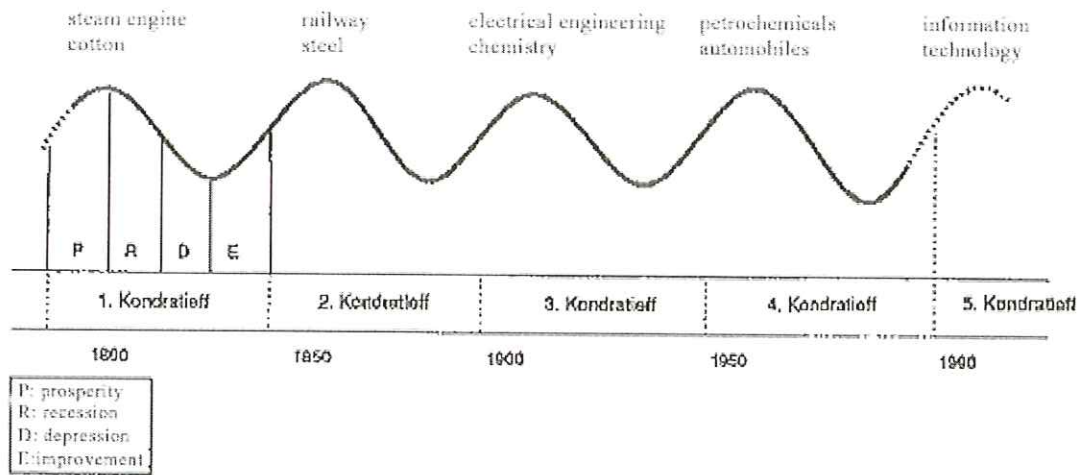


Figure 1. Kondratieff waves in timeline (Aivazov and Kobayakov, 2008)

Kondratieff emphasized in 1925 that during the recession of long waves, an especially large number of important discoveries and inventions in production techniques and communication are made, which are usually applied on a large scale only at the beginning of the next long upswing.

The rise of post-Fordism and the long waves of Kondratieff, reshaped the idea of creative destruction of Schumpeter. In 1939, Schumpeter redefined the long waves of Kondratieff and argued that each business cycle was driven by technological innovation. Creative destruction, for Schumpeter (1939), is the process of industrial mutation and change creating a new economic structure while incessantly destroying the existing (old) one, thus always revolutionizing the economic structure from within.

Within this approach every Kondratieff wave is associated with a certain leading sector (or leading sectors), technological system or technological style (Korotayev and Grinin, 2012). Each wave represents and coincides with major economic or industrial turmoil such as the third Kondratieff wave, which is sometimes characterized as 'the age of steel, electricity, and heavy

engineering' coinciding with World War I. The fourth wave, which coincides with the world economic growth, takes in the age of oil, the automobile and mass production. Finally, the current fifth wave is described as the age of information and telecommunications (Papenhausen, 2008), whereas the forthcoming sixth wave is sometimes supposed to be connected first of all with nano- and biotechnologies (Lynch, 2004; Dator, 2006).

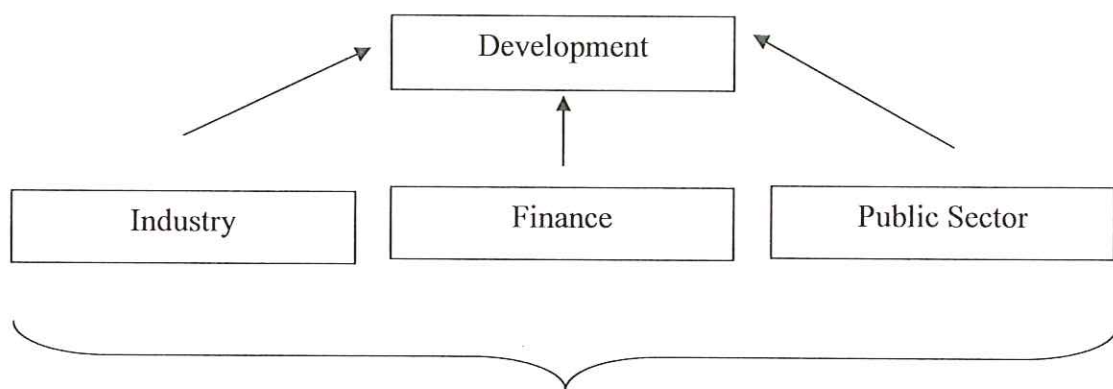
Table 1. Long waves and their phases identified by Kondratiev (Grinin et al., 2012)

Long Wave Number	Long Wave Phase	Beginning Dates	Ending Dates
One	Upswing	The end of the 1780s	1810-1817
	Downswing	1810-1817	1844-1851
Two	Upswing	1844-1851	1870-1875
	Downswing	1870-1875	1890-1896
Three	Upswing	1890-1896	1914-1920
	Downswing	1914-1920	1939-1950
Four	Upswing	1939-1950	1968-1974
	Downswing	1968-1974	1984-1991
Five	Upswing	1984-1991	2008-2010?
	Downswing	2008-2010?	?

Assuming that the driving force of economic growth is knowledge rather than capital accumulation, the newly trending Neo-Schumpeterian economics puts a strong emphasis on knowledge, innovation and entrepreneurship at the micro level (individual) and also underlines the importance of Marshall's conception of meso-economics which takes place between the macro and the micro levels of economic analysis (Hanusch and Pyka, 2007). In Neo-Schumpeterian economics, innovation competition takes the place of price competition as the coordinating mechanism of interest. Although pricing strategies are still considered significant, they are not central when one considers the driving forces of economic development. Since in economic reality, every process cycle has an end, innovations are the key

responsible factors for setting new process circles and limiting conditions whereas prices are responsible only for limiting the existing conditions (Hanusch and Pyka, 2007).

Neo-Schumpeterian economics deals mainly with the uncertainty of the future with three main pillars or actors in the economy as indicated in Figure 2. Industry, finance and the public sector are dominoes; one mistake by any of them can hinder the development of the whole economic system. That is why, according to the Neo-Schumpeterian approach, not only technological innovations but institutional, organizational, social and political innovations are the key pillars in a knowledge-based economy (Hanusch, 2007).



Orientation Toward the Future: Uncertainty

Figure 2. The three pillars of comprehensive Neo-Schumpeterian economics (Hanusch, 2005)

Definitions of Knowledge Based Economy

Friedman, in 2005, mentioned that the world is getting flatter, especially since the 1980s. According to Friedman, there are ten flatteners that he conceptualized as milestones of the global playing field:

1. Collapse of the Berlin Wall in 1989
2. Netscape went public in 1995
3. Workflow software that linked machines together without humans
4. Uploading information
5. Outsourcing services and manufacturing
6. Offshoring to increase competitiveness
7. Increasing supply-chaining efficiency as Walmart did
8. Insourcing between companies
9. Informing and increasing the number of search engines
10. The steroids which include wireless, voice over internet, and file sharing.

Friedman and Mandelbaum (2011) argued that with increased use of ICT, the world moves from the stage of a flat world to the stage of hyperconnectivity. In this new stage, people do not just easily access any kind of information they desire; they also create their own knowledge by continuous production and distribution through technology.

This rapid transformation from an industrial economy to a knowledge economy brings some key definitions to light.

Fritz Machlup, as the first economist to identify knowledge as an economic resource, describes knowledge as a commodity and information source (Boettke, 2002). For Machlup, information is knowledge only if it is communicated and used., Machlup's definition of knowledge includes all kinds of knowledge such as scientific, daily and religious knowledge (Bodin, 1998). Distinguishing five types of knowledge, Machlup (1962) categorizes knowledge as practical knowledge,

intellectual knowledge, pastime knowledge, spiritual knowledge and accidentally acquired knowledge.

On the other hand, Demarest (1997) defines knowledge as the actionable information embodied in the set of work practices, theories-in-action, skills, equipment, processes and heuristics of the firm's employees.

Quah (2009) provides main characteristics of knowledge in three different properties. He first emphasizes that production of knowledge and knowledge products are uncertain, meaning that an increase in the input does not create a certain increase in the output. The invention and the implementation process of knowledge is uncertain and unknown. Then he underlines that knowledge and knowledge products are superstar dynamics, which means that for any hard product, the buyer pays for the physical material plus the implementation, but in knowledge products, he argues, multiple implementations does not require physical material thus 'instances of a specific knowledge product beyond the first takes zero price in a well-functioning market'. He lastly emphasizes the infinite expansibility of knowledge, meaning the interminableness in impact with an increasing number of users and underlines that knowledge is expandable disrespecting the geographical distance. Agreeing with Quah, Houghtan and Sheehan (2000) and Stiglitz (1999) argue that once knowledge is made public, expansiveness comes along with more users. In addition, Stiglitz (1999) underlines that once the knowledge becomes a pure public good, it is hard to prevent public usage.

According to Warsh (2006) and Foray (2006), intellectual property rights can be one solution to the non-excludability of knowledge. Foray (2006) argues intellectual property rights are important for granting temporary exclusive rights to the inventor

but the main economic challenge raised by the patent system is to keep a balance between the social objective of ensuring efficient use of knowledge, once it has been produced, and the objective of providing ideal motivation to the private producer.

Justifying that knowledge is essentially a public good and that retaining knowledge for one's own advantage is hard, Brinkley (2006) indicates that knowledge is the ultimate economic renewable, meaning that the stock of knowledge is not depleted by use and that the value added by knowledge comes about by increasing share and usage of it.

Since there does not exist a one-size fits all definition of knowledge, the extended definition of a knowledge economy varies across institutions and actors.

The Organisation for Economic Co-operation and Development (OECD, 1996) defines a knowledge economy as an economy which is directly based on the production, distribution and use of knowledge and information, while Powell and Snellman (2004) describe a knowledge economy as production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance with equally rapid obsolescence. Smith (2002) argues that the OECD's definition of a knowledge economy is a good example of the problem of the term since every economy is based on knowledge to a certain degree and it is hard to differentiate which one is directly based on knowledge.

Going even further, Quah (1999) refers to knowledge-based economy as weightless economy, meaning the four categories in KBE which are ICT, all kinds of intellectual property including patents and utility models etc, electronic databases and clouds, biotechnology. He refers to knowledge-based economy as weightless

economy, since the value added to GDP has little physical manifestation due to the increase use of ICT.

The Economic and Social Research Council (2005) describes a knowledge economy as the effective utilization of intangible assets such as knowledge, skills and innovative potential as the key resource for competitive advantage. Apart from these definitions, the United Nations portrays a knowledge economy as one where the production, distribution and use of knowledge maintains the growth, wealth creation and employment in the overall economy, while David & Foray (2003) describe the move to a knowledge or knowledge-based economy as a 'sea change' or 'soft discontinuity' rather than a sharp discontinuity or break from the past structure of the economy.

The World Bank (WB), on the other hand, defines a knowledge economy as one where organizations and people acquire, create, disseminate, and use knowledge more effectively for greater economic and social development. The World Bank also defines four key pillars that help countries articulate strategies for their transition to a knowledge economy (World Bank Knowledge for Development Program Website, 2014):

- An economic and institutional regime that provides incentives for the efficient use of existing and new knowledge and the flourishing of entrepreneurship.
- An educated and skilled population that can create, share, and use knowledge well.
- An efficient innovation system of firms, research centers, universities, think tanks, consultants, and other organizations that can tap into the growing stock

of global knowledge, assimilate and adapt it to local needs, and create new technology.

- Information and Communication Technologies (ICT) that can facilitate the effective communication, dissemination, and processing of information.

This coordination and cooperation among the pillars that the WB underlined can be included in the scope of the Neo-Schumpeterian economics discussed in the previous chapter.

In addition to the WB, the OECD emphasizes the coordination and cooperation between actors in the market to maintain high rates of knowledge diffusion. By differentiating between tacit knowledge and codified knowledge, the OECD underlines the growing importance of highly-skilled workers related to increasing demand in high-tech goods and knowledge-intensive industries. In order to emphasize the importance of tacit and codified knowledge, Van den Berg (2001) notes that the quality of the labor force, its accumulated experience and its education system determine an economy's ability to create new ideas and adapt old technology.

Smith (2002) also criticizes Drucker's and the OECD's claims about the increasing importance of knowledge. Drucker (1993) stresses the importance of human capital as a carrier of knowledge, stating that knowledge is 'the real and controlling resource and the absolutely decisive factor of production' while the OECD (1996) suggests that the role of knowledge (as compared to other factors of production such as capital and labour) has taken on greater importance. Smith (2002) examines Drucker's position that 'knowledge is sidelining capital' by propounding that separating knowledge accumulation from capital accumulation is impossible and knowledge cannot be converted into a product without capital investment.

The OECD, on the other hand, underlines the importance of knowledge by arguing that the definition of knowledge is broader than information and categorizes knowledge into four groups where the first two are the parts of codified knowledge and the last two are the parts tacit knowledge (2006);

1. Know-what refers to the facts that are known by everybody and are written.
2. Know-why refers to scientific knowledge of nature's laws and the cause-and-effect relationship of scientific incidents.
3. Know-how refers to skills and capability of doing something. It is usually learnt and developed within the actor and not shared generally.
4. Know-who refers to the information of knowing who does what. This has an increasing importance in the mounting need for efficiency in the supply chain mechanism.

While measuring know-what and know-why can easily be used in classical production functions, know-how and know-who are more difficult to codify and measure without conducting a necessary network since those kinds of knowledge can be transmitted by either formal or informal channels of information. This difficulty in measuring tacit knowledge is seen in reports comparing the knowledge bases of economies since there are no specific indicators which fully reflects the total amount of tacit knowledge and its positive effects in increasing wealth.

Definition of Innovation and National Innovation Systems

Adam Smith in his 'Wealth of Nations' emphasized that the wealth and prosperity of nations depends heavily on the productive powers of the labor in addition to the capital (1776). This remarkable point later turned into the notion of innovation, which is shaped by the codified and tacit knowledge of the worker.

Referring to innovation as any kind of new combination, Schumpeter (1939) defines innovation as 'setting up a new production function' that creates disequilibrium and carries the existing economic system to a new stationary situation of equilibrium. Rather than a shift along the production function frontier, Schumpeter's definition of innovation refers to the economic notion of a shift of the production function itself (Hagedoorn, 1996).

Rather than the technological innovations that Schumpeter named as 'creative destruction', in today's world, any kind of change that creates a new added value to the existing economic system is considered innovation. For example, for the OECD, innovation is the implementation of a new or significantly improved product (good or service), or a process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations (OECD Oslo Manual, 2005) while Van de Ven (2008) defines innovation as an idea that is perceived as new to the people involved. According to Van de Ven, even though it may appear to be an imitation of something that exists elsewhere, it can be called innovation since it is new to the people who benefit from it.

Taking the OECD definition of innovation as the basis, which is explained previously, all of the policy recommendations for the sustainable economic growth

and development underline the role of the innovation, the sustainable and efficient investment in knowledge creation. The use of this fresh knowledge for the transformation of the old economic system into a knowledge-based economic system is programmed to create continual economic value.

Despite similarly large investments in research and development (R&D) by various industrialized and semi-industrialized countries starting in the 1950s and 60s, Freeman (1995) argued that the rates of technical change and economic growth depend on efficient use of resources and innovation efficiency rather than being the first in the world with radical innovations. In addition, Freeman emphasizes that as much as technical innovation, social innovations play a significant role in economic growth and development.

Thus in the recent decade, rather than excessive R&D spending in each and every sector, national and regional innovation systems and strategies arose which give necessary importance to the concept of Triple Helix and factor endowments of countries and regions in order to maximize their competitive advantage. In order to understand the notion of national innovation system, it is crucial to understand the evolution of the innovation's definition and occurrence of endogenous growth theory.

Evolution of Innovation

One of the first (theoretical) frameworks developed for historically understanding science and technology and its relation to the economy has been the "linear model of

innovation” (Godin, 2005). Starting with basic research, the innovation process continues with applied research and development on a subject and finally ends with the creation of economic value, which is the production and diffusion of the product (good or service).

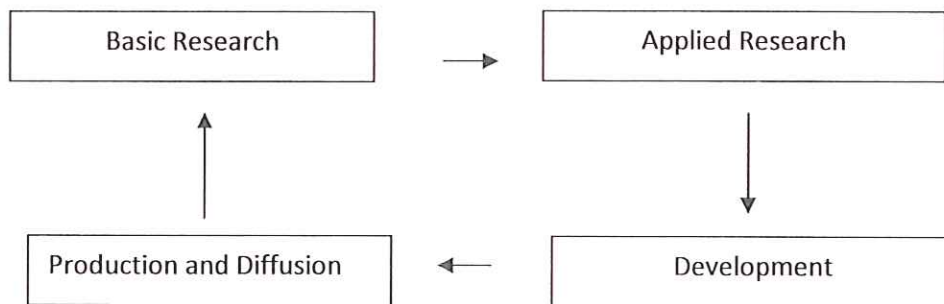


Figure 3. Linear model of innovation (Godin, 2005).

In the linear model of innovation, innovation occurs due to two factor of conditions, which are demand pull or technology push. In the former approach, the market conditions or the consumers’ demands are the catalyzators of the innovation. In the latter approach, on the other hand, technology and investment in R&D forms the innovation process.

Mensch (1979) showed in his study that the feedbacks from consumers or other producers and users in the process of innovation may deter the linear representations of innovations. He gives the example of computer life cycles in the UK during the sixties by emphasizing that linearity of the innovation process may get affected by the users’ feedback and this linearity may turn into a more complex process.

Kline and Rosenberg (1986) came up with a new formation of innovation called the chain-linked model of innovation, which focuses on the uncertainty and

complexity in the innovation process as shown in Figure 4. Contrary to the linear model of innovation, Kline and Rosenberg argue that new knowledge is not necessarily needed for innovation. With complex feedback loops between all stages in the process and due to product life cycles, the uncertainty in the market's reaction to the innovation may require re-designing and re-producing without any basic research, as indicated in the linear model of innovation.

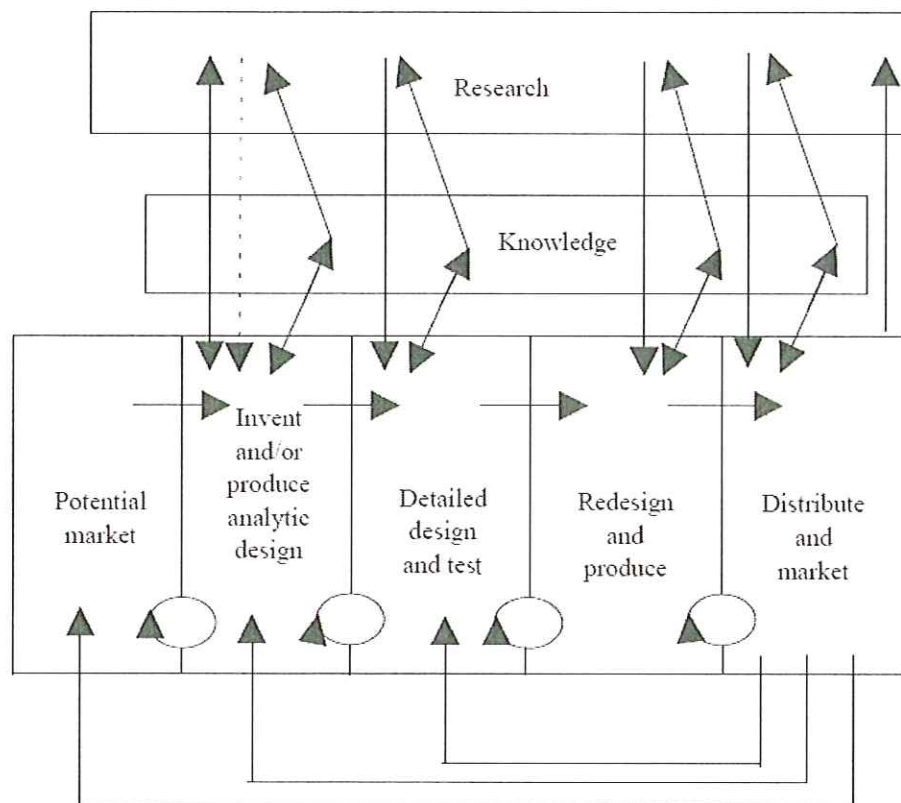


Figure 4.Chain link model of innovation (Kline and Rosenberg, 1986)

In 1992, Rothwell created his famous five generations of innovation models. By giving a historical overview of innovation models, Rothwell classifies the transformation of innovation models under five generations as technology push, demand pull, coupling model, integrated model and systems integration and extensive networking model as given in Table 2.

Table 2. Rothwell's five generation of innovation model (Kutvonen, 2007)

Generation	Key Features
First	Technology Push: Simple Linear Model
Second	Demand Pull: Simple Linear Model
Third	Coupling Model: Recognising the feedback and loops between different elements
Fourth	Integrated Model: Integration within the firm and the supply chain.
Fifth	Systems integration and extensive networking model: Flexible and customised response, continuous innovation

Leger and Swaminathan (2007) reconsider the chain-link model of innovation and create their own model by introducing new four aspects in the firm level:

1. The need to appropriate the returns from innovation by maintaining intellectual property rights.
2. The distinction between knowledge and information by assuming there are other firms in the market, there will also be firm-specific tacit knowledge.
3. The environment in which the firm exists is also has significance. From structure of the market to the competitiveness of the market play important roles. The presence of other firms also implies the possibility of imitation, underlying the importance of appropriation mechanisms.
4. The characteristics of the firm, meaning the size, resources, investment in R&D, employee education, and firm-specific factors.

By introducing four new aspects, they divide the general notion of 'knowledge' in a chain link model of innovation into sub-categories of information, industry information and firm-specific knowledge as shown in Figure 5.

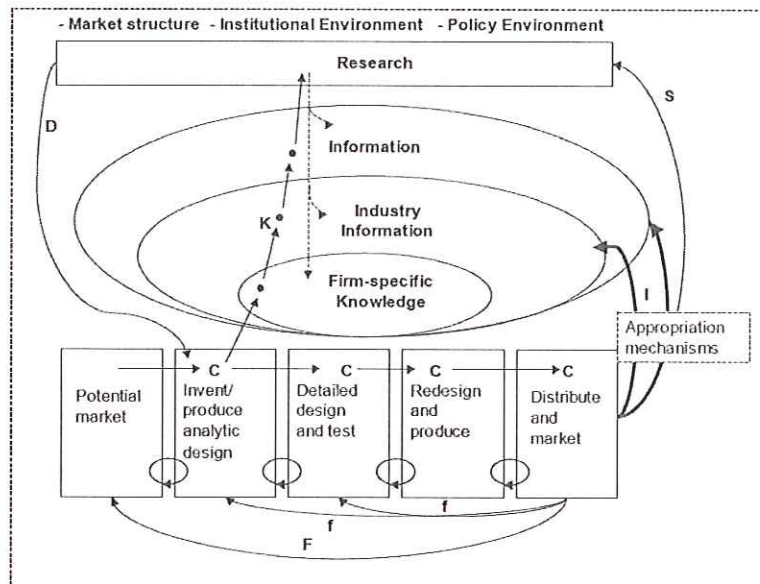


Figure 5. Leger and Swaminathan's model of innovation (Leger and Swaminathan, 2007)

These different approaches of innovation processes can also be linked to approaches of growth theories, which are the exogenous growth model of Solow and the endogenous growth model of Romer.

In Solow's neoclassical growth model, the source of the growth, which is technological progress, is left unexplained whereas Romer follows Arrow's seminal work on the economics of learning by doing. Arrow noted from case studies that there was strong evidence that experience and increasing productivity were associated (Ickes, 1996).

Romer (1986), by emphasizing the notion of 'learning by doing', which is also the knowledge stock specific to the each country investigated, also gives significance to the concept of 'country specific factors'. Country specific factors are always considered as the initial factors affecting the innovation capacity of countries. National innovation capacity, which is composed of the country specific factors, is the ability of a country to produce and to commercialize a flow of

innovative technology over the long term (Furman et al., 2002). This ability of the country depends on environmental factors that the country had, has and will have.

According to evolutionary economics, the environment that the firms, markets, institutions and other actors operating in the economy should be taken into consideration while analyzing the transformation process of countries. The cooperation and the coordination of the actors, the inter-industry, the inter-governmental and even the geographical differences are crucial in the way that the country's growth rates converge and innovation diffuses.

National Innovation Systems

National Innovation Systems (NIS), discussed and explained by Freeman in 1987, Lundvall in 1992 and Nelson in 1993, can be briefly summarized as the relationship between the actors in the Triple Helix. These differences in the relationships affect the national innovation capacity of the countries as explained in the previous section. Freeman (1987) defines NIS as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies, while Lundvall (1992) describes it as the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge. Nelson (1993) portrays it as a set of institutions whose interactions determine the innovative performance of national firms.

Pavitt and Pavel (1994) emphasized that the rate and direction of technological learning of a nation is determined by the national institutions and their

incentives, while Metcalfe (1995) includes not just the national institutions but all actors in the economy as their joint or individual activities contribute to the development and diffusion of existing and new technologies. The notion of ‘flat world’ and hyperconnectivity can be adapted to the national level since national innovation systems flatten the nations and increase the inter-connectedness.

The smooth operation of innovation systems depends on the fluidity of knowledge flows – among enterprises, universities and research institutions (OECD, 1997). The importance of tacit knowledge and know-how exchanged through informal channels, and codified knowledge in publications, patents and other formal sources are undeniable. The mechanisms for knowledge flows include joint industry research, public/private sector partnerships, technology diffusion and movement of personnel as indicated in Figure 6 (OECD, 1997).

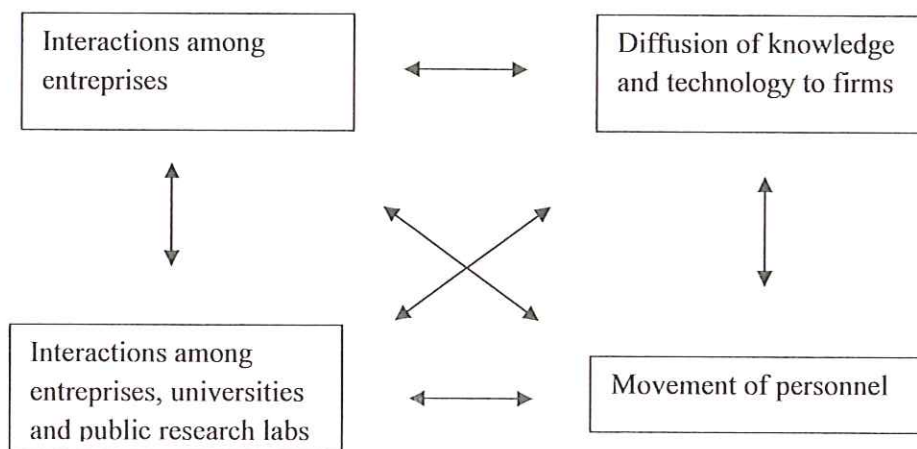


Figure 6. OECD knowledge flows among actors in NIS (OECD, 1997)

National innovation systems are crucial for nations on their way to determine the short run and long run national and regional innovation strategies. As one-size-fits-all innovation strategies do not work for each and every country, policymakers should be aware of national and regional specific factors and build the Triple Helix

model on these specific competitive areas which, in the end, help a country to win a competitive advantage. Chen et al. (2011) emphasize the importance of an innovation environment by suggesting that an innovation environment affects the efficiency and productivity of the innovation process for all kinds of decision making units in the economy.

Porter (1990) underlines that competition in today's world is more dynamic than in the days of classical production functions, and that nations with the economic goal of producing a high and rising standard of living for its citizens should increase their ability to maintain an efficient productivity. This efficient productivity lies on competitive advantage, which rests on continual innovation. Thus, it is crucial to compare national innovation efficiency of nations in order to implement sound policies for increasing the efficient use of scarce resources.

Since these terms have played a significant role in the sustainable economic growth and social welfare since the 2007 financial crisis, policies implemented by countries at the regional or national level to maintain growth and welfare have strategic arguments about innovation and knowledge-based economy to realize the goals set for the short term, the mid-term and the long term. In order to set these goals and implement the necessary policies, countries should be able to measure their input and how efficiently they turn these input into value added output. By bearing this question in mind, the next chapter argues whether these inputs, outputs and the efficiency of innovation systems can be measured or not by analyzing and explaining the current indices used by institutions.

CHAPTER III

MEASURING KNOWLEDGE

In this chapter, the indices that are used to measure the innovation capacity and ICT usage of countries are explained in detail. For every index, in addition to the rankings of top ten countries, the rankings of Brazil, Russia, India and China (BRICS), Mexico, Australia, Vietnam, Indonesia, Nigeria and South Africa (MAVINS) and Turkey are given and compared in detail.

Why and How to Measure Knowledge

Porter (1990) emphasizes that companies achieve competitive advantage through acts of innovation but innovation requires investments in skills and knowledge. Since tangible assets have a decreasing rate of return in maintaining competitive advantage, tacit knowledge is the key pillar in maintaining continuous competitiveness.

As OECD's report about knowledge-based economy in 1996 indicated, traditional economic indicators have fallen short of fully describing and measuring economic activity and performance in the market. Measuring the knowledge based economy performance may be even harder since it comprises the multiplier effects of codified and tacit knowledge. Hence, in order to calculate national accounts, traditional inputs and outputs of classical production functions are used. On the other

hand, knowledge is not a traditional economic input like capital or labor, as OECD underlines (1996).

The OECD develops unique indicators to measure and calculate the economic performance of a knowledge based economy by measuring knowledge inputs, knowledge stocks and flows, knowledge outputs, knowledge networks and finally learning (1996). In general, R&D expenditures, the number of patents taken, and the number of researchers are considered the main sub-pillars of measuring knowledge inputs. Knowledge stocks and flows are measured by the diffusion of knowledge as either embodied diffusion or disembodied diffusion.

Outputs, on the other hand, can be measured by the growth in high-technology production and high-skilled labor needs. In order to measure knowledge networks, one should take into consideration the number of geographical clusterings or industrial clusterings which leads to diffusion of tacit knowledge. Finally, measuring the private and social rates of return on investments in education and training will help point to means of enhancing the learning capacity of individuals and firms (OECD, 1996).

In addition, new concepts such as high-technology products, knowledge-intensive sectors and knowledge workers are introduced into the knowledge measurement. In order to measure the effects of knowledge on labor and production, a diversification of labor and industry is needed.

The OECD uses a very simple indicator for the categorization of sectors, ranging from high technology sectors to low technology. The OECD takes the percentage of R&D expenditure in turnover as an indicator of technological intensity, for example, high-technology sectors spend more than 4% of their turnover on R&D, medium-

technology sectors spend 1-4% of their turnover on R&D and finally low-technology sectors spend less than 1% of their turnover on R&D.

Brinkley (2006) argues that defining the knowledge-based economy in terms of knowledge intensive and less intensive sectors has some negative externalities since knowledge intensive sectors are important parts of the knowledge economy but the knowledge economy is not limited to knowledge intensive industrial sectors. David & Foray (2003) explained that knowledge-based economies are not restricted to the realm of high technology, but science and technology are central to the new sectors, giving momentum to the upward growth of the economy as a whole over the past few decades and also in future.

Defining knowledge workers may give an idea of knowledge-intensive sectors and their share in the GDP of the countries. The KoK Report written by Wim Kok in 2004 about the Lisbon Strategy for the European Union estimates that up to 30 % of the working population will be working directly in the production and diffusion of knowledge in the manufacturing, service, financial and creative industries alike. Managers, professionals, associate professionals who define the knowledge workers in terms of occupational classification and who are also in National Vocational Qualification (NVQ) 4 Level in job description (having a deep knowledge in application of complex, technical or professional work activities performed in a variety of contexts and with a substantial degree of personal responsibility and autonomy and responsibility for the work of others and the allocation of resources is often present). The report also emphasizes that in order to satisfy the goals set in the Lisbon Strategy – integrated, competitive and dynamic knowledge-based economy that is among the best in the world – the rest of the workforce should be no less knowledge-based.

As discussed above, although actors try to frame the definitions of knowledge-intensive sectors and knowledge workers, there are no clear and set definitions for these terms. Nevertheless the OECD still provides a list of sectors to be used in the measurement of KBE as indicated in Table 3.

Table 3. OECD Categorization of ICT Goods (OECD, 2009).

Broad Level Categories	Number of subclasses
Computers and peripheral equipment	19
Communication equipment	8
Consumer electronic equipment	11
Miscellaneous ICT components and goods	14
Manufacturing services for ICT equipments	5
Business and productivity software and licensing services	11
Information technology consultancy and services	10
Telecommunications services	12
Leasing or rental services for ICT equipment	3
Other ICT services	6
Total	99

Indices Measuring Innovation and Knowledge Based Economy

This sub-chapter contains nine different indices and their indicators which are used to measure the ICT usage and capability, innovation capability and knowledge of countries:

1. ICT Development Index
2. Measuring Information Society (MIS)
3. Technology Achievement Index (TAI)
4. Networked Readiness Index (NRI)
5. IT Industry Competitiveness Index (IT-CI)

6. European Innovation Union Scorecard (IUS)
7. OECD Science, Technology and Industry Scoreboard (STI)
8. Global Competitiveness Index (GCI)
9. Global Innovation Index

The first five indices listed above focus on ICT usage, ICT access, ICT skills and ICT market competitiveness and readiness while the last four indices focus on broader indicators which analyze not just inputs but also outputs such as high technology outputs, creative outputs, and economic variables. Since the IT infrastructure is one of the main drivers of a knowledge based economy and innovation, it is important for any country to develop its infrastructure, ICT usage and skills as a matter of priority.

ICT Development Index (IDI)

The ICT Development Index (IDI) covers 157 economies and compares two consecutive years to analyze the progress in different indicators. The IDI ranks countries' performances with regard to ICT infrastructure and recent uptakes in the industry based on 11 indicators, as seen in Table 4.

Table 4. ICT Development Index indicators (IDI, 2013)

Dimensions	Indicators
ICT Access	<ol style="list-style-type: none"> 1. Fixed telephone lines per 100 inhabitants 2. Mobile cellular telephone subscriptions per 100 inhabitants 3. International Internet bandwidth (bit/s) per Internet user 4. Proportion of households with a computer 5. Proportion of households with Internet access at home
ICT Use	<ol style="list-style-type: none"> 1. Internet users per 100 inhabitants 2. Fixed broadband Internet subscribers per 100 inhabitants 3. Mobile broadband subscribers per 100 inhabitants
ICT Skills	<ol style="list-style-type: none"> 1. Adult literacy rate 2. Secondary gross enrollment ratio 3. Tertiary gross enrolment ratio

The main objectives of the IDI are to measure the following (MIS, 2013):

1. the level and evolution of ICT developments over time within countries and in relation to other countries;
2. the progress in ICT development in both developed and developing countries: the index should be global and reflect changes taking place in countries at different levels of ICT development;
3. the digital divide, i.e. differences between countries with different levels of ICT development;
4. the development potential of ICTs or the extent to which countries can make use of ICTs to enhance growth and development, based on available capabilities and skills.

According to the IDI, in order to become an information society, a country should pass through three substantial stages:

1. ICT readiness: showing the infrastructure, network and access to ICTs;
2. ICT intensity: level of use of ICT technologies and the skills to use those technologies;
3. ICT impact: reflecting the outcome of ICT readiness and intensity.

The results of IDI 2012 indicates that the top ten countries are mainly in Europe, Asia and the Pacific such as South Korea, Sweden, Iceland, Denmark, Finland, Norway, the Netherlands, UK, Luxembourg and Hong Kong. A comparison with 2011 shows that, as it is in other indices, there is hardly any change in the best performed top ten countries. By contrast, some countries which are called dynamic countries, e.g. the UAE, Lebanon, Barbados and the Seychelles, moved up on average more than five places compared to their 2011 rankings.

Table 5. ICT Development Index 2012 (IDI, 2012)

ICT Development Index 2012			
Top Ten Countries	Rank	Developing Countries	Rank
South Korea	1	Turkey	69
Sweden	2	Brazil	62
Iceland	3	Russia	40
Denmark	4	India	121
Finland	5	Indonesia	97
Norway	6	China	78
Netherlands	7	South Africa	84
United Kingdom	8	Mexico	83
Luxembourg	9	Australia	11
Hong Kong	10	Vietnam	88
		Nigeria	122

In Tables 6 to 8, in addition to the top ten countries in each sub index, Turkey, BRIC and MAVINS' rankings are given. As it is seen, the rankings of the all countries that are listed in the tables change according to the sub-index. In the ICT Access Sub-Index, Hong Kong, Luxembourg, Iceland, Switzerland, Germany, UK, Sweden,

Netherlands and Malta are the top ten countries whereas in the ICT Use Sub-Index, South Korea, Denmark, Norway, Finland, Japan and Australia are added to the list but countries like Hong Kong, Switzerland, Germany, the UK, Singapore and Malta drop off the list. It is important to note that in the ICT Skills Sub-Index, countries like Greece, Belarus, Slovenia and Spain succeed in joining the top ten countries list.

In the developing countries list, one should emphasize the significance of the rankings of Australia. Although it is listed as one of the countries in MAVINS group, Australia has the highest rankings in all sub-indices and outdistances all developing countries. It ranks eleventh in the ICT Development Index overall, but it is in the top ten countries in ICT Use and Skills Sub-Index.

India and Nigeria have the lowest ranking in all sub-indices of the developing countries, whereas Russia has the highest ranking in all sub-indices. Turkey, on the other hand, while having a high ranking in the skills sub-index than other developing countries, is still in the lower ranks in terms of the access and use sub-indices. By contrast, Vietnam has a higher rank in the access and use sub-index but a very low ranking in the skills sub-index.

Table 6. ICT Access Sub-Index 2012 (IDI, 2013)

ICT Access Sub-Index 2012			
Top Ten Countries	Rank	Developing Countries	Rank
Hong Kong	1	Turkey	72
Luxembourg	2	Brazil	67
Iceland	3	Russia	37
Switzerland	4	India	122
Germany	5	Indonesia	98
United Kingdom	6	China	80
Sweden	7	South Africa	85
Singapore	8	Mexico	87
Netherlands	9	Australia	11
Malta	10	Vietnam	89
		Nigeria	135

Table 7. ICT Use Sub-Index (IDI, 2013)

ICT Use Sub-Index 2012			
Top Ten Countries	Rank	Developing Countries	Rank
Sweden	1	Turkey	68
South Korea	2	Brazil	57
Denmark	3	Russia	42
Norway	4	India	121
Finland	5	Indonesia	96
Japan	6	China	66
Iceland	7	South Africa	75
Australia	8	Mexico	82
Netherlands	9	Vietnam	83
Luxembourg	10	Nigeria	93

Table 8. ICT Skills Sub-Index (IDI, 2013)

ICT Skills Sub-Index 2012			
Top Ten Countries	Rank	Developing Countries	Rank
South Korea	1	Turkey	55
Finland	2	Brazil	72
United States	3	Russia	23
Greece	4	India	117
Belarus	5	Indonesia	98
Slovenia	6	China	93
New Zealand	7	South Africa	95
Spain	8	Mexico	80
Australia	9	Vietnam	101
Iceland	10	Nigeria	138

Measuring the Information Society (MIS)

Measuring the Information Society (MIS) has been published annually since 2009, and in addition to IDI facts and data, the 2013 edition also presents the latest results of the ICT Price Basket (IPB), along with the the first complete price data set for mobilebroadband services, the first-ever model to measure the world's digital native population, and a quantitative assessment of recent digital TV broadcasting trends (MIS, 2013).

The growing importance of measuring broadband affordability is also evident from the changing situation in terms of the uptake of different ICT services and their relevance in delivering access to today's information society (MIS, 2013). Thus, in 2011 the Broadband Commission for Digital Development set a target for affordable broadband services in developing countries, with a targeted amount of less than 5% of the average monthly income (MIS, 2013). It is thus clear that the minimum price of entry-level broadband services is one of the significant steps to the knowledge based economy and the strategies set by countries for broadband pricing can be an indicator against which to benchmark innovativeness and ranking as an information society.

According to the MIS 2013 report, from 2008 to 2012, the fixed broadband prices expressed as a percentage of the GNI had fallen globally by an average rate of 30% annually. While fixed broadband became more affordable globally, the minimum advertised fixed broadband speeds increased globally from 2008 to 2012. The lowest fixed broadband prices expressed as a percentage of the GNI in 2012 were in Macao, Kuwait, the USA, Switzerland, Luxembourg, Andorra, the UK, Japan, Norway and Hong Kong, in that order. Average prices in Africa and Asia were still well above the world average fixed broadband prices. Vietnam, Indonesia and Nigeria had the highest fixed broadband prices compared to other developing countries such as Russia, Turkey and Australia. It is important to note that prices as expressed as a percentage of the GNI in Turkey and Russia are lower than in Australia.

Table 9. Fixed broadband prices as % of GNI in 2012 (MIS, 2013).

FixedBroadband Prices 2012 as % of GNI (Lowest to Highest)			
Top Ten Countries	Rank	Developing Countries	Rank
Macao	1	Turkey	34
Kuwait	2	Brazil	55
USA	3	Russia	29
Switzerland	4	India	93
Luxembourg	5	Indonesia	114
Andorra	6	China	99
United Kingdom	7	South Africa	88
Japan	8	Mexico	62
Norway	9	Australia	42
Hong Kong	10	Vietnam	119
		Nigeria	142

On the other hand, mobile broadband prices are relatively higher on average globally compared to fixed broadband prices, and developing countries have the highest prices for prepaid mobile broadband services, with 18% of GNI on average, while the world and the developed countries pay on average 10% of GNI and 2% of GNI respectively. The differences in price and affordability of mobile-broadband services across countries are considerable, with a range of 0.14 % of GNI and 300 % of GNI. Austria, the UK, Germany, Qatar, France, Italy, Bahrain, Australia, Estonia and Kuwait had the lowest prices in 2012. It is important to emphasize that, although Australia has a lower ranking in the fixed broadband prices list, it outdistanced all developing countries and ranked eighth in the prepaid mobile broadband price list. Other developing countries such as Turkey, Brazil and Russia had lower rankings in comparison with the fixed broadband prices whereas, surprisingly, countries like Vietnam, Indonesia and Nigeria ranked higher in comparison with their rankings in fixed broadband prices.

Table 10. Prepaid mobile broadband prices as % of GNI (MIS, 2013)

Prepaid Mobile Broadband Prices 2012 as % of GNI (Lowest to Highest)			
Top Ten Countries	Rank	Developing Countries	Rank
Austria	1	Turkey	48
United Kingdom	2	Brazil	75
Germany	3	Russia	47
Qatar	4	India	67
France	5	Indonesia	58
Italy	6	China	72
Bahrain	7	South Africa	73
Australia	8	Mexico	59
Estonia	9	Vietnam	51
Kuwait	10	Nigeria	99

Technology Achievement Index (TAI)

The Technology Achievement Index (TAI) is used by the United Nations Development Programme (UNDP) to measure how well a country is creating and diffusing technology and building a human skill base, reflecting its capacity to participate in the technological innovations of the network age. Introduced by Desai et al. (2002), the TAI focuses on four dimensions of technological capacity: creation of technology, diffusion of recent innovations, diffusion of old innovations, and human skills and provides a composite measure of technological progress as indicated in Table 11. The TAI focuses more on output rather than input of innovation, as also focused in other indices. The TAI is not a measure of which country is leading in global technology development; it focuses instead on how well the country as a whole is participating in creating and using technology (Desai et al., 2002).

Table 11. TAI indicators (Desai et al., 2002)

TAI Sub-index	Indicators
Creation of Technology	Patents granted per capita Receipts of royalty and license fees from abroad per capita
Diffusion of Recent Innovation	Internet hosts per capita High- and medium-technology exports as a share of all exports
Diffusion of Old Innovation	Telephones per capita (mainline and cellular combined) Electricity consumption per capita
Development of Human Skills	Mean years of schooling Gross enrollment ratio at tertiary level in science, mathematics and engineering

The latest TAI was assessed in 2009 by Nasir et al.(2010), who reported on 91 countries and rankings in each sub-dimension. According to the study of Nasir et al., the highest TAI value is 0.765 for South Korea whereas the lowest value is 0.111, for Cambodia. Russia, Indonesia and Vietnam are not included in the 91 countries, so rankings for them are not available in Table 12. It is important to note that Australia, as indicated in IDI as well, has the highest ranking between Turkey, BRIC and MAVINS countries.

Table 12. Technology Achievement Index 2009 (Nasir et al., 2009)

Technology Achievement Index 2009			
Top Ten Countries	Rank	Developing Countries	Rank
South Korea	1	Turkey	64
Finland	2	Brazil	53
Sweden	3	Russia	
Singapore	4	India	81
Japan	5	Indonesia	
Netherlands	6	China	54
Luxembourg	7	South Africa	55
United States	8	Mexico	48
United Kingdom	9	Australia	14
Canada	10	Vietnam	
		Nigeria	87

Desai et al. (2002) grouped countries under four categories: leaders, potential leaders, dynamic adopters and marginalized, based on their overall performance in the chosen indicators seen in Table 13.

Table 13. TAI grouping of countries according to their scores (Nasir et al., 2010)

TAI Score	Specialties	2009 Countries
Leaders (TAI > 0.5)	These countries are innovation-driven countries.	18 countries including: South Korea, Finland, Sweden, UK, USA, Japan, Iceland, Estonia, Australia etc.
Potential leaders (TAI = 0.35–0.49)	These countries innovate little but use old technologies widely and invest heavily in human resources.	33 countries including: Most EU countries, Israel, Hong Kong, Chile, Ukraine, UAE, Argentina, Mexico
Dynamic adopters (TAI = 0.20–0.34)	These are mostly developing countries eager to adapt new technologies.	30 countries including: Brazil, China, South Africa, Iran, Turkey, Peru, India
Marginalized (TAI < 0.20)	These countries are lagging in technology usage and innovation and the old technology is barely diffused.	10 countries including: Pakistan, Nigeria, Bangladesh

While Australia places in the leaders group, and Mexico in the potential leaders group, Brazil, China, South Africa and Turkey rank as dynamic adopters. It is important for these developing countries to become members of the potential leader group in order to maintain sustainable economic growth and welfare.

In comparison with 2002, the 2009 results show that South Korea, Singapore, Canada, Germany, Slovenia, Greece, Cyprus, Poland, Romania and China moved up due to their improved performances in innovation creation and diffusion of recent innovations in particular.

Networked Readiness Index (NRI)

The World Economic Forum's (WEF) Global Information Technology Report, published annually, is based on the Networked Readiness Index (NRI). The

NRI offers a comprehensive assessment of the present state of network readiness in the world by putting a detailed inquiry about the relationship of ICT and growth (GITR, 2013). The NRI index of 2013 covers 144 economies accounting more than 98% of the world GDP.

According to the results of the 2013 NRI, Nordic countries and Asian Tigers dominate the top ten list with their well-developed business environment, government support and digital agenda strategy. As indicated in Table 14, relying on four sub-indices with 10 different pillars, the NRI analyzes 53 particular indicators to measure countries' ability and capability in innovation and their successful use of ICT.

Table 14. NRI Sub-indices and pillars (NRI, 2013)

NRI Sub-index	Pillars
Environmental Sub-index	1. Political and Regulatory Environment 2. Business and Innovation Environment
Readiness Sub-index	1. Infrastructure and Digital Content 2. Affordability 3. Skills
Usage Sub-index	1. Individual Usage 2. Business Usage 3. Government Usage
Impact Sub-index	1. Economic Impacts 2. Social Impacts

Table 15 lists the top ten countries and rankings of Turkey, BRICS and MAVINS countries. In the top ten list, Nordic countries (Finland, Sweden, Norway) and the Netherlands occupy the top five, while Australia again has the highest rank among developing countries. Nigeria has the lowest.

Table 15.NRI (NRI, 2013).

Network Readiness Index			
Top Ten Countries	Rank	Developing Countries	Rank
Finland	1	Turkey	51
Singapore	2	Brazil	69
Sweden	3	Russia	50
Netherlands	4	India	83
Norway	5	Indonesia	64
Switzerland	6	China	62
US	7	South Africa	70
Hong Kong	8	Mexico	79
United Kingdom	9	Australia	18
South Korea	10	Vietnam	84
		Nigeria	112

IT Industry Competitiveness Index (IT-CI)

First published in 2007 by the Economic Intelligence Unit, the IT Industry Competitiveness Index (IT-CI) consists of 26 sub-indicators in six main indicators and is published biennially. Covering 66 countries, the IT-CI compares countries in relation to the extent they have the required conditions and infrastructure to support and develop a strong IT industry, which is the main pillar of a knowledge-based economy.

According to the data gathered for the sub-indicators shown in Table 16 of the 2011 report, most of the Nordic and North American countries remained the best performing countries: the USA, Finland, Singapore, Sweden, the UK, Denmark, Canada, Ireland, Australia, the Netherlands and Israel.

Table 16. IT-CI indicators and subindicators (IT-CI, 2011)

Indicator	Sub-Indicators
Overall business environment	Foreign investment policy Private property protection Government regulation Freedom to compete
IT infrastructure	IT investment PC ownership Broadband penetration Internet security Mobile penetration
Human capital	Enrolment in higher education Enrolment in science Employment in IT Quality of technology skills
Legal environment	Intellectual property protection Enforcement of IP rights Electronic signature Data privacy and spam Cybercrime
R&D environment	Public sector R&D Private sector R&D Patents Royalty and license fees
Support for IT industry development	Access to investment capital E-government strategy Public procurement of IT Government technology neutrality

As indicated in Table 17, the USA is the top country in this index, which may be due to additional indicators such as legal environment, support in IT and R&D budget.

Australia ranks as the ninth country, passing the Netherlands, which surpassed Australia in the NRI and the TAI Index.

Table 17. IT-CI rankings (IT-CI 2011)

IT Industry Competitiveness Index			
Top Ten Countries	Rank	Developing Countries	Rank
USA	1	Turkey	41
Finland	2	Brazil	39
Singapore	3	Russia	46
Sweden	4	India	34
UK	5	Indonesia	57
Denmark	6	China	38
Canada	7	South Africa	47
Ireland	8	Mexico	44
Australia	9	Australia	9
Netherlands	10	Vietnam	53
		Nigeria	62

To summarize, it is important to emphasize that, in overall IT indices, Australia surpasses the developing countries and is listed in the top 10 countries in the index of IT-CI. The difficulty in measuring IT infrastructure, usage and skill can be observed from the changes in the rankings. Each additional variable plays a significant role in the rankings, so it is important to select the right indicators and not miss any specific input which have an effect in a country's ability to use and develop its IT market and infrastructure.

Sweden, the Netherlands, the UK and Finland rank in the top ten countries list in every index, whereas Japan ranks in the top ten countries only in the TAI and Ireland only in the IT-CI.

After analyzing mainly the IT sector and its impacts, it is important to measure the effects of ICT infrastructure, skills and usage on innovation and competitiveness, which are the main drivers of economic and social welfare in a knowledge based economy.

In the context of this study, four different regional and global indices are explained in detail:

1. European Innovation Union Scorecard (IUS)
2. OECD Science, Technology and Industry Scoreboard
3. Global Competitiveness Index
4. Global Innovation Index

European Innovation Union Scorecard (IUS)

The European Union, with its Europe 2020 targets, aims to achieve

1. A smart growth based on a knowledge economy and innovation;
2. A sustainable growth with a more resource efficient, environment-friendly and competitive economy;
3. An inclusive growth with a high employment rate for a socially more harmonized EU.

In order to realize these goals, the European Commission underlines specific targets:

1. 75% of the population aged 20-64 should be employed.
2. 3% of the EU's GDP should be invested in R&D.
3. The "20/20/20" climate/energy targets should be met (including an increase to 30% in emissions reduction if the conditions are right).
4. The percentage of early school leavers should be under 10%, and at least 40% of the younger generation should have a tertiary degree.
5. 20 million fewer people should be at risk of poverty.

The European Union developed the idea of 'Innovation Union' to deepen the process of smart, sustainable and inclusive growth. Since there also exist inequalities

across the Union, a scorecard for a detailed analysis and monitoring of the process was needed.

The European Innovation Union Scorecard (IUS) started as a pilot application in 2000 under the auspices of the European Commission in order to monitor the implementation of Europe 2020 goals. By covering 28 EU member states, 4 candidate states (Iceland, Macedonia, Serbia and Turkey) as well as Switzerland and Norway, the Scorecard provides a comparative analysis of the research and innovation performance of Europe. By identifying countries' strengths and weaknesses, it presents a brief summary which enables countries to concentrate on specific areas to foster their innovation performance and efficiency. It also compares the EU results with those of BRICS and developed countries such as Japan, South Korea, the USA, Canada and Australia.

The IUS consists of three main dimensions: enablers, firm activities and outputs. The enablers dimension covers three innovation dimensions with eight sub-indicators to analyze the innovation performance external to a firm. Firm activities, on the other hand, covers three dimensions with nine sub-indicators which analyze the innovation performance drivers at the firm level. After the assessment of inputs, 'the output' dimension, with eight sub-indicators, captures the effects of the external and firm level indicators. Under these three main dimensions, there exist eight indicators with a total of 25 sub-indicators, as indicated in Table 18 below.

Table 18. Main indicators of IUS (IUS, 2014)

Main type/innovation dimension/indicator
ENABLERS
Human Resources
1.1.1. New doctorate graduates per 1000 population aged 25-34
1.1.2. Percentage of the population aged 30-34 having completed tertiary education
1.1.3. Percentage youth aged 20-24 having attained at least upper secondary level education
Open, excellent and attractive research systems
1.2.1. International scientific co-publications per million population
1.2.2. Scientific publications among the most 10% cited publications worldwide as % of total scientific publications of the country
1.2.3. Non-EU doctorate students as a % of all doctorate students
Finance and Support
1.3.1. R&D expenditure in the public sector as % of GDP
1.3.2. Venture capital investment as % of GDP
FIRM ACTIVITIES
Firm Investments
2.1.1. R&D expenditure in the business sector as % of GDP
2.1.2. Non R&D innovation expenditures as % of turnover
Linkages & entrepreneurship
2.2.1. SMEs innovating in-house as % of SMEs
2.2.2. Innovative SMEs collaborating with others as % of SMEs
2.2.3. Public-private co-publications per million population
Intellectual Assets
2.3.1. PCT patents applications per billion GDP (in PPS)
2.3.2. PCT patent applications in societal challenges per billion GDP
2.3.3. Community trademarks per billion GDP (in PPS)
2.3.4. Community designs per billion GDP (in PPS)
OUTPUTS
Innovations
3.1.1. SMEs introducing product or process innovations as % of SMEs
3.1.2. SMEs introducing marketing or organizational innovations as % of SMEs
3.1.3. Employment in fast growing firms of innovative sectors
Economic Effects
3.2.1. Employment in knowledge intensive activities as % total employment
3.2.2. Contribution of medium and high-tech product exports as % total service exports
3.2.3. Knowledge-intensive services exports as % total service exports
3.2.4. Sales of new to market and new to firm innovations as % of turnover
3.2.5. License and patent revenues from abroad as % of GDP

The IUS distinguishes between member and candidate countries under four sets of groups according to their overall innovation performance, as indicated in Table 19 below.

Table 19. IUS categorization of countries (IUS, 2014)

Type of innovators	Definition	Countries
Innovation leaders	including Member States in which the innovation performance is well above that of the EU, i.e. more than 20% above the EU average	Denmark, Finland, Germany and Sweden
Innovation followers	including Member States with a performance close to that of the EU average i.e. less than 20% above, or more than 90% of the EU average	Austria, Belgium, Cyprus, Estonia, France, Ireland, Luxembourg, the Netherlands, Slovenia and the UK
Moderate innovators	including Member States where the innovation performance is below that of the EU average at relative performance rates between 50% and 90% of the EU average	Croatia, Czech Republic, Greece, Hungary, Italy, Lithuania, Malta, Poland, Portugal, Slovakia and Spain
Modest innovators	Including Member States that show an innovation performance level well below that of the EU average, i.e. less than 50% of the EU average	Bulgaria, Latvia, and Romania, Turkey

In addition to overall innovation performance, the IUS also provides innovation growth rates of individual countries. As an innovation leader, Sweden and an innovation follower, the UK, have the lowest innovation growth rates, while Portugal, Estonia and Latvia are innovation growth leaders in the IUS 2014. Croatia, on the other hand, has the lowest growth rate in the moderate innovators group.

Figure 7 shows that with an overall annual innovation growth performance averaging 1.7% between 2006 and 2013, the European Union has not been equally strong in all indicators, especially given negative growth in finance and firm investments. This may be due to the regional Euro crisis, which still has downturn effects in Europe.

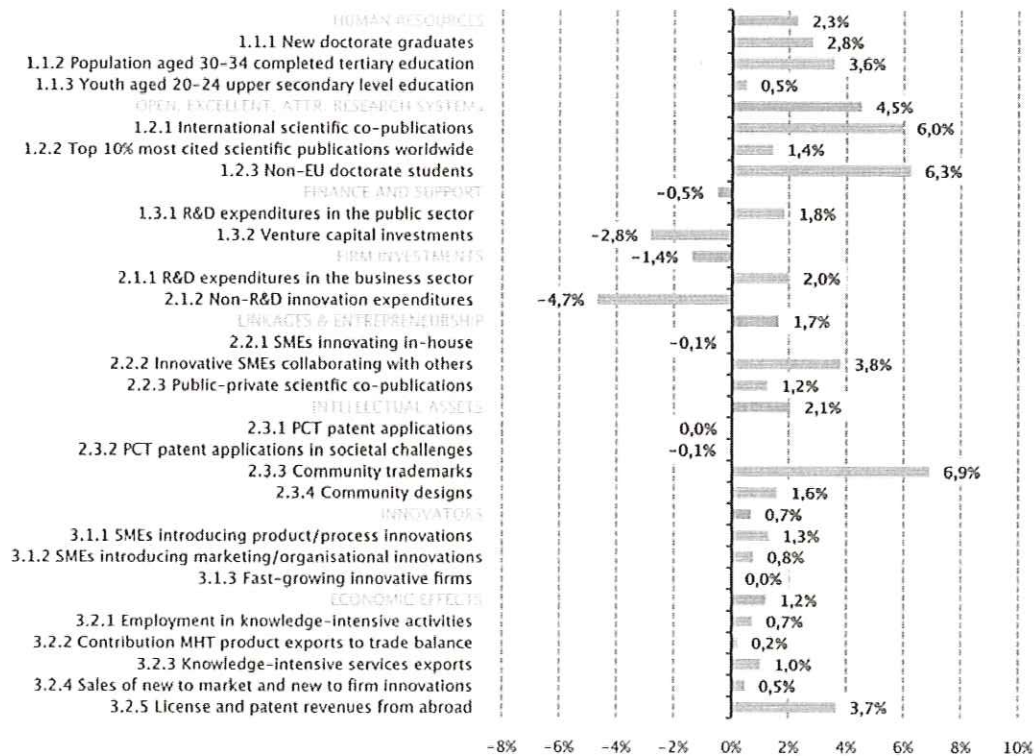


Figure 7. Annualized EU growth performance 2006-2013 (IUS, 2014)

The highest growth rates in Figure 7 are in open, and excellent research systems with 4.5% and human resources with 2.3%. The growth in non-EU doctorate students and international scientific co-publications show increasing mobility and cooperation of EU with non-EU countries. The increase in new doctorate graduates and the percentage of the population with tertiary education shows that investments made in education and research bring positive results to the economy. The high growth in community trademarks with 6.9% and innovative SMEs collaborating with others signal that incubation centers and established networks can be turned into economic value.

Figure 8 shows that when the overall innovation performance of the EU-28 is compared with global competitor countries such as South Korea, the USA, Japan and BRICS countries, the EU-28 performs better than the BRICS countries in global

innovation performance but worse than South Korea, the USA and Japan. In addition, the average innovation growth rate of the EU-28 between 2006 and 2013 was substantially lower than that of South Korea and China but higher than that of the USA and BRICS countries, as indicated in Figure 9. Although China has a lower innovation performance, it invests more to achieve high innovation growth rates. It is important to underline that, although South Korea is the innovation leader, as shown in Figure 8, it also has the highest innovation growth rate, meaning that in order to sustain its innovation performance, South Korea keeps investing in innovation drivers and maintaining high growth rates.

Figure 8. Global innovation performance (IUS, 2014)

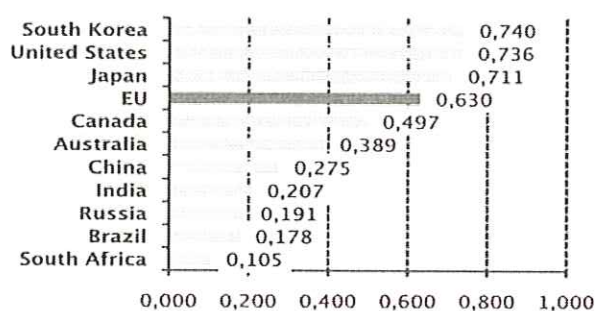
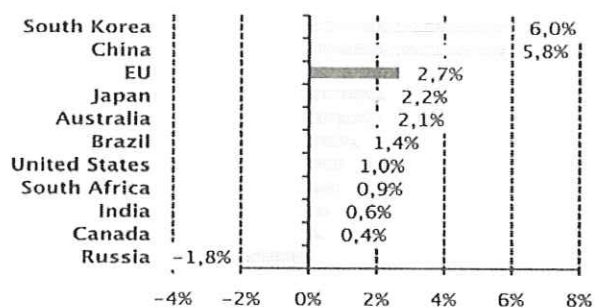


Figure 9. Global innovation growth rates (IUS, 2014)



The Community Innovation Survey is another facet of the IUS, since data gathered voluntarily from the private sector on the basis of country is used for the IUS also.

Surveys are conducted every two years and data are added to the EUROSTAT Database to be analyzed. The harmonized survey in 2010 covered 22 countries across Europe and it is designed to provide information on the innovativeness of sectors by enterprise type, innovation types and various aspects of the development of an innovation, such as objectives, sources of information, public funding, innovation expenditures(CIS, 2010).

OECD Science, Technology and Industry Scoreboard (STI)

Based on 260 indicators and published every two years, the OECD Science, Technology and Industry Scoreboard (STI) shows how the OECD and partner economies are performing in a wide range of areas with the aim of helping governments design more effective and efficient policies and monitor progress towards their desired goals. Through statistical indicators, it also gives a detailed report of the OECD in comparison with country groupings such as ASEAN, BRIICS, the Euro Area, the EU, the G7, NAFTA, and the rest of the World and in Table 20, the main categorization of the indicators is listed.

Table 20. List of indicator groups in OECD STI (OECD MSTI, 2013)

Gross domestic expenditure on R&D (GERD)
R&D Personnel (FTE)
GERD by source of funds
GERD by performance sectors
Researchers (headcount)
Business Enterprise Expenditure on R&D (BERD)
Business Enterprise R&D Personnel (FTE)
BERD by source of funds
BERD performed in selected industries
Higher Education Expenditure on R&D (HERD)
Higher Education R&D Personnel (FTE)

Table 20 continued

Government Expenditure on R&D
Government R&D Personnel (FTE)
Government Budget Appropriations or Outlays for R&D by socio-economic objectives
R&D Expenditure of Foreign Affiliates
Patents
Technology Balance of Payments (TBP)
International trade in R&D-intensive industries

According to the data analyzed, in 2012 OECD governments invested on average the equivalent of 0.8% of their GDP in direct funding of R&D at home or abroad. The best university ranking still has geographical concentration while the researchers became more mobile. Firms younger than 5 years old with 50 or fewer employees maintained a positive job growth while the net employment in the OECD area continued to fall by 2% between 2008 and 2011. China passed the EU-28 in the proportion of economic output being invested in R&D by reaching almost 2% of GDP. In addition, Korea reached GERD level of 4% of GDP by surpassing the OECD average, the USA, Japan and the EU-28.

Global Competitiveness Index (GCI)

The world's most comprehensive competitiveness report, the Global Competitiveness Report (GCI), is an annual report published by the World Economic Forum since 2004, covering 148 economies. By providing a conception about the drivers of countries' productivity and prosperity, the GCR presents an analysis of major economic transformation and country-specific factors which directly or indirectly affect a nation's competitiveness.

Table 21. Global Competitiveness Index indicators (GCI, 2013).

Global Competitiveness Index		
Basic Requirements Sub-index	1. Institutions 2. Infrastructure 3. Macroeconomic environment 4. Health and primary education	Key for Factor-Driven Economies
Efficiency Enhancers Sub-index	1. Higher education and training 2. Goods market efficiency 3. Labor market efficiency 4. Financial market development 5. Technological readiness 6. Market size	Key for Efficiency-Driven Economies
Innovation and Sophistication Factors Sub-index	1. Business sophistication 2. Innovation	Key for Innovation-Driven Economies

The GCI presents data and insights under 12 main pillars that determine the productivity and thus the competitiveness of the country and then classifies these pillars according to the nature of the driver of their economies. As indicated in Table 22, and according to the Index and its pillars, there are three types of economies: factor-driven, efficiency-driven and innovation-driven. The weight of each pillar changes according to the type of the economy, as indicated in Table 22.

Table 22. Type of sub-index and economy type (GCI, 2013)

Type of Sub-index	Factor Driven	Transition	Efficiency Driven	Transition	Innovation Driven
GDP Per Capita (US\$)	< 2.000	2.000-2.999	3.000-8.999	9.000-17.000	>17.000
Weight for Basic Req. Sub-index	60%	40-60%	40%	20-40%	20%
Weight for Efficiency Enhancers Sub-index	35%	35-50%	50%	50%	30%
Weight for Innovation Sophistication Sub-index	5%	5-10%	10%	10-30%	50%

According to the data in Table 23, the most competitive countries in 2013-2014 are Switzerland, Singapore, Finland, Germany, the US, Sweden, Hong Kong, the

Netherlands, Japan and the UK. BRICS countries, as expected, have relatively low rankings, with South Africa 53rd, Brazil 56th, India 60th, and finally Russia 64th. On the other hand, Turkey has a better ranking than most BRICS countries with a rank of 44. It is important to emphasize that, although China is still an efficiency-driven country, it is more competitive than other BRICS countries and Turkey. Australia, on the other hand, ranks 21st as the best performance in developing countries, whereas Nigeria ranks 120th, with the worst performance.

Table 23. Global Competitiveness Index (GCI, 2013)

Global Competitiveness Index			
Top Ten Countries	Rank	Developing Countries	Rank
Switzerland	1	Turkey	44
Singapore	2	Brazil	56
Finland	3	Russia	64
Germany	4	India	60
United States	5	Indonesia	38
Sweden	6	China	29
Hong Kong SAR	7	South Africa	53
Netherlands	8	Mexico	55
Japan	9	Australia	21
United Kingdom	10	Vietnam	70
		Nigeria	120

In Table 24, 148 countries are grouped according to economic stage to show which ones are innovation-driven, and which are factor- and efficiency-driven.

Table 24. Countries according to stage of development (GCI, 2014)

Countries/Economies at Each Stage of Development				
Stage 1: Factor Driven	Transition from stage 1 to stage 2	Stage 2: Efficiency Driven	Transition from stage 2 to stage 3	Stage 3: Innovation Driven
Bangladesh	Algeria	Albania	Argentina	Australia
Benin	Angola	Bosnia and Herzegovina	Barbados	Austria
Burkina Faso	Armenia	Bulgaria	Brazil	Bahrain
Burundi	Azerbaijan	Cape Verde	Chile	Belgium
Cambodia	Bhutan	China	Costa Rica	Canada
Cameroon	Bolivia	Colombia	Croatia	Cyprus
Chad	Botswana	Dominican Rep.	Estonia	Czech Republic
Cote d'Ivoire	Brunei Darussalam	Ecuador	Hungary	Denmark
Ethiopia	Gabon	Egypt	Kazakhstan	Finland
Gambia	Honduras	El Salvador	Latvia	France
Ghana	Iran, Islamic Rep.	Georgia	Lebanon	Germany
Guinea	Kuwait	Guatemala	Lithuania	Greece
Haiti	Libya	Guyana	Malaysia	Hong Kong SAR
Kenya	Moldova	Indonesia	Mexico	Iceland
Kyrgyz Republic	Morocco	Jamaica	Oman	Ireland
Lao PDR	Philippines	Jordan	Panama	Israel
Lesotho	Saudi Arabia	Macedonia, FYR	Poland	Italy
Liberia	Sri Lanka	Mauritius	Russian Federation	Japan
Madagascar	Venezuela	Montenegro	Seychelles	Korea, Rep.
Malawi		Namibia	Slovak Republic	Luxembourg
Mali		Paraguay	Turkey	Malta
Mauritania		Peru	Uruguay	Netherlands
Mozambique		Romania		New Zealand
Myanmar		Serbia		Norway
Nepal		South Africa		Portugal
Nicaragua		Suriname		Puerto Rico
Nigeria		Swaziland		Qatar
Pakistan		Thailand		Singapore
Rwanda		Timor-Leste		Slovenia
Senegal		Tunisia		Spain
Sierra Leone		Ukraine		Sweden
Tanzania				Switzerland
Uganda				Taiwan
Vietnam				Trinidad and Tobago
Yemen				UAE
Zambia				UK, USA

Global Innovation Index (GII)

Recognizing the key role of innovation as an engine of economic growth, the Global Innovation Index adopts an inclusive and a horizontal vision of innovation by giving necessary emphasis to local dynamics of innovation and comparing 142 countries all over the world.

The GII, over the last six years, has evolved into a valuable ranking by including necessary and influencing indicators for local and global innovation efficiency. Covering 94.9% of the world's population and 98.7% of the world's Gross Domestic Product (GDP in US\$), the GII is composed of two sub-indices called the Innovation Input Sub-Index and the Innovation Output Sub-Index as shown in Table 1.

A total of 84 individual indicators is used in the calculation of the weighted average of the sub-pillars which are used in the calculation of the pillar scores. Four measures are then calculated:

1. The Innovation Input Sub-Index is the simple average of the first five pillar scores.
2. The Innovation Output Sub-Index is the simple average of the last two pillar scores.
3. The overall GII is the simple average of the Input and Output Sub-Indices.
4. The Innovation Efficiency Ratio is the ratio of the Output Sub-Index over the Input Sub-Index.

The GII stresses the significant role of the local dynamics of the innovation especially due to the existence of tacit knowledge of each country. Thus, investing in innovation requires a detailed analysis of the geographic concentration and the

country-specific factors in order to build efficient industry-specific clusters and local hubs which could help increase the connectivity between the Triple Helix and generalize the understanding of open innovation. Open innovation is defined here as the principle whereby companies offer their innovation to third parties and use the innovation of others in their own products to create a win-win opportunity (Global Innovation Report, 2013).

Table 25. GII sub-index and indicators (GII, 2013)

Global Innovation Index (average) Innovation Efficiency Ratio (ratio)	Innovation Input Sub-Index	
	Institutions	Political Environment Regulatory Environment Business Environment
	Human Capital and Research	Education Tertiary Education Research and Development
	Infrastructure	ICT General Infrastructure Ecological Sustainability
	Market Sophistication	Credit Investment Trade & Competition
	Business Sophistication	Knowledge Workers Innovation Linkages Knowledge Absorption
	Innovation Output Sub-Index	
	Knowledge and Technology Output	Knowledge Creation Knowledge Impact Knowledge Diffusion
	Creative Output	Intangible Assets Creative Goods and Services Online Creativity

The countries listed in Table 26 are those which are used in the DEA analysis of this study. It is important to analyze the change in the rankings from the crisis period to 2013 so that this summary table can be used for further recommendations.

Table 26. GII rankings 2007 to 2013 (GII Reports 2013, 2011, 2009, 2007)

Global Innovation Index	2013	2011	2009	2007
Argentina	56	58	75	63
Australia	19	21	18	17
Austria	23	19	21	22
Belgium	21	24	17	15
Brazil	64	47	68	40
Bulgaria	41	42	49	81
Canada	11	8	12	8
Chile	46	38	42	33
China	35	29	43	29
Colombia	60	71	90	57
Croatia	37	44	45	55
Cyprus	27	28	32	46
Czech Republic	28	27	27	32
Denmark	9	6	5	11
Egypt	108	87	74	74
Estonia	25	23	29	31
Finland	6	5	6	13
France	20	22	22	5
Germany	15	12	16	2
Greece	55	63	46	49
Hong Kong	7	4	3	10
Hungary	31	25	36	36
Iceland	13	11	1	20
India	66	62	56	23
Indonesia	85	99	72	48
Ireland	10	13	19	21
Israel	14	14	23	18
Italy	29	35	38	24
Japan	22	20	13	4
Latvia	33	36	44	50
Lithuania	40	40	39	47
Luxembourg	12	17	15	16
Malaysia	32	31	28	26
Malta	24		31	42
Mexico	63	81	69	37
Netherlands	4	9	8	9
New Zealand	17	15	9	28
Nigeria	120	96	96	72
North Korea				
Norway	16	18	10	25
Pakistan	137	105	103	73
Peru	69	83	88	69

Table 26 continued

Global Innovation Index	2013	2011	2009	2007
Philippines	90	91	76	66
Poland	49	43	47	56
Portugal	34	33	34	39
Romania	48	50	52	62
Russia	62	56	64	54
Singapore	8	3	7	7
Slovakia	36	37	37	35
Slovenia	30	30	26	43
South Africa	58	59	51	38
South Korea	18	16	20	19
Spain	26	32	30	27
Sweden	2	2	2	12
Switzerland	1	1	4	6
Taiwan			25	
Thailand	57	48	60	34
Turkey	68	65	67	45
Ukraine	71	60	61	75
United Kingdom	3	10	14	3
USA	5	7	11	1
Venezuela	114	102	124	77
Vietnam	76	51	71	65

The top ten countries according to the GII 2013 Index are Switzerland, Sweden, the UK, the Netherlands, the USA, Finland, Hong Kong, Singapore, Denmark and Ireland, all developed countries with high incomes. The important point to be made here is that, although the rankings of these countries vary across the years, the list of the top countries changes little between 2011 and 2013, as indicated in Table 26. According to the 2013 rankings, in addition to the BRICS countries, Argentina, Poland and Turkey have been showing a significantly high growth rate in their R&D spending from 2008 to 2013, but this does not help them achieve higher rankings in the Index.

In addition to the rankings, the GII also maintains an innovation efficiency ratio (IER) which analyzes the ratio of innovation inputs to innovation outputs as indicated earlier. This ratio shows the efficient use of scarce resources. A country can maintain a high IER either by maximizing its outputs with a given amount of inputs or by minimizing its inputs to produce the same amount of output. The innovation efficiency ratio in the GII demonstrates that being an innovator country does not necessarily mean being an innovation efficient country. The top ten innovation-efficient countries are Mali, Moldova, Guinea, Malta, Swaziland, Indonesia, Nigeria, Kuwait and Venezuela, all of which, with the exception of Moldova, have very low rankings, as indicated in Table 27. Hong Kong and Singapore also have very low innovation-efficiency ratios, which again proves the substantiality of the efficient use of scarce resources. It is surprising that Australia, although it ranks 16th in the GII, ranks 116th in the IER.

The GII also provides an IER ranking according to income group. For example, IER countries with high incomes are Malta, Switzerland, Hungary, Netherlands, Iceland, Luxembourg, Germany, Cyprus; IER with upper-middle income countries are Venezuela, China, Argentina, Turkey, Romania; IER with lower middle income countries are Moldova, Indonesia, Nigeria, India, Pakistan, Vietnam and IER with low income countries are Mali, Uganda, Zimbabwe, Tajikistan, Burkina Faso.

Table 27. Innovation and efficiency rankings (GII, 2013)

Country	Innovation Ranking	Efficiency Ranking
Switzerland	1	12
Sweden	2	55
UK	3	60
Netherlands	4	26
USA	5	86
Finland	6	67
Hong Kong	7	109
Singapore	8	121
Denmark	9	78
Ireland	10	57
Mali	106	1
Moldova	45	2
Guinea	126	3
Malta	24	4
Swaziland	104	5
Indonesia	85	6
Nigeria	120	7
Kuwait	50	8
Costa Rica	39	9
Venezuela	114	10

Table 28. GII innovation efficiency ranking (GII, 2013)

Global Innovation Index Innovation Efficiency Ranking			
Top Ten Countries	Rank	Developing Countries	Rank
Mali	1	Turkey	29
Moldova	2	Brazil	69
Guinea	3	Russia	104
Malta	4	India	11
Swaziland	5	China	14
Indonesia	6	South Africa	99
Nigeria	7	Mexico	56
Kuwait	8	Australia	116
Costa Rica	9	Vietnam	17
Venezuela	10		

After the 2007 financial crisis and the Euro crisis, developing countries turned the crisis into an opportunity and maintained unusually high GDP growth rates. While high income countries achieved on average 1% growth between the years of 2007 and 2012 (including Russia, with a GDP growth average of 4%, according to the World Bank classification), middle income countries achieved almost 6% on average. These high GDP growth rates maintained by developing countries raise the question of a middle income trap. The biggest challenge for those countries who wanted to avoid a middle income trap and sustain their growth rates was moving from resource-driven to innovation-driven growth, which is based on innovation and high productivity. As Cai (2011) underlines, few countries like Japan and South Korea have leaped into the developed nations category by avoiding a middle income trap.

All the indices mentioned in this chapter actually represent a model global economy and each country's role in the global economy. It is important to compare and analyze in detail each of these indices in order to understand the strengths, the weaknesses and the inefficient use of resources of each country.

CHAPTER IV

LITERATURE REVIEW

There is an abundance of studies on the innovation and productive efficiency of local, regional and country-based decision making units in addition to various organizational structures such as government bodies, educational institutions, health institutions and firms. Since the focus of this study is the innovation efficiency of countries relative to each other, a literature review on measuring the innovation efficiency is presented. It is important to emphasize that in all research R&D, expenditures and patents are assumed as the key input and output for innovation and R&D efficiency.

Emphasizing the difficulty of measuring the productive efficiency of an industry, Farrell (1957) underlined that taking the average productivity of labor as an indicator of production efficiency is inadequate since there exists a number of inputs which are not taken into the account in this kind of simple calculations.

Farrell differentiates two types of productive efficiency: technical efficiency and price efficiency. The former is realized if one decision making unit producing the maximum output from the minimum quantity of inputs, whereas the latter is realized when there is no dead-weight loss in the country and the price is equal to marginal cost. Since there exist cases where quantifying inputs and outputs in terms of prices is impossible or deceptive, technical efficiency became one of the key practices in measuring the productive efficiency of decision making units (DMU). This is the case, for example, where a DMU devotes its sources to R&D in

science and technology but no universally agreed weight or price is attached to each outcome (Wang and Huang, 2007).

The data envelopment analysis model (DEA) developed by Charnes, Cooper and Rhodes (CCR) in 1978 allows measuring and comparing efficiency ratios without requiring a predefined function of R&D and knowledge, since R&D and knowledge cover multiple inputs and outputs, making it hard to place into the functions. DEA overcomes this problem by enabling each DMU's efficiency as a ratio of weighted outputs to inputs subject to the condition that the similar ratios for DMUs are between 0 and 1 (Charnes et al., 1978).

By emphasizing the difficulty of evaluating the efficiency of public institutions, Rousseau (1997) defines public institutions as the DMUs of his research and uses a constant returns to scale (CRS) and output oriented DEA model on 18 countries. He defines his input indicators as active population, R&D expenditure and GDP. The reason for choosing active population is that the larger the active population in the economy, the greater the potential of the nation, according to Rousseau. For output indicators, he chooses the number of publications in ISI's 1993 Science Citation Index (sources) and the number of patents granted in 1993 by the European Patent Office (EPO). According to the data model, Austria, Germany, Ireland, the Netherlands, Switzerland, the UK and Canada achieve the highest efficiency in comparison with 11 other countries (Table 29). This study also emphasizes that spending a higher ratio of the GDP as R&D does not bring higher efficiency ratios, since the relatively most efficient countries have different R&D expenditures ratios.

Table 29. The efficiency comparison of Rousseau's DEA study (1997)

Country	Efficiency	Country	Efficiency
Austria	100	Norway	70.4
Belgium	73,6	Spain	74
Denmark	94,5	Sweden	100
Finland	84,3	Switzerland	100
France	60,2	United Kingdom	100
Germany	100	Australia	96.2
Ireland	100	Canada	100
Italy	50,1	Japan	35.6
Netherlands	100	USA	83.3

Rousseau and Rousseau (1998) analyze the same set of countries with the same set of inputs and outputs but assigning different weight to outputs and inputs. Their study, conducted for the year 1993, shows that no matter what weight is given to inputs and outputs, Switzerland is by far the most efficient and effective country among the 18 countries chosen for the study.

Nasierowski and Arcelus (2003) choose 46 countries that are listed in the World Competitiveness Report and apply a CRS input-oriented DEA model to analyze the national innovation system efficiency for the years 1993 and 1997. Japan, Taiwan and Switzerland remain the fully efficient countries in all three different models and in both years.

By treating R&D capital stocks and manpower as inputs and patents and academic publications as outputs for 30 countries, Wang and Huang (2006) use 23 OECD countries and 7 non-OECD countries for their study. Assuming that the R&D performance is affected by environmental factors, Wang and Huang include the gross enrollment rate in tertiary education, personal computers per 1000 residents, and proficiency in English as exogenous variables. Based on the previous empirical work of Goto and Suzuki (1989), Adams and Griliches (2000) and Guellec and van

Pottelsberghe de la Potterie (2004), Wang and Huang consider the time lag as three years and assume that the input data of 1997, 1998 and 1999 corresponds to the output data of 2000, 2001, 2002. Since the addition of inputs does not lead to immediate change in the output, time lag is introduced to the literature (Griliches, 1979; Goto and Suzuki, 1989). Showing that enrollment rate in tertiary education, personal computers per 1000 residents, and proficiency in English have a significant positive impact on R&D performance, the study lacks detailed results on a country base but gives brief information on average results.

Hollanders and Esser (2007) used the main dimensions of the European Innovation Scorecard to employ a CRS output oriented DEA model on 28 EU countries and Iceland and Sweden. As Wang and Huang (2007) did Hollander and Esser (2007) also emphasized the importance of time lags since the transformation of innovation inputs into innovation outputs requires time. As input, innovation drivers, knowledge creation and innovation & entrepreneurship dimensions are taken while as output, applications and intellectual property dimension of the EIS are considered. Several models and variable set specifications are run in the study and it is proven that variations in the set of input and output variables cause a difference in the rankings of efficiency scores. It is also emphasized that high efficiency scores do not guarantee a high innovation performance, as these can occur by combining low levels of input with moderate levels of output. Romania is a prime example, where low levels of inputs are combined with a moderate performance level in output (Hollanders and Esser, 2007).

Another cross country analysis was conducted by Sharma and Thomas (2008) on 22 countries with gross domestic expenditure on R&D, researchers per million population, gross domestic product (GDP) as input variables and patents granted to

residents; all author publication counts as output variables and created four different models with different output-input combinations. The results showed that the total number of efficient nations varies significantly from one model to the other. Model 1 with gross domestic expenditure on R&D (GERD) as input and patents granted to residents as output shows that only Japan, the SouthKorea and Slovenia are found to be technically efficient. While in Model 2, Japan, the South Korea, China, India, Slovenia and Hungary tend to be technically efficient and the USA is the only country exhibiting decreasing returns to scale. 18 countries exhibit increasing returns to scale under Model 2 with GERD and researchers per million population as inputs and patents granted to residents as output. By including China, Hungary, India and Russia and showing that these countries are VRS technically efficient, this study proves that the efficient use of R&D resources may shift the growth scenarios to the East.

Cullman et al.(2009), by analyzing 26 OECD countries and two non-member countries (Argentina, China), performed a DEA analysis by considering two years of timelag between the inputs (gross expenditure on R&D[GERD], business expenditure on R&D [BERD], higher education expenditure on R&D [HERD], government intramural expenditure on R&D [GOVERD], researchers) and outputs (weighted and unweighted patents). Constructing three different models, the study found out Germany and Sweden were the most efficient countries, while China and Mexico were the least efficienct countries under various variable returns to scale (VRS) output oriented DEA model. It is important to note that this study considered the Banker-Gifford model, which is a procedure of peeling off a fraction of the observations to obtain more reliable production frontier estimates, and eliminated

Iceland and Slovak Republic due to significantly lower efficiencies and their outlier status. (Banker and Chang, 2005).

Abbasi et al.(2010) use their own virtual index of the NIS efficiency model, which is based on the VRS output oriented DEA model, on 44 countries in 2003. Since the relationships between the inputs and outputs are far from formulation and still unknown, the index they form focuses on a country's creation of technology and distribution power of the innovation system. By concentrating on the the differences between efficient and inefficient decision-making units, Abbasi et al. (2010) apply the ordinary least square (OLS) regression for the first time in the literature instead of widely used Tobit regression.

By conducting a study on the national innovation efficiency of 22 countries including BRICS and G7 countries, and by using GERD and the total number of researchers as input indicators along with the World Intellectual Property Organization(WIPO) patents granted, scientific articles and high tech and the ICT sector exports as output indicators,Cai (2011) finds that BRICS countries have a difference in their relative efficiency of NIS. India, Russia and China have good efficiency scores while Brazil and South Africa have low efficiency.

In addition to macro-level studies, studies on meso- and micro-level (regional and city level respectively) were also conducted by Macmillan (1986), Charnes et al. (1989) and Sueyoshi (1992) on Chinese cities where Hashimoto and Ishikawa (1993) apply the DEA model to Japan prefectures. Hongli and Leilei (2013) conducted a study on the 11 cities of Zhejiang province of China to measure innovation capacity in 2009. They found that the innovation capability of strong economic cities like Wenzhou and Taizhou was not strong enough, which once again proves that economic growth or wealth is not equal to innovation efficiency. Martic and Savic

(2000) use a CRS output-oriented DEA model to estimate how well the regions of Serbia utilize their resources by taking four inputs (arable area, active fixed assets, consumption of electricity and population) and four outputs (gross domestic product, total number of physicians, total number of pupils in primary school, total number employed in the social sector). After finding that 13 regions are relatively inefficient, the sensitivity of the region's efficiency scores on changes in the list of inputs is examined.

All these studies conducted to measure the national innovation efficiency consider certain input and output indicators such as R&D expenditure, total number of researchers in the country in inputs, and publications, patents and high tech exports as GDP. OECD and BRICS countries are most frequently studied since the data available for those countries is more reliable and missing data is least. In addition, the missing data set creates little country bias and most of the studies mentioned in the literature review either eliminate countries assumed to be outliers or else categorize them as efficient countries.

CHAPTER V

METHODOLOGY AND DATA

In this study, the data envelopment analysis method was employed to empirically evaluate the input-output efficiency of 58 countries during the global crisis between 2007 and 2012. Before conducting the analysis and policy recommendations, it is important to give a detailed explanation of the data envelopment model and the way it is integrated to the existing literature in the field of measuring innovation efficiency and the capability of national innovation systems.

Data Envelopment Analysis (DEA)

Originally developed by Charnes, Cooper and Rhodes (CCR) in 1978 to evaluate the efficiency of nonprofit and public sector organizations, Data Envelopment Analysis (DEA) is a nonparametric method which is used to measure the productive efficiency of decision making units (DMU). Measuring the relative efficiency in terms of the ratio of inputs to outputs, the DEA model assigns efficiency scores to DMUs ranging from 0 to 1, where a score of 1 given to the DMU which is relatively the most efficient in the group measured. The most efficient DMUs form a efficiency frontier where fewer performing units need more inputs to produce the same amount of outputs and are therefore situated at some distance from the frontier, and their inefficiency is represented by the radial distance (Rousseau, 1997).

Charnes et al. (1978) proposed the measure of efficiency for any DMU as ‘the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU would be less than or equal to unity’. The formulation is as follows:

$$\max h_0 = \frac{\sum_{r=1}^s u_r y_{r0}}{\sum_{i=1}^m v_i x_{i0}}$$

subject to:

$$\frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1 ; \quad j = 1, \dots, n,$$

$$v_r, v_i \geq 0 ; \quad r = 1, \dots, s ; \quad i = 1, \dots, m.$$

The known outputs and inputs of the i^{th} DMU which are the y_{rj} , $x_{ij} \geq 0$ and the u_r , $v_i \geq 0$ are the variable weights attained to each input and output. The weight given to each input and output can be changed and attained according to constraints set and predetermined subject to the data.

The first classical DEA model developed by Charnes, Rhodes and Cooper in 1978 is also known as the constant return on scale DEA model (CRS DEA). The variable returns to scale DEA (VRS DEA) model developed by Banker, Charnes and Cooper (1984, BCC) argue that there can be increasing, constant and diminishing returns to scale at different points on the production frontier and by introducing the term ‘scale efficiency’ they quantify the ratio of CRS DEA to VRS DEA. The main difference between the CRS DEA and the VRS DEA is that in the CRS DEA an increase in input leaves the average productivity unchanged, whereas in increasing returns to scale the same increase in the input also increases the average productivity.

By contrast, in decreasing or diminishing return to scale, the same amount of increase in the input causes a decline in the average productivity.

The DEA model can also be classified under two depending on whether it is input-oriented or output-oriented. The choice of an input-oriented or output-oriented model depends on the process in the DMU and the model created to analyze. Minimizing the use of inputs to produce a given level of output defines the input-oriented method whereas maximizing the level of output given the levels of input defines the output-oriented method.

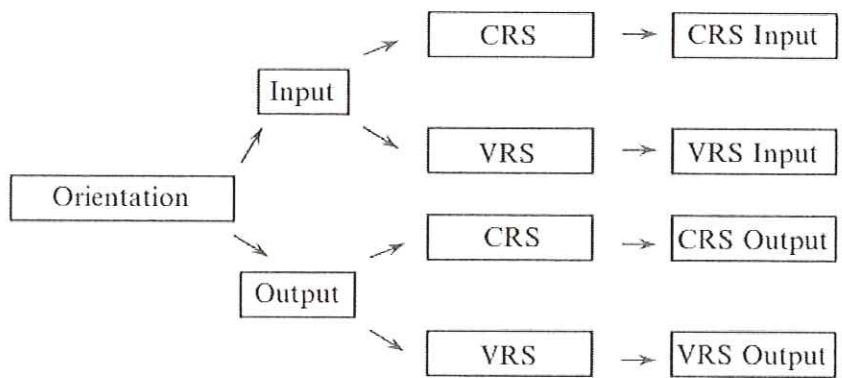


Figure 10. Basic DEA model classifications (Ozcan, 2008)

Figure 11 represents a simple visual explanation of the input- and output-oriented DEA model. In CRS, point C (with OA amount of input and OD amount of output) is below the efficiency frontier, so it can be classified as an inefficient point relative to points E and B. From the perspective of input-oriented measure, the same amount of output can be produced with DE amount inputs, whereas in output-oriented measure AB amount of output can be produced with OA amount of input.

In VRS, the degree of input-oriented innovation efficiency can be achieved with DG amount of input whereas the degree of output-oriented innovation efficiency can be achieved by producing AF amount of output with OA amount of input. Since there is

no proportion in the BCC model, the DG/DC in the input-oriented model is not equal to AC/AF in the output-oriented model for a country which is inefficient located at point C.

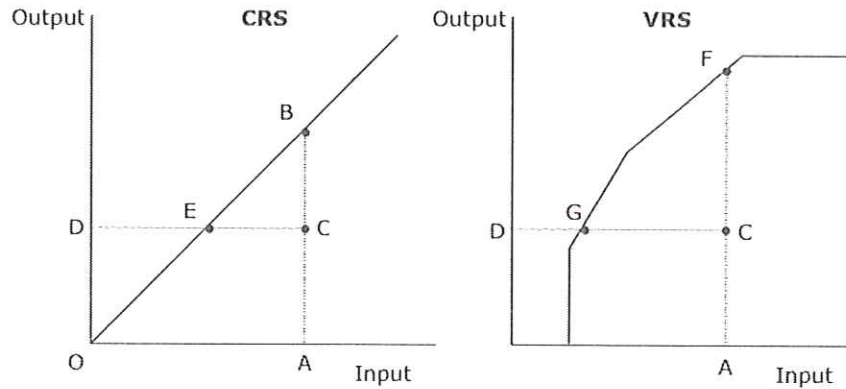


Figure 11. CRS and VRS, input and output oriented model (Hollanders and Esser, 2007)

Figure 12 below gives a brief visualization of the CRS and the VRS DEA model with defining the full capacity of outputs with a given fixed inputs. The efficiency frontier is defined by the points of A, C and D while the B point below the frontier remained as inefficient or less efficient in comparison with other points on the frontier. With constant returns to scale, point C defines the frontier and all other points in the figure remain inefficient or less efficient in comparison with point C. One should also note that in this figure, the capacity output corresponding to variable returns to scale is lower than the capacity output corresponding to constant returns to scale (FAO).

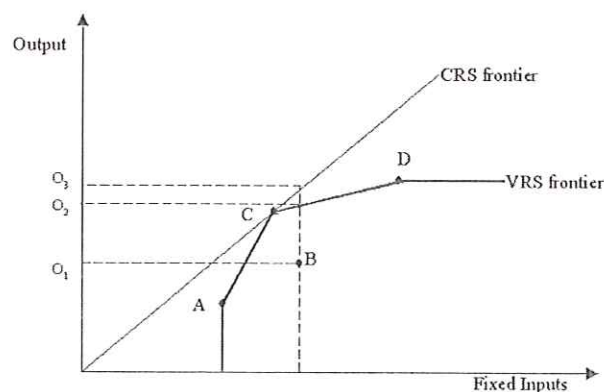


Figure 12. CRS and VRS DEA model (FAO Documentary)

Advantages and Disadvantages of the DEA Model

According to Cooper et al. (2006), the DEA model has its own advantages and disadvantages that must be considered in conducting a study. Since it has four different types of models based on the data chosen depending on whether it is input- or output-oriented and whether it is CRS or VRS, one should analyze its data in detail and choose the most suitable version of the model.

One of the main advantages of the DEA model is that there exists no need for predetermined offsetting of the functional form of transformation of resources (input variables) into results (output variables) (Kotsemir, 2013). Since input and output variables can be explained in different units with no predetermined formulation, weights are attained to input and output variables without their *a priori* setting (Cooper et al., 2006). This openness in the application also gives room for including several variables of inputs and outputs into the model.

As mentioned in the literature review, DEA analysis allows users to analyze the effects of exogenous factors under the form of environmental variables and provides the opportunity for further analysis of sensitivity.

On the other hand, the DEA model has inherent key disadvantages which necessitate a deep reasonable breakdown such as a strong bias in the efficiency scores due to statistical noise and outlier DMUs. Wang and Huang's (2007) main caveat on the DEA model is its heavy reliance on the accuracy of the data since there is no allowance for measurement errors. In addition, adding a new input or output variable produces significant changes in efficiency scores and recalculation is

needed. Small sample size and an overly large set of input and output variables seriously bias the efficiency scores.

Furthermore, the DEA assumes that at least one DMU is technically efficient, since it lies on the efficiency frontier and the resting DMUs certainly suffer from a lack of efficiency since they lie below the efficiency frontier. The DMU on the frontier is deemed as the most efficient since there no other units in the sample are more efficient.(Wang and Huang, 2007).

Eventually, it is important to internalize that the DEA is a form of analysis which ensures benchmarking in efficiency, so it is a model working on relativity rather than on absolute numbers.

Data

In order to conduct this study, for our decision making units we first considered the whole sample that included developed and developing countries, and then we classified the sample set according to their economic capacity and income per capita. Countries in the sample set are listed in Table 26 in the previous chapter. Table 30 shows the definitions and the sources of indicators that are used in this study as inputs and outputs.

In the literature, a “small country” phenomenon exists in many empirical analyses. Thus Rousseau and Rousseau (1997), Cullman et al. (2009) and Cai (2011) refuse to include small countries in their study to avoid the small country phenomenon. Small is defined in terms of the national innovation system scope and level of development. Hollanders and Esser (2007) remove Malta from the analysis

due to its small size, because the country is combining low input with high output scores leading to outlier efficiency scores. In this study, countries like Cyprus, Malta, Iceland, Taiwan and North Korea are excluded due to lack of consistent data.

Table 30. Input and Output Indicators in the study

Indicator of	Inputs	Source
Market Size	GDP (\$)	World Bank
	GDP per capita (\$)	World Bank
	Population (total number)	World Bank
R&D Diffusion from abroad	Net FDI Inflow in billions (current US\$)	World Bank
Human Resources and Research Infrastructure	Expenditure on education	UNESCO
	Expenditure on R&D in billions (current US\$)	World Bank
	Population with tertiary education	UNESCO
	Total number of graduates	UNESCO
	Total researchers per million habitants	World Bank
ICT Infrastructure	Internet users per 100 people	World Bank
	Mobile subscriptions per 100 people	World Bank
General Infrastructure	Electricity Consumption (kWh per capita)	World Bank
Ecological sustainability	GDP per unit of energy use (constant 2011 PPP \$ per kg of oil equivalent)	World Bank
	Outputs	Source
Knowledge Creation	Patents per million population	WIPO
Knowledge Creation	Publications per million population	Scientific Journal Rankings All Documents
Knowledge Impact	ISO 9001 certificates issued in absolute numbers	International Organization for Standardization
Knowledge Diffusion	High technology exports in billions (current US\$)	World Bank

The size of the economy and the active population are considered indicators of a potential source for R&D. This potential can be realized through a proper education

system. Therefore, expenditure on education, gross expenditures on R&D, population with tertiary education, total number of graduates and R&D personnel are assumed as indicators for potential human resources in research. The literature shows that gross expenditures on R&D and total numbers of researchers per million inhabitants are considered key input indicators (Nasierowski and Arcelus, 2003; Hollanders and Esser, 2007; Sharma and Thomas, 2008; Cullman et al., 2009; Abbasi et al., 2010; Guan and Chen, 2011; Cai, 2011; Chen et al., 2011).

Internet users and mobile subscriptions per 100 habitants are chosen as two of the other input indicators since ICT usage, infrastructure, price and skills foster knowledge diffusion. Considering this positive correlation, Hollanders and Esser (2007) include broadband penetration rate per 100 population as an input in their study. We also include Net FDI Inflow as an indicator, since it provides a brief idea about the economic conditions of the country. The FDI is also a source of knowledge diffusion and know-how transfer to the host country which fosters the innovation capability and global competitiveness (Coe et al, 1997; Maskus, 2000).

It is also important to include electricity consumption per capita and GDP per unit of energy use because the former indicator shows the urbanization rate of citizens (World Energy Council, 2010) and the latter one shows the production and the value created per unit of energy.

On the output side, patents per million habitants and publications are always considered the best indicators available to measure a country's innovation capability and capacity (Rousseau and Rousseau, 1997; Nasierowski and Arcelus, 2003; Sharma and Thomas, 2008; Abbasi et al., 2010; Pan et al., 2010; Cai, 2011; Chen et al, 2011; Hsu, 2011; Guan and Chen, 2011). It is important to underline that, since

there are measurement problems such as co-authoring in publication counts and language bias, some studies reject using this indicator as an output (Sharma and Thomas, 2008; Cullman et al., 2009).

Since the ISO 9001 certificates are the qualification of productivity and process, and have positive correlations with innovation capacity (Ratnasingam, 2013), it is a right output which shows the improvement in process management systems.

Finally, high technology exports in billions of US\$ or its share in overall exports indicates a country's innovation capacity (Furman et al., 2002; Guan and Chen, 2011; Hsu, 2011; Cai, 2011; Abbasi, 2011).

As a first step, correlation among variables was tested to determine appropriate variables in the model. Market size indicators (GDP, GDP per capita and population) were dropped from the model due to a high correlation with the other variables. Expenditures on education and population with tertiary education were also eliminated from the model due to their high correlation with the variables of internet users, publications and high technology exports. The variables employed in the study are presented in Table 31.

Table 31. Input and Output Indicators in the study

Indicator of	Inputs	Source
R&D Diffusion from abroad	Net FDI Infow in billions (current US\$)	World Bank
Human Resources and Research Infrastructure	Expenditure on R&D in billions (current US\$)	World Bank
	Total Number of Graduates	UNESCO
	Total researchers per million habitants	World Bank
ICT Infrastructure	Internet users per 100 people	World Bank
	Mobile subscriptions per 100 people	World Bank

Table 31 continued

Indicator of	Inputs	Source
General Infrastructure	Electricity Consumption (kWh per capita)	World Bank
Ecological sustainability	GDP per unit of energy use (constant 2011 PPP \$ per kg of oil equivalent)	World Bank
Knowledge Creation	Patents per million population	WIPO
Knowledge Creation	Publications per million population	Scientific Journal Rankings All Documents
Knowledge Impact	ISO 9001 certificates issued in absolute numbers	International Organization for Standardization
Knowledge Diffusion	High technology exports in billions (current US\$)	World Bank

The data that is utilized under two different input-oriented CRS and VRS DEA models between 2007 and 2012, the global economic crisis period. One of the aims was to determine whether innovation policies and national innovation strategies have been affected by the global crisis. The second aim was to capture the impact of the ‘time lag effect’ in the sample. Therefore, the second model takes into account time lag effect. Studies conducted by Wang and Huang (2007) and Hollanders and Esser (2007) indicate that the transformation of innovation inputs to innovation outputs needs time to diffuse and realize itself. Although Wang and Huang set the time lags as three years, based on the empirical work of Goto and Suzuki (1989), Adams and Griliches (2000), and Guellec and Van Pottelsberghe de la Potterie (2004), this study set the time lag as two years Hollanders and Esser, 2007; Sharma and Thomas, 2008; Cullman et al., 2009) such that for the output data taken for the years 2007-2012, the input data gathered for the years 2005-2010 was used.

CHAPTER VI

EMPIRICAL RESULTS

In this study, two alternative models (base model and lag model) with two different assumptions (CCR and BCC) and two specifications (input-oriented and output-oriented) were utilized to trace innovation performance across countries during the global crisis period. The Base Model uses related values of the same year for each variable. However, there might be a time lag between the time when investment in innovation and R&D and time when the outcome of these investments is realized. There is no generally accepted time lag length for R&D output in the literature. Adam and Griliches (2000) state that time lag is 5 years in eight fields of university research output, while Guelloc and van Pottelsberghe de la Potterie (2000) mention that lag effect is between 1 and 2 years. Wang and Huang (2007) argue that a 3-year lag is most appropriate. Parallel to the arguments in the literature, the lag model was also considered in the study and a 2-year lag was used for the input variables, as Hollanders and Esser (2007) did. The efficiency scores for 58 countries based on the input-oriented CCR model for both models are presented in Table 32. The CCR assumes CRS and model measures the distance of the point under consideration from the CRS frontier, which has a constant slope.

Table 32. CCR efficiency scores across countries

DMU	Base Model CCRI							Lag Model CCRI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Argentina	0.51	0.46	0.28	0.26	0.25	0.28	0.34	0.63	0.54	0.34	0.31	0.31	0.31	0.41
Australia	0.73	0.74	0.77	0.81	0.82	0.81	0.78	1.00	0.88	0.91	0.97	1.00	1.00	0.96
Austria	0.54	0.53	0.57	1.00	0.59	0.61	0.63	0.62	0.63	0.61	0.64	0.67	1.00	0.69

Table 32 continued

DMU	Base Model CCRI							Lag Model CCRI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Belgium	0.66	0.68	0.69	0.68	0.69	0.81	0.70	0.80	0.82	0.83	0.86	0.91	0.94	0.86
Brazil	0.25	0.24	0.26	0.31	0.32	0.31	0.28	0.29	0.25	0.26	0.31	0.33	0.31	0.29
Bulgaria	0.57	0.50	0.47	0.50	0.41	0.42	0.47	0.91	0.72	0.63	0.56	0.47	0.49	0.63
Canada	1.00	0.97	0.96	0.91	0.88	0.88	0.93	1.00	0.99	1.00	0.99	1.00	0.96	0.99
Chile	0.78	0.77	0.97	0.85	0.85	0.89	0.85	0.94	0.91	0.90	0.83	0.93	0.87	0.90
China	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
Columbia	1.00	0.96	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.90	0.86	1.00	1.00	0.96
Czech Republic	0.56	0.54	0.64	0.68	0.68	0.57	0.61	0.76	0.69	0.70	0.72	0.82	0.79	0.75
Denmark	0.65	0.66	0.72	1.00	0.84	0.89	0.79	0.84	0.82	0.84	0.85	0.96	1.00	0.88
Egypt, Arab Rep.	0.22	0.27	0.26	0.26	0.30	0.28	0.26	0.29	0.29	0.26	0.32	0.34	0.32	0.30
Estonia	0.41	0.42	0.45	0.51	0.53	0.52	0.47	1.00	0.92	0.88	0.92	1.00	1.00	0.95
Finland	0.72	0.70	0.91	0.74	0.85	1.00	0.81	0.93	0.93	0.93	0.93	1.00	1.00	0.95
France	0.53	0.57	0.68	0.71	0.71	0.78	0.66	0.61	0.60	0.57	0.59	0.68	0.64	0.62
Germany	0.91	1.00	0.80	0.94	0.93	1.00	0.92	0.73	0.66	0.75	0.97	0.86	0.95	0.82
Greece	0.86	0.86	0.84	0.83	0.73	0.71	0.80	1.00	0.92	0.85	0.84	0.84	0.87	0.89
Hong Kong	0.68	0.66	0.68	0.63	0.64	0.62	0.65	0.85	0.83	0.85	0.86	0.84	0.81	0.84
Hungary	0.64	0.62	0.64	1.00	0.52	0.47	0.64	0.74	0.73	0.66	0.64	0.75	1.00	0.75
Iceland	0.63	0.73	0.89	1.00	0.96	1.00	0.86	0.87	0.94	1.00	0.96	0.95	1.00	0.95
India	1.00	0.83	0.79	0.72	0.65	0.65	0.77	1.00	0.82	0.74	0.69	0.62	0.59	0.74
Indonesia	1.00	1.00	1.00	1.00	0.64	0.76	0.89	1.00	1.00	0.93	1.00	0.64	0.76	0.89
Ireland	0.71	0.69	0.74	0.79	0.75	0.70	0.73	0.91	0.82	0.87	0.87	0.94	0.95	0.89
Israel	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	1.00	0.93	0.93	1.00	0.97	0.97
Italy	0.96	1.00	0.97	1.00	1.00	0.98	0.98	0.98	0.88	0.86	1.00	0.90	1.00	0.94
Japan	1.00	0.90	0.95	1.00	1.00	0.95	0.96	0.99	1.00	0.71	0.67	0.77	0.90	0.84
Latvia	0.69	0.94	1.00	1.00	1.00	0.95	0.93	0.82	1.00	0.93	0.91	1.00	0.98	0.94
Lithuania	0.28	0.38	0.37	0.37	0.37	0.38	0.35	0.63	0.84	0.70	0.68	0.83	0.83	0.75
Luxembourg	1.00	0.36	0.47	0.53	0.62	0.62	0.59	0.38	0.47	1.00	0.60	0.73	0.75	0.65
Malaysia	1.00	0.73	1.00	0.81	0.80	0.83	0.86	1.00	0.69	0.88	1.00	1.00	0.79	0.89
Mexico	0.64	0.59	0.54	0.58	0.60	0.66	0.60	0.51	0.50	0.45	0.50	0.56	0.53	0.51
Netherlands	0.73	0.80	0.74	1.00	0.83	0.92	0.84	0.86	1.00	0.86	0.89	0.97	1.00	0.93
New Zealand	1.00	0.87	0.90	0.88	0.86	0.87	0.89	1.00	0.96	0.95	0.96	1.00	1.00	0.98
Nigeria	0.58	0.54	0.51	0.43	0.40	0.37	0.47	0.63	0.61	0.58	0.56	0.55	0.45	0.56
Norway	0.64	0.65	0.73	0.73	0.77	0.79	0.72	0.70	0.71	0.77	0.77	0.82	0.82	0.77
Pakistan	0.24	0.27	0.33	0.35	0.37	0.38	0.32	0.41	0.25	0.26	0.31	0.34	0.34	0.32
Philippines	1.00	1.00	1.00	1.00	0.79	1.00	0.96	1.00	0.94	0.78	0.79	0.68	1.00	0.86
Poland	0.33	0.34	0.37	0.36	0.37	0.39	0.96	0.47	0.50	0.49	0.48	0.52	0.50	0.49
Portugal	0.56	0.60	0.63	0.64	0.65	0.63	0.62	0.67	0.78	0.67	0.69	0.76	0.78	0.73
Romania	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Russian Federation	0.21	0.21	0.24	0.20	0.16	0.18	0.20	0.26	0.24	0.22	0.21	0.22	0.21	0.23

Table 32 continued

DMU	Base Model CCRI							Lag Model CCRI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Singapore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slovak Republic	0.39	0.41	0.39	0.37	0.41	0.45	0.40	0.60	0.65	0.56	0.58	0.67	0.64	0.62
Slovenia	0.79	0.87	0.88	0.81	0.90	0.92	0.86	1.00	1.00	1.00	0.97	1.00	1.00	0.99
South Africa	0.41	0.43	0.41	0.28	0.30	0.31	0.36	0.28	0.37	0.31	0.32	0.32	0.26	0.31
South Korea	0.94	0.92	0.87	1.00	0.99	0.99	0.95	0.93	1.00	0.82	1.00	1.00	1.00	0.96
Spain	0.67	0.63	0.67	0.63	0.63	0.67	0.65	0.72	0.67	0.58	0.55	0.63	0.64	0.63
Sweden	0.73	0.73	0.74	0.76	0.75	0.78	0.75	0.90	0.86	0.88	0.93	0.96	1.00	0.92
Switzerland	0.99	0.95	0.95	0.98	0.99	1.00	0.98	1.00	0.99	0.96	1.00	1.00	1.00	0.99
Thailand	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.88	1.00	1.00	1.00	0.97
Turkey	0.49	0.46	0.49	0.39	0.35	0.32	0.42	0.64	0.60	0.52	0.46	0.46	0.39	0.51
Ukraine	0.46	0.31	0.26	0.20	0.16	0.16	0.26	0.53	0.51	0.42	0.26	0.21	0.21	0.36
United Kingdom	0.62	0.62	0.86	0.66	0.69	0.68	0.69	0.74	0.73	0.73	0.75	0.93	0.80	0.78
United States	0.90	0.88	0.74	0.76	0.74	0.74	0.79	0.90	0.85	0.75	0.76	0.77	0.75	0.80
Average	0.71	0.69	0.71	0.72	0.69	0.71		0.79	0.77	0.74	0.75	0.77	0.78	

The striking result in Table 32 is that the lag model reveals higher efficiency scores in general. This finding supports the arguments of the ‘time lag effect’ in the literature. The average efficiency score of the sample is higher in the lag model for each year. The highest score in the base model is 0.71 and the lowest is 0.69. There is thus not much divergence among the average efficiency scores. However, the efficiency scores range between 0.74 and 0.79 in the lag model. An efficiency score of 0.51 (Turkey) indicates that the same outputs can be realized with 51% of its inputs.

Germany, Japan, China, Canada, South Korea, Italy, Israel, Poland, Singapore and Switzerland have efficiency scores above 0.90 in the base model. By contrast, small countries (Chile, Columbia, Greece, Latvia, the Philippines, Romania and Thailand) with lower expenses on R&D also have high scores, revealing a ‘small country’ phenomenon in the literature. Sometimes, they are referred to as ‘exotic’ countries.

These small countries appear to be efficient due to the sample size and the set of variables but not due to performance of their national innovation system (Kotsemir, 2013). In addition to the efficient countries in the base model, the innovation efficiency scores become higher (above 0.90) in the lag model for Australia, the Netherlands, New Zealand, Slovenia and Spain. On the other hand, the efficiency scores drop below 0.90 for Germany (0.82), the Philippines (0.86), and Poland (0.49) in the lag model.

Another important observation is that the findings also reveal the negative impact of the global crisis on the sample. The average efficiency scores in 2008 are lower than the score in 2007. However, the negative impact continues in 2009 in the lag model. An improvement in the efficiency scores is seen in 2012. The number of efficient countries also supports the negative impact of the global crisis. The efficient number of countries in the base model is 14, 7 and 10 in 2007, 2008 and 2009, respectively. More dramatic decline is seen in the number of efficient countries in the lag model. The number of efficient countries is 16, 11 and 6 in 2007, 2008 and 2009, respectively. It reaches 11 in the base model, while it was 20 in the lag model in 2012.

In order to overcome the restrictive assumption of the CCR model with CRS, the VRS BCC model is utilized and the results are compared. The BCC DEA model captures returns to scale (RTS) difference among countries, indicating increasing, constant and decreasing returns, whereas the CCR DEA model simply assumes CRS. Efficiency scores for all countries using the input-oriented BCC model are presented in Table 33.

Table 33. Input-oriented BCC efficiency scores across countries

DMU	Base Model 1 BCCI							Lag Model 1BCCI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Argentina	0.71	0.63	0.57	0.53	0.50	0.51	0.57	0.74	0.67	0.54	0.52	0.53	0.52	0.59
Australia	0.80	0.81	0.84	0.87	0.87	0.85	0.84	1.00	0.94	0.94	0.98	1.00	1.00	0.98
Austria	0.63	0.65	0.64	1.00	0.65	0.67	0.71	0.74	0.73	0.71	0.72	0.74	1.00	0.77
Belgium	0.75	0.76	0.77	0.75	0.74	0.89	0.78	0.93	0.93	0.91	0.93	0.96	0.98	0.94
Brazil	0.56	0.54	0.52	0.53	0.53	0.52	0.53	0.53	0.51	0.51	0.51	0.51	0.52	0.52
Bulgaria	1.00	0.95	1.00	1.00	0.98	0.96	0.98	1.00	0.98	0.91	0.87	0.82	0.89	0.91
Canada	1.00	1.00	1.00	0.96	0.92	0.91	0.96	1.00	0.99	1.00	0.99	1.00	0.97	0.99
Chile	0.89	0.85	1.00	0.90	0.91	0.94	0.91	1.00	0.97	0.96	0.88	1.00	0.92	0.95
China	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Columbia	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.89	1.00	1.00	0.97
Czech Republic	0.74	0.74	0.82	0.83	0.81	0.70	0.77	0.93	0.91	0.86	0.88	0.96	0.92	0.91
Denmark	0.71	0.74	0.75	1.00	0.85	0.90	0.83	0.85	0.84	0.85	0.87	0.96	1.00	0.89
Egypt, Arab Rep.	0.95	0.72	0.67	0.57	0.73	0.61	0.71	1.00	0.85	0.70	0.58	0.58	0.51	0.70
Estonia	0.97	0.90	0.93	0.92	0.79	0.74	0.88	1.00	0.97	0.92	0.95	1.00	1.00	0.97
Finland	0.78	0.75	0.94	0.77	0.86	1.00	0.85	0.99	0.99	0.97	0.96	1.00	1.00	0.99
France	0.62	0.68	0.81	0.81	0.81	0.86	0.76	0.74	0.72	0.70	0.70	0.75	0.72	0.72
Germany	0.92	1.00	0.82	0.96	0.93	1.00	0.94	0.77	0.72	0.77	1.00	0.87	1.00	0.85
Greece	0.97	0.96	0.93	0.92	0.81	0.78	0.89	1.00	0.93	0.87	0.86	0.86	0.90	0.90
Hong Kong	0.73	0.70	0.71	0.67	0.67	0.66	0.69	0.86	0.84	0.86	0.86	0.85	0.82	0.85
Hungary	0.73	0.69	0.77	1.00	0.67	0.63	0.75	0.85	0.82	0.74	0.73	0.84	1.00	0.83
Iceland	0.94	0.96	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	0.97	1.00	1.00	0.99
India	1.00	0.99	0.98	0.87	0.81	0.78	0.91	1.00	0.94	0.85	0.83	0.80	0.72	0.86
Indonesia	1.00	1.00	1.00	1.00	0.81	0.84	0.94	1.00	1.00	0.95	1.00	0.86	0.84	0.94
Ireland	0.74	0.73	0.78	0.82	0.79	0.76	0.77	0.92	0.82	0.87	0.87	0.94	0.95	0.90
Israel	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.95	0.97	1.00	0.97	0.98
Italy	0.97	1.00	0.98	1.00	1.00	1.00	0.99	1.00	0.90	0.87	1.00	0.93	1.00	0.95
Japan	1.00	0.95	0.97	1.00	1.00	0.95	0.98	1.00	1.00	0.77	0.77	0.83	0.92	0.88
Latvia	0.89	0.97	1.00	1.00	1.00	0.97	0.97	1.00	1.00	0.93	0.91	1.00	1.00	0.97
Lithuania	0.88	0.82	0.95	0.84	0.75	0.75	0.83	1.00	0.98	0.88	0.86	1.00	0.95	0.94
Luxembourg	1.00	0.46	0.51	0.56	0.64	0.65	0.63	0.54	0.55	1.00	0.61	0.76	0.78	0.71
Malaysia	1.00	0.90	1.00	0.90	0.86	0.88	0.92	1.00	0.84	0.95	1.00	1.00	0.89	0.95
Mexico	0.80	0.74	0.72	0.69	0.69	0.76	0.73	0.65	0.62	0.59	0.62	0.65	0.61	0.62
Netherlands	0.73	0.82	0.76	1.00	0.85	0.93	0.85	0.93	1.00	0.91	0.92	0.98	1.00	0.96
New Zealand	1.00	0.89	0.92	0.91	0.89	0.89	0.92	1.00	0.97	0.95	0.97	1.00	1.00	0.98
Nigeria	1.00	1.00	1.00	1.00	0.89	0.90	0.97	1.00	1.00	0.95	0.99	1.00	0.88	0.97
Norway	0.71	0.71	0.79	0.77	0.80	0.82	0.77	0.72	0.73	0.78	0.79	0.83	0.85	0.78
Pakistan	0.98	0.95	1.00	1.00	1.00	1.00	0.99	1.00	0.81	0.72	0.71	0.98	1.00	0.87
Philippines	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.92	1.00	1.00	1.00	0.98
Poland	0.61	0.58	0.57	0.58	0.56	0.60	0.58	0.75	0.76	0.73	0.71	0.71	0.72	0.73
Portugal	0.67	0.70	0.72	0.71	0.70	0.67	0.69	0.73	0.79	0.71	0.72	0.78	0.79	0.75
Romania	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Russian Federation	0.77	0.70	0.67	0.65	0.63	0.62	0.67	0.70	0.84	0.58	0.57	0.59	0.61	0.65
Singapore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slovak Republic	0.79	0.74	0.77	0.72	0.70	0.71	0.74	0.95	0.89	0.77	0.77	0.84	0.81	0.84

Table 33 continued

Base Model 1 BCCI								Lag Model 1BCCI						
DMU	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Slovenia	0.88	0.93	0.93	0.87	0.93	0.95	0.91	1.00	1.00	1.00	0.97	1.00	1.00	1.00
South Africa	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00
South Korea	0.99	0.98	0.95	1.00	0.99	1.00	0.98	0.99	1.00	0.94	1.00	1.00	1.00	0.99
Spain	0.68	0.63	0.68	0.63	0.63	0.68	0.65	0.72	0.68	0.63	0.63	0.70	0.67	0.67
Sweden	0.79	0.77	0.79	0.83	0.81	0.81	0.80	0.94	0.89	0.91	0.94	0.97	1.00	0.94
Switzerland	1.00	0.99	0.97	0.98	0.99	1.00	0.99	1.00	0.99	0.96	1.00	1.00	1.00	0.99
Thailand	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.93	1.00	1.00	1.00	0.98
Turkey	0.54	0.52	0.56	0.53	0.49	0.49	0.52	0.65	0.62	0.53	0.51	0.55	0.52	0.56
Ukraine	1.00	0.97	1.00	1.00	0.98	1.00	0.99	1.00	1.00	0.93	0.91	1.00	1.00	0.97
United Kingdom	0.67	0.65	0.89	0.67	0.71	0.69	0.71	0.82	0.81	0.80	0.82	0.93	0.86	0.84
United States	0.91	0.89	0.75	0.76	0.74	0.74	0.80	0.92	0.85	0.78	0.79	0.79	0.78	0.82
Average	0.86	0.84	0.86	0.86	0.83	0.84		0.91	0.88	0.85	0.85	0.88	0.89	

Findings of the input-oriented BCC model reveal a pattern similar to that of the CCR model. The lag model has higher efficiency scores for most of the countries in the sample. However, the divergence between scores is much lower. The average efficiency scores range from 0.83 to 0.86 in the base model, where these range from 0.85 to 0.91 in the lag model. Similarly, the negative impact of the global crisis can be traced in both models but it is more apparent in the lag model. The average efficiency score declined from 0.91 in 2007 to 0.85 in 2009 and 2010. An improvement in the average efficiency scores was seen in 2012. When the number of efficient countries is investigated, a decline from 2007 to 2008 is observed in both models. There were 19 efficient countries in 2007 but this number declined to 11 in the base model. The decline is much more apparent in the lag model. The number of efficient countries in 2007, 2008, 2009 and 2010 are 28, 15, 7 and 12, respectively. The decline continues in the lag model and by 2012 had not reached its pre-crisis level in 25 efficient countries .

The leading countries in innovation and R&D with efficiency scores above 0.90 are Australia, Belgium, Canada, Finland, Ireland, Italy, Israel, the Netherlands, New Zealand, Singapore, South Korea and Switzerland. There are also a number of emerging countries such as China, the Czech Republic, Estonia, India, Nigeria, Bulgaria, Chile, Colombia, Iceland, Indonesia, Latvia, Malaysia, Nigeria, Pakistan, the Philippines, Romania, Slovenia, South Africa, Thailand and Ukraine that have high scores. Some of these countries might have efficiency scores owing to 'small country' bias, while some have high efficiency scores due to the performance of their national innovation systems. However, it is interesting to observe that the efficiency scores of Germany and Japan decline in the lag model, while they were above 0.90 in the base model. Similarly, efficiency scores decline for India and Pakistan among emerging countries. Turkey exhibits a similar score, 0.56, in the lag model, but 0.51 in the base model. It is also interesting to see improvement in the efficiency scores for some countries when the lag model is used. The efficiency score for the Russian Federation improves from 0.23 to 0.65, for Egypt from 0.30 to 0.70, for South Africa from 0.31 to 1.00, and for Ukraine from 0.36 to 0.97. One possible explanation is that the VRS DEA model captures differences in technologies with the BCC model, whereas time lag is much more important for these countries.

Although in input-oriented or output-oriented measurements of the CCR give the same efficiency results, the BCC model does not provide the same efficiency results in input- and output-oriented measurement due to the efficiency frontier assumption.

Efficiency scores for all countries using the output-oriented BCC model are presented in Table 34.

Table 34. Output-oriented BCC efficiency scores across countries

DMU	Base Model 1BCCO							Lag Model 1 BCCO						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Argentina	0.52	0.46	0.28	0.27	0.25	0.28	0.34	0.63	0.54	0.35	0.32	0.31	0.31	0.41
Australia	0.76	0.76	0.80	0.84	0.84	0.82	0.80	1.00	0.92	0.92	0.98	1.00	1.00	0.97
Austria	0.55	0.54	0.57	1.00	0.59	0.61	0.64	0.63	0.64	0.62	0.65	0.68	1.00	0.70
Belgium	0.69	0.70	0.71	0.69	0.69	0.84	0.72	0.88	0.88	0.88	0.90	0.95	0.97	0.91
Brazil	0.25	0.24	0.26	0.31	0.33	0.31	0.28	0.29	0.25	0.26	0.32	0.34	0.31	0.30
Bulgaria	1.00	0.70	0.79	1.00	0.69	0.62	0.80	1.00	0.90	0.76	0.68	0.55	0.66	0.76
Canada	1.00	1.00	1.00	0.94	0.90	0.89	0.96	1.00	0.99	1.00	0.99	1.00	0.96	0.99
Chile	0.84	0.81	1.00	0.88	0.89	0.92	0.89	1.00	0.96	0.94	0.85	1.00	0.90	0.94
China	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Columbia	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.87	1.00	1.00	0.96
Czech Republic	0.59	0.54	0.65	0.68	0.68	0.58	0.62	0.88	0.84	0.78	0.80	0.93	0.87	0.85
Denmark	0.65	0.66	0.72	1.00	0.84	0.89	0.79	0.84	0.82	0.85	0.85	0.96	1.00	0.89
Egypt, Arab Rep.	0.40	0.28	0.26	0.27	0.35	0.29	0.31	1.00	0.52	0.29	0.33	0.35	0.33	0.47
Estonia	0.52	0.43	0.46	0.52	0.54	0.53	0.50	1.00	0.95	0.90	0.93	1.00	1.00	0.96
Finland	0.73	0.71	0.91	0.74	0.87	1.00	0.83	0.99	0.99	0.96	0.94	1.00	1.00	0.98
France	0.53	0.57	0.73	0.74	0.74	0.80	0.69	0.63	0.61	0.57	0.59	0.69	0.64	0.62
Germany	0.91	1.00	0.80	0.95	0.93	1.00	0.93	0.75	0.70	0.79	1.00	0.91	1.00	0.86
Greece	0.96	0.95	0.91	0.90	0.78	0.75	0.87	1.00	0.93	0.86	0.85	0.85	0.89	0.90
Hong Kong	0.70	0.68	0.69	0.64	0.65	0.63	0.66	0.85	0.83	0.85	0.86	0.84	0.81	0.84
Hungary	0.64	0.62	0.65	1.00	0.53	0.47	0.11	0.75	0.74	0.66	0.64	0.77	1.00	0.76
Iceland	0.64	0.73	0.95	1.00	1.00	1.00	0.89	0.96	1.00	1.00	0.96	0.96	1.00	0.98
India	1.00	0.92	0.83	0.74	0.68	0.69	0.81	1.00	0.83	0.77	0.73	0.68	0.64	0.77
Indonesia	1.00	1.00	1.00	1.00	0.64	0.76	0.90	1.00	1.00	0.94	1.00	0.65	0.76	0.89
Ireland	0.71	0.70	0.76	0.80	0.76	0.72	0.74	0.92	0.82	0.87	0.87	0.94	0.95	0.90
Israel	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.95	0.94	1.00	0.98	0.98
Italy	0.97	1.00	0.98	1.00	1.00	1.00	0.99	1.00	0.92	0.91	1.00	0.96	1.00	0.96
Japan	1.00	0.93	0.96	1.00	1.00	0.95	0.97	1.00	1.00	0.72	0.68	0.78	0.94	0.85
Latvia	0.72	0.95	1.00	1.00	1.00	0.95	0.94	1.00	1.00	0.93	0.92	1.00	1.00	0.97
Lithuania	0.30	0.40	0.39	0.39	0.38	0.39	0.37	1.00	0.96	0.79	0.75	1.00	0.92	0.90
Luxembourg	1.00	0.36	0.47	0.55	0.63	0.64	0.61	0.40	0.49	1.00	0.71	0.85	0.86	0.72
Malaysia	1.00	0.75	1.00	0.82	0.81	0.84	0.87	1.00	0.70	0.90	1.00	1.00	0.82	0.90
Mexico	0.70	0.61	0.55	0.59	0.61	0.67	0.62	0.52	0.50	0.46	0.51	0.57	0.54	0.52
Netherlands	0.76	0.80	0.76	1.00	0.86	0.94	0.85	0.90	1.00	0.88	0.90	0.97	1.00	0.94
New Zealand	1.00	0.88	0.90	0.88	0.86	0.87	0.90	1.00	0.96	0.95	0.96	1.00	1.00	0.98
Nigeria	1.00	1.00	1.00	1.00	0.69	0.63	0.89	1.00	1.00	0.88	0.97	1.00	0.74	0.93
Norway	0.65	0.65	0.73	0.74	0.77	0.79	0.72	0.70	0.71	0.77	0.78	0.83	0.83	0.77
Pakistan	0.70	0.54	1.00	1.00	1.00	1.00	0.87	1.00	0.35	0.29	0.34	0.81	1.00	0.63
Philippines	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.79	1.00	1.00	1.00	0.96
Poland	0.34	0.34	0.37	0.36	0.37	0.39	0.36	0.49	0.53	0.51	0.50	0.53	0.53	0.52
Portugal	0.60	0.64	0.67	0.66	0.67	0.64	0.65	0.68	0.78	0.68	0.71	0.77	0.79	0.73
Romania	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Russian Federation	0.25	0.24	0.26	0.21	0.16	0.19	0.22	0.34	0.39	0.25	0.24	0.25	0.24	0.28
Singapore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slovak Republic	0.40	0.41	0.39	0.37	0.41	0.47	0.41	0.81	0.74	0.57	0.58	0.67	0.64	0.67

Table 34 continued

DMU	Base Model 1BCCO							Lag Model 1 BCCO						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Slovenia	0.83	0.92	0.92	0.83	0.92	0.95	0.90	1.00	1.00	1.00	0.97	1.00	1.00	0.99
South Africa	1.00	1.00	1.00	1.00	0.94	0.93	0.98	1.00	1.00	0.85	1.00	1.00	1.00	0.97
South Korea	0.98	0.96	0.91	1.00	0.99	1.00	0.97	0.99	1.00	0.85	1.00	1.00	1.00	0.97
Spain	0.68	0.64	0.67	0.65	0.64	0.69	0.66	0.73	0.69	0.60	0.58	0.63	0.64	0.64
Sweden	0.75	0.73	0.74	0.76	0.77	0.80	0.76	0.93	0.87	0.88	0.93	0.97	1.00	0.93
Switzerland	1.00	0.99	0.96	0.98	0.99	1.00	0.99	1.00	0.99	0.96	1.00	1.00	1.00	0.99
Thailand	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.88	1.00	1.00	1.00	0.97
Turkey	0.49	0.46	0.49	0.40	0.35	0.33	0.42	0.64	0.60	0.52	0.46	0.46	0.39	0.51
Ukraine	1.00	0.64	1.00	1.00	0.68	1.00	0.89	1.00	1.00	0.67	0.51	1.00	1.00	0.86
United Kingdom	0.62	0.62	0.87	0.69	0.72	0.71	0.71	0.76	0.74	0.74	0.76	0.93	0.81	0.79
United States	0.92	0.90	0.75	0.77	0.76	0.75	0.81	0.93	0.86	0.75	0.77	0.77	0.75	0.81
Average	0.77	0.73	0.77	0.79	0.75	0.76	0.75	0.87	0.82	0.78	0.79	0.84	0.84	0.82

In Table 34, in both the base model and lag model, the innovation efficiency ratio on average decreased in 2008 in comparison with 2007. In the lag model, the effects of the crisis are seen for two consecutive years, 2008 and 2009. In addition, the difference in the base model between the highest the lowest efficiency scores is very small, with the highest efficiency score in the base model being 0.79 in 2010 and the lowest score is 0.75 in 2011. In the lag model, however, the scores range from 0.87 in 2007 to 0.78 in 2009, which reflects the 2005 and 2007 inputs respectively. It is also important to underline that, in the lag model, 28 countries are classed as efficient in 2007, while in 2009 it is only 7.

When the efficiency scores between the inward-oriented BCC and the output-oriented BCC DEA models are compared, it is seen that the efficiency scores of output-oriented DEA model are lower compared to input-oriented DEA model. The group of countries that are efficient in the base and lag models are very similar to the

results in the input-oriented BCC DEA model. In addition, the countries that became more efficient in the lag model show the same trend.

To sum up the findings of the CCR DEA model, the input-oriented BCC and the output-oriented BCC DEA models, the average scores and the number of the efficient countries are presented for the period studied. Table 35 compares the base model and lag model averages across the years and gives a summary of the innovation efficiency of the 58 countries included in the study. It is important to emphasize that in the base model, the lowest efficiency ratios are seen right after the crisis in 2008, while in the lag model the lowest ratios are seen after 2 years, in 2009. It is also worth noting that the BCC input-oriented model presents the highest average efficiency ratios in both the base model and the lag model.

Table 35. Average efficiency scores during the global crisis

	Base Model						Lag Model					
	2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
CCR	0.71	0.69	0.71	0.72	0.69	0.71	0.79	0.77	0.74	0.75	0.77	0.78
BCC Input	0.86	0.84	0.86	0.86	0.83	0.84	0.91	0.88	0.85	0.85	0.88	0.89
BCC Output	0.77	0.73	0.77	0.79	0.75	0.76	0.87	0.82	0.78	0.79	0.84	0.84

Table 36 below presents the number of efficient countries according to model and year. In the base model for the year 2010, the input-oriented BCC efficiency ratio is higher than the same year's output-oriented BCC average, although the number of efficient countries is lower.

Table 36. Number of efficient countries

	Base Model						Lag Model					
	2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
CCR	14	7	10	16	9	11	16	11	6	9	16	20
BCC Input	19	11	18	19	11	15	28	15	7	12	23	25
BCC Output	19	11	16	22	11	15	28	15	7	12	22	24

Sharma and Thomas (2008) state that the decision on the choice of input-or output-orientation of the model depends on the importance of input conservation or output augmentation. Since the efficiency/inefficiency in resource is the focus in this study, the input-oriented BCC DEA model was preferred. Another reason was that R&D and innovation are continuing processes and inputs cannot generate immediate results or outputs. Therefore, the input-oriented BCC DEA model with lag model was used for the rest of the analysis.

Countries have more control over their innovation and R&D inputs than over their outputs, as Nasierowski and Arcelus (2003) mention in their study. Therefore, an input-oriented variable returns to scale model was used for the further analysis. Table 37 presents countries that exhibit variable returns to scale under the input-oriented BCC model for the lag model.

Table 37. Variable returns to scale under input-oriented BCC model for lag model.

Country	2007	RTS	2012	RTS
Argentina	0.74	IRS	0.52	IRS
Australia	1.00	CRS	1.00	IRS
Austria	0.74	IRS	1.00	CRS
Belgium	0.93	IRS	0.98	IRS
Brazil	0.53	IRS	0.52	IRS
Bulgaria	1.00	IRS	0.89	IRS
Canada	1.00	CRS	0.97	IRS
Chile	1.00	IRS	0.92	IRS
China	1.00	CRS	1.00	CRS
Columbia	1.00	CRS	1.00	CRS
Czech Republic	0.93	IRS	0.92	IRS
Denmark	0.85	IRS	1.00	CRS
Egypt, Arab Rep.	1.00	IRS	0.51	IRS
Estonia	1.00	CRS	1.00	CRS
Finland	0.99	IRS	1.00	CRS
France	0.74	IRS	0.72	IRS

Table 37 continued

Country	2007	RTS	2012	RTS
Germany	0.77	IRS	1.00	DRS
Greece	1.00	CRS	0.90	IRS
Hong Kong	0.86	IRS	0.82	IRS
Hungary	0.85	IRS	1.00	CRS
Iceland	0.98	IRS	1.00	CRS
India	1.00	CRS	0.72	IRS
Indonesia	1.00	IRS	0.84	IRS
Ireland	0.92	IRS	0.95	CRS
Israel	1.00	CRS	0.97	CRS
Italy	1.00	DRS	1.00	CRS
Japan	1.00	IRS	0.92	IRS
Latvia	1.00	IRS	1.00	IRS
Lithuania	1.00	IRS	0.95	IRS
Luxembourg	0.54	IRS	0.78	CRS
Malaysia	1.00	CRS	0.89	IRS
Mexico	0.65	IRS	0.61	IRS
Netherlands	0.93	IRS	1.00	CRS
New Zealand	1.00	CRS	1.00	CRS
Nigeria	1.00	IRS	0.88	IRS
Norway	0.72	IRS	0.85	IRS
Pakistan	1.00	IRS	1.00	IRS
Philippines	1.00	CRS	1.00	CRS
Poland	0.75	IRS	0.72	IRS
Portugal	0.73	IRS	0.79	IRS
Romania	1.00	CRS	1.00	CRS
Russian Federation	0.70	IRS	0.61	IRS
Singapore	1.00	CRS	1.00	CRS
Slovak Republic	0.95	IRS	0.81	IRS
Slovenia	1.00	CRS	1.00	CRS
South Africa	1.00	IRS	1.00	IRS
South Korea	0.99	IRS	1.00	CRS
Spain	0.72	IRS	0.67	IRS
Sweden	0.94	IRS	1.00	CRS
Switzerland	1.00	CRS	1.00	CRS
Thailand	1.00	CRS	1.00	CRS
Turkey	0.65	IRS	0.52	IRS
Ukraine	1.00	IRS	1.00	IRS
United Kingdom	0.82	IRS	0.86	IRS
United States	0.92	DRS	0.78	IRS

The findings show 37 countries exhibiting increasing returns to scale, 16 countries exhibiting constant returns to scale and two countries with decreasing returns to scale in 2007, just before the global crisis. The number of countries that exhibit increasing returns to scale declines to 32 in 2012, whereas the number of countries with constant returns to scale increases from 16 in 2007 to 22 in 2012. The decline in the number of countries that exhibit IRS indicates that more countries had passed through the earlier stages of the production life cycle from 2007 to 2012. For example, Luxembourg had an efficiency score of 0.54 exhibiting IRS in 2007. This finding can be interpreted as Luxembourg's ability to generate the same output levels by cutting back 46% of the current inputs level. IRS also indicates that more innovative output can be generated by more than a corresponding change in inputs. In 2012, the efficiency score of Luxembourg improves to 0.78 and exhibit CRS. This finding shows that Luxembourg is still inefficient in terms of utilizing its resources: the same level of output can be realized by cutting back 22% of the current inputs. However, output changes by that same proportional change in inputs in 2012. Italy and the United States exhibit DRS in 2007. Germany is the only country with DRS in 2012. This shows that Germany completed all stages of the production life cycle from 2007 to 2012 and was able to benefit from scaling down the innovation process. Turkey exhibits IRS so that any improvement in the resources can attribute more than that proportional change in inputs. But the efficiency score of 0.52 reveals that Turkey can generate the same output level by cutting back almost half of the inputs.

In order to overcome the "small country" problem, two approaches were used to categorize countries in the sample set. The first step was to classify countries according to their GDP ranking and the second step was to group them according to Global Competitiveness Index criteria.

Four groups were formed according to the countries' economic capacity:

1. Group 1: GDP more than 1.5 trillion USD (top 10 countries in GDP ranking: United States, China, Japan, Germany, France, the United Kingdom, Brazil, Italy, India, Canada)
2. Group 2: GDP between 500 billion USD and 1.5 trillion USD (countries ranking between 10 and 19 in GDP ranking: the Russian Federation, Spain, Australia, Mexico, South Korea, the Netherlands, Turkey, Indonesia, Switzerland)
3. Group 3: GDP between 100 and 499 billion USD (Belgium, Poland, Sweden, Norway, Austria, Argentina, Nigeria, South Africa, Thailand, Denmark, Greece, Columbia, Malaysia, Finland, Singapore, Israel, Portugal, Hong Kong, Egypt, Chile, Ireland, Philippines, Czech Republic, Pakistan, Romania, New Zealand, Ukraine, Hungary)
4. Group 4: GDP less than 100 billion USD (Slovak Republic, Luxembourg, Bulgaria, Slovenia, Lithuania, Latvia, Estonia, Iceland)

Table 38 shows the input-oriented CCR model results according to GDP group and each group's average efficiency ratios.

Table 38. Input oriented CCR model according to GDP group

DMU	Base Model CCRI							Lag Model CCRI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 1														
Brazil	0.40	0.44	0.44	0.44	0.45	0.45	0.44	0.42	0.44	0.45	0.47	0.48	0.48	0.46
Canada	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
China	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
France	0.79	0.80	0.84	0.87	0.88	0.90	0.85	1.00	0.98	0.82	0.82	0.86	0.85	0.89
Germany	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
India	1.00	0.87	0.87	0.84	0.82	0.81	0.87	1.00	0.89	0.84	0.81	0.80	0.79	0.86
Italy	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
Japan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.95	0.96	0.94	0.96
United Kingdom	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
United States	1.00	0.99	0.97	0.98	0.96	0.92	0.97	1.00	0.95	0.87	0.91	0.95	0.93	0.93
Average	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.94	0.92	0.89	0.90	0.90	0.90	0.91
Group 2														
Australia	0.87	0.90	1.00	1.00	1.00	1.00	0.96	1.00	0.93	0.93	0.98	1.00	1.00	0.97
Indonesia	1.00	1.00	1.00	1.00	0.85	0.81	0.94	1.00	1.00	1.00	1.00	0.87	0.83	0.95
Mexico	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.98	0.89	1.00	1.00	1.00	0.98
Netherlands	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.94	1.00	1.00	0.98
Russian Federation	0.42	0.43	0.58	0.62	0.56	0.71	0.55	0.58	0.55	0.55	0.55	0.51	0.68	0.57
South Korea	0.96	0.98	0.94	1.00	1.00	1.00	0.98	1.00	1.00	0.85	1.00	1.00	1.00	0.97
Spain	1.00	1.00	1.00	0.99	0.95	1.00	0.99	1.00	1.00	0.94	0.95	1.00	1.00	0.98
Switzerland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00
Turkey	0.74	0.71	0.80	0.64	0.52	0.44	0.64	0.87	0.82	0.73	0.63	0.63	0.53	0.70
Average	0.89	0.89	0.92	0.92	0.88	0.88	0.90	0.94	0.92	0.87	0.89	0.89	0.89	0.90

Table 38 continued

DMU	Base Model CCRI							Lag Model CCRI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 3														
Argentina	0.77	0.67	0.38	0.36	0.31	0.40	0.48	0.72	0.66	0.35	0.33	0.33	0.38	0.46
Austria	0.67	0.69	0.71	1.00	0.75	0.79	0.77	0.69	0.69	0.69	0.70	0.75	1.00	0.75
Belgium	0.86	0.89	0.95	0.99	1.00	1.00	0.95	0.87	0.89	0.91	0.94	0.99	1.00	0.93
Chile	0.88	0.85	1.00	0.89	0.93	0.97	0.92	1.00	0.97	0.97	0.88	1.00	0.92	0.96
Colombia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.91	0.87	1.00	1.00	0.96
Czech Republic	0.65	0.70	0.83	0.88	0.93	0.79	0.80	0.81	0.73	0.76	0.80	0.84	0.82	0.79
Denmark	0.80	0.80	0.87	1.00	0.97	1.00	0.91	0.86	0.85	0.88	0.87	0.96	1.00	0.90
Egypt	0.30	0.32	0.31	0.30	0.36	0.35	0.32	0.40	0.39	0.30	0.34	0.37	0.34	0.36
Finland	1.00	0.96	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.96	1.00	1.00	0.99
Greece	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.96	0.91	0.91	0.93	0.96	0.95
Hong Kong	0.96	0.97	1.00	0.96	0.95	0.89	0.96	0.98	0.96	1.00	0.99	0.98	0.96	0.98
Hungary	0.74	0.74	0.80	1.00	0.73	0.70	0.78	0.81	0.80	0.69	0.67	0.81	1.00	0.80
Ireland	0.86	0.85	0.92	1.00	1.00	0.96	0.93	0.96	0.90	0.94	0.97	1.00	1.00	0.96
Israel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Malaysia	1.00	0.77	1.00	0.83	0.86	0.86	0.89	1.00	0.69	0.88	1.00	1.00	0.82	0.90
New Zealand	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.96	0.99	1.00	1.00	0.99
Nigeria	1.00	1.00	1.00	0.82	0.71	0.72	0.88	1.00	1.00	0.89	0.94	0.94	0.77	0.92
Norway	0.81	0.81	0.93	0.96	0.98	1.00	0.92	0.85	0.85	0.93	0.95	0.99	1.00	0.93
Pakistan	0.59	0.56	0.67	0.69	0.71	0.70	0.65	1.00	0.43	0.48	0.52	0.50	0.47	0.57
Philippines	1.00	1.00	1.00	1.00	0.79	1.00	0.96	1.00	0.95	0.83	0.94	0.79	1.00	0.92
Poland	0.49	0.50	0.53	0.52	0.53	0.57	0.52	0.52	0.54	0.52	0.53	0.57	0.57	0.54
Portugal	0.63	0.67	0.72	0.74	0.80	0.85	0.73	0.70	0.82	0.73	0.73	0.81	0.85	0.77
Romania	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Singapore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
South Africa	0.50	0.52	0.49	0.31	0.33	0.34	0.41	1.00	0.38	0.45	0.37	0.36	0.34	0.05
Sweden	0.94	0.94	0.96	1.00	1.00	1.00	0.97	0.96	0.91	0.93	0.98	1.00	1.00	0.96
Thailand	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.89	1.00	1.00	1.00	0.97
Ukraine	0.52	0.33	0.28	0.23	0.20	0.23	0.30	0.73	0.67	0.55	0.29	0.23	0.22	0.45
Average	0.82	0.80	0.83	0.84	0.82	0.83	0.82	0.89	0.82	0.80	0.80	0.83	0.84	0.81
Group 4														
Bulgaria	0.71	0.65	0.59	0.63	0.56	0.55	0.62	1.00	0.84	0.71	0.65	0.58	0.61	0.73
Estonia	0.55	0.48	0.51	0.64	0.70	0.65	0.59	1.00	0.93	0.91	0.94	1.00	1.00	0.96
Iceland	1.00	0.84	1.00	1.00	1.00	1.00	0.97	0.99	0.96	1.00	1.00	1.00	1.00	0.99
Latvia	0.72	1.00	1.00	1.00	1.00	1.00	0.95	0.91	1.00	1.00	0.95	1.00	1.00	0.98
Lithuania	0.52	0.61	0.53	0.65	0.63	0.67	0.60	0.77	0.94	0.74	0.74	0.95	0.94	0.85
Luxembourg	1.00	0.71	0.85	1.00	1.00	1.00	0.93	1.00	0.89	0.84	0.81	0.80	0.79	0.86
Slovakia	0.87	0.85	0.84	0.83	0.92	1.00	0.88	0.86	0.94	0.78	0.87	1.00	1.00	0.91
Slovenia	0.94	1.00	1.00	0.92	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Average	0.79	0.77	0.79	0.83	0.85	0.86	0.81	0.94	0.94	0.87	0.87	0.92	0.92	0.91

The findings shown in Table 38 are remarkable. In Group 1, Brazil has the lowest efficiency ratio in both models and it would have been useful for Brazil to compare itself with the other top 9 economies to discover its weakness to avoid the middle income trap. It is also notable that France and India had lower ratios than the seven largest economies. India, as a developing nation, can be considered as having a good performance in comparison with Brazil, but France, as a European Union member, had a lower ratio in both models compared to the UK, Germany and Italy. In Group 2, Russia and Turkey had a performance lower than that of Indonesia, and other countries had almost the same average in both models. In Group 3, Israel and Singapore sustained their efficiencies both in the base model and the lag model during the years of crisis, while Thailand, in the lag model in 2009, suffered from a decrease in efficiency. In addition to those countries, most of the EU countries, especially the ones like Belgium, Denmark, Finland, Ireland and Sweden sustained higher than the average efficiency. Countries like Egypt, Ukraine, Poland, South Africa and Argentina suffered from significantly low efficiency ratios and it is surprising that Poland, as an EU member, did not improve its efficiency ratio.

Table 39. Input oriented BCCI model according to the GDP groups

DMU	Base Model BCCI							Lag Model BCCI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 1														
Brazil	0.73	0.70	0.72	0.70	0.70	0.70	0.71	0.92	0.74	0.69	0.70	0.69	0.70	0.74
Canada	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
China	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
France	0.84	0.85	0.93	0.91	0.91	0.96	0.90	1.00	0.98	0.84	0.84	0.89	0.85	0.90
Germany	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
India	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00
Italy	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
Japan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.95	0.96	0.95	0.96
United Kingdom	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
United States	1.00	1.00	0.99	1.00	0.97	0.95	0.99	1.00	1.00	0.87	0.93	0.98	0.96	0.96
Average	0.96	0.95	0.96	0.96	0.96	0.96	0.96	0.99	0.97	0.93	0.94	0.95	0.95	0.96

Table 39 continued

DMU	Base Model BCCI							Lag Model BCCI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 2														
Australia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.00	1.00	1.00	0.99
Indonesia	1.00	1.00	1.00	1.00	0.94	0.93	0.98	1.00	1.00	1.00	1.00	1.00	0.93	0.99
Mexico	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.92	1.00	1.00	1.00	0.99
Netherlands	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.97	1.00	1.00	0.99
Russian Federation	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.97	1.00	0.99
South Korea	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
Spain	1.00	1.00	1.00	0.99	0.97	1.00	0.99	1.00	1.00	0.97	0.97	1.00	1.00	0.99
Switzerland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00
Turkey	0.81	0.80	0.85	0.80	0.77	0.75	0.80	0.87	0.82	0.76	0.72	0.75	0.72	0.77
Average	0.98	0.98	0.98	0.98	0.96	0.96	0.97	0.99	0.98	0.95	0.96	0.97	0.96	0.97
Group 3														
Argentina	0.83	0.72	0.62	0.60	0.56	0.59	0.65	0.90	0.79	0.56	0.54	0.57	0.57	0.66
Austria	0.76	0.77	0.77	1.00	0.78	0.81	0.81	0.78	0.77	0.75	0.76	0.80	1.00	0.81
Belgium	0.96	0.98	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.97	0.98	1.00	1.00	0.98
Chile	1.00	0.91	1.00	0.92	0.95	0.98	0.96	1.00	0.98	0.97	0.90	1.00	0.94	0.97
Colombia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.90	1.00	1.00	0.97
Czech Republic	0.88	0.88	0.98	1.00	1.00	0.95	0.95	0.98	0.96	0.95	0.97	1.00	0.99	0.97
Denmark	0.84	0.85	0.90	1.00	0.98	1.00	0.93	0.88	0.86	0.89	0.87	0.96	1.00	0.91
Egypt	1.00	0.79	0.76	0.57	0.73	0.61	0.74	1.00	0.88	0.74	0.64	0.63	0.53	0.74
Finland	1.00	0.97	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.97	1.00	1.00	0.99
Greece	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.93	0.93	0.96	1.00	0.97
Hong Kong	0.97	0.97	1.00	0.97	0.96	0.90	0.96	0.99	0.97	1.00	0.99	0.98	0.96	0.98
Hungary	0.81	0.80	0.87	1.00	0.82	0.77	0.84	0.89	0.87	0.76	0.74	0.87	1.00	0.86
Ireland	0.86	0.86	0.93	1.00	1.00	0.97	0.94	0.96	0.91	0.95	0.97	1.00	1.00	0.97
Israel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Malaysia	1.00	0.92	1.00	0.92	0.92	0.94	0.95	1.00	0.85	0.96	1.00	1.00	0.91	0.95
New Zealand	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.97	0.99	1.00	1.00	0.99
Nigeria	1.00	1.00	1.00	1.00	0.90	0.90	0.97	1.00	1.00	0.95	1.00	1.00	0.88	0.97
Norway	0.87	0.89	0.96	0.97	0.98	1.00	0.94	0.87	0.86	0.94	0.95	0.99	1.00	0.93
Pakistan	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.82	0.75	0.74	1.00	1.00	0.88
Philippines	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.92	1.00	1.00	1.00	0.98
Poland	0.76	0.76	0.75	0.76	0.75	0.74	0.75	0.78	0.79	0.76	0.75	0.75	0.77	0.77
Portugal	0.75	0.77	0.81	0.80	0.83	0.87	0.80	0.75	0.83	0.76	0.76	0.83	0.86	0.80
Romania	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Singapore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
South Africa	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	0.17
Sweden	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.95	0.99	1.00	1.00	0.98
Thailand	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.94	1.00	1.00	1.00	0.98
Ukraine	1.00	0.98	1.00	1.00	0.98	1.00	0.99	1.00	1.00	0.98	0.93	1.00	1.00	0.99
Average	0.94	0.92	0.94	0.95	0.93	0.93	0.93	0.96	0.93	0.90	0.90	0.94	0.94	0.90

Table 39 continued

DMU	Base Model BCCI							Lag Model BCCI						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 4														
Bulgaria	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.91	0.90	1.00	0.96
Estonia	0.97	0.95	0.96	0.96	0.94	0.88	0.94	1.00	0.98	0.96	0.98	1.00	1.00	0.99
Iceland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Latvia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	0.99
Lithuania	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.94	1.00	1.00	0.98
Luxembourg	1.00	0.87	0.93	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slovakia	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	0.91	0.96	1.00	1.00	0.98
Slovenia	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Average	1.00	0.98	0.99	0.99	0.99	0.98	0.99	1.00	1.00	0.97	0.97	0.99	1.00	0.99

In comparison with the findings of Table 39, according to the BCCI model in Table 39, Brazil increased its efficiency ratio, while India became an efficient country for six consecutive years. It is important again to note that Japan and the USA, in the lag model for both BCCI and CCRI, experienced a significant decrease in their efficiency scores for 2009, which shows the negative externalities of the 2007 crisis on their economies.

In Group 2, Turkey had the lowest efficiency scores in both models, whereas Mexico and Turkey faced a significant decrease in their efficiency scores in the lag model in the year 2009. Russia, compared to input oriented CCRI model, was categorized as an efficient country for six consecutive years in the base model.

In Group 3, countries like South Africa and Ukraine, which had the lowest ratios in the CCRI model, were categorized as efficient countries while Egypt, Argentina and Poland still had very low efficiency ratios. It is also significant to emphasize that the average base model scores of Group 4 are higher than the averages of other countries. This again shows that high GDPs do not give birth to high efficiency ratios.

Figure 13 and Figure 14 show graphical representations of GDP groups in the base and the lag model year. It gives a summary of the changes of the trends in innovation efficiency. In Figure 13, the rise of the innovation efficiency of Group 4 is seen to be substantial. On the other Group 1 has a very slight change in its average ratios. In the base model, in the year 2008, all groups had a decrease in their efficiency ratios while in the lag model, the years 2009 and 2010 represent significant decreases in efficiency ratios, especially in Group 3's average efficiency.

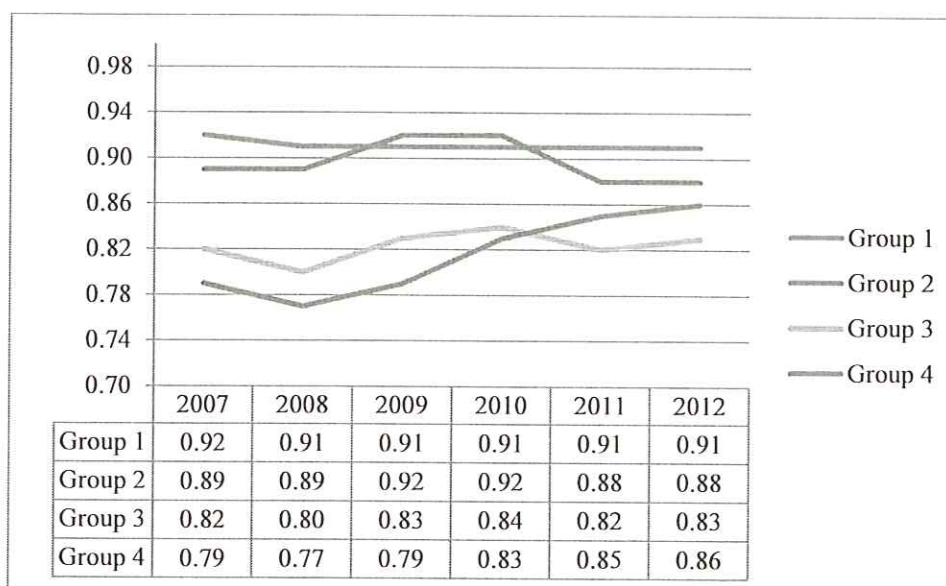


Figure 13. Base model input oriented CCR according to GDP group

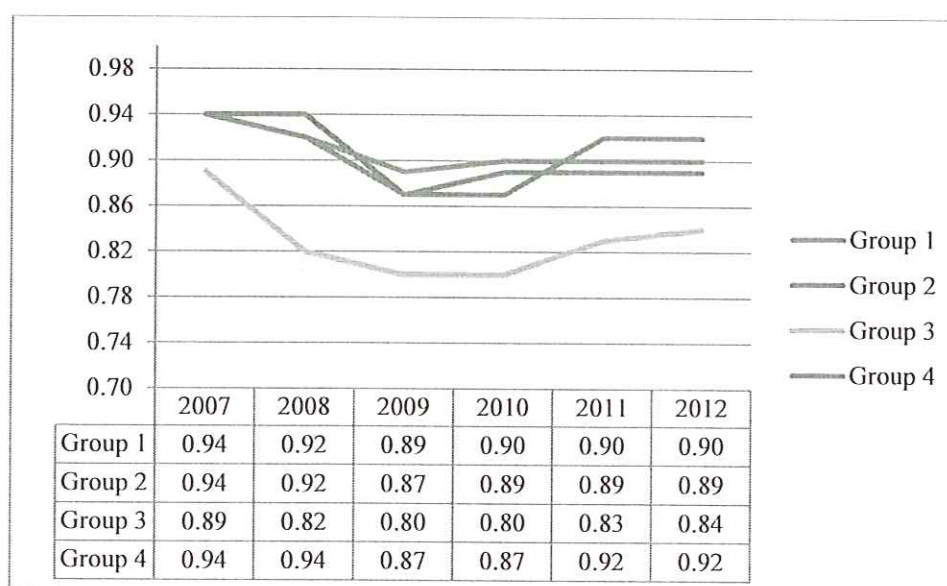


Figure 14. Lag model input oriented CCR according to GDP group

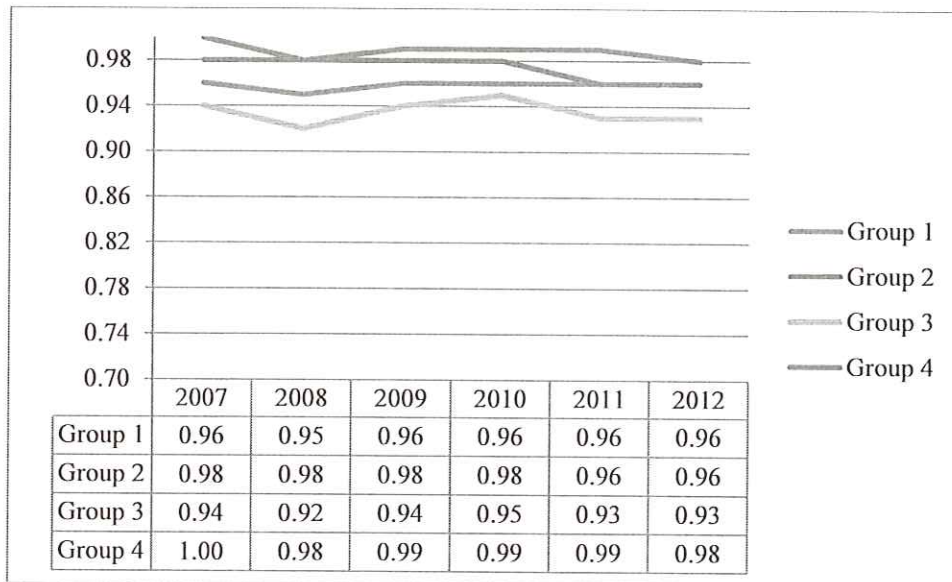


Figure 15. Base model input oriented BBC according to GDP group

Figure 15 and Figure 16 are graphical representations of GDP groups in base and lag models by yearly base with BBC model. The BBC model represents sharper decreases than the CCR model for all Groups except Group 2 in base model year of 2008-2009. It is also important to underline that the efficiency ratio of Group 4 in the lag model is higher than any Group average, as shown in Figure 16.

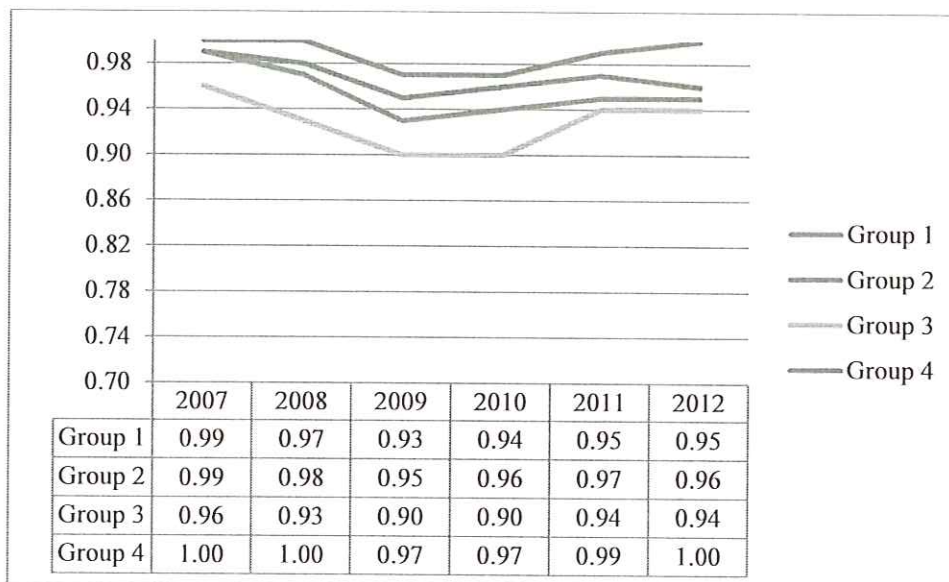


Figure 16. Lag model input oriented BBC according to GDP group

A second approach was used to overcome the “small country” problem. Countries were classified in the context of the Global Competitiveness Framework (2013). There are three main groups: factor-driven, efficiency-driven and innovation-driven countries. There are also two more groups, which are referred to as transition from factor-driven to efficiency-driven and transition from efficiency-driven to innovation-driven. The countries are ranked according to the weight distributed to the sub-indices created to measure the global competitiveness. The first index, which is called the basic requirements sub-index containing indicators like infrastructure, health, primary education, macroeconomic environment is key for factor driven economies. The efficiency enhancers sub-index measures technological readiness, higher education, market efficiency which are key for efficiency driven economies. The last one, which is called innovation and sophistication, is key for innovation-economies (Table 21).

The weight of each pillar changes according to the type of economy, as indicated in Table 41.

Table 41. Type of sub-index and economy type (GCI, 2013)

Type of Sub-index	Factor Driven	Transition	Efficiency Driven	Transition	Innovation Driven
GDP Per Capita (US\$)	< 2.000	2.000-2.999	3.000-8.999	9.000-17.000	>17.000
Weight for Basic Req. Sub-index	60%	40-60%	40%	20-40%	20%
Weight for Efficiency Enhancers Sub-index	35%	35-50%	50%	50%	30%
Weight for Innovation Sophistication Sub-index	5%	5-10%	10%	10-30%	50%

Countries in the sample set are classified as follows:

1. Group 1: Innovation-driven countries (Luxembourg, Norway, Switzerland, Denmark, Australia, Sweden, the United States, the Netherlands, Canada, Ireland, Singapore, Austria, Finland, Belgium, Japan, Germany, Iceland, France, the United Kingdom, Italy, New Zealand, Hong Kong, Israel, Spain, Greece, Slovenia, Portugal, South Korea, Czech Republic)
2. Group 2: Countries in transition from efficiency-driven to innovation-driven stage (Slovak Republic, Estonia, Hungary, Chile, Poland, Lithuania, Latvia, Brazil, the Russian Federation, Turkey, Argentina)
3. Group 3: Efficiency-driven countries (Mexico, Malaysia, Romania, South Africa, Bulgaria, Columbia, Thailand, China)
4. Group 4: Countries in transition from factor-driven to efficiency-driven stage (Ukraine, Indonesia, Egypt, Nigeria, the Philippines) Factor-driven countries (India, Vietnam, Pakistan)

Since there are only three countries in the factor-driven country group, these are combined with countries in transition from factor-driven to efficiency-driven stage. Table 42 shows country efficiency ratios, grouped according to GDP per capita in CCRI. When the group averages are compared to those in base model, it is found that Group 4 has a higher average efficiency ratio than any group, including the innovation-driven countries (Group 1) for 6 consecutive years. On the other hand, in the lag model, Group 3 achieves a higher efficiency ratio than any other group. In the lag model, the effect of the crisis can be seen in the year 2009 in all groups, with a decrease in efficiency, with the exception of Group 3. In addition, in the base model Group 2 and Group 4 increased their efficiency ratio in the year 2008 and sustained this increase for three consecutive years. Argentina, Mexico and Pakistan have the

lowest efficiency ratios in their groups while Brazil, Poland, Turkey, Egypt and Ukraine have better results compared to the CCRI model conducted according to the GDP groups.

Table 42. Input oriented CCRI model according to GDP per capita group

DMU	Base Model CCR							Lag Model CCR						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 1														
Australia	0.74	0.75	0.79	0.84	0.85	0.84	0.80	1.00	0.89	0.92	0.97	1.00	1.00	0.96
Austria	0.54	0.53	0.57	1.00	0.59	0.61	0.64	0.62	0.63	0.61	0.64	0.67	1.00	0.69
Belgium	0.66	0.70	0.71	0.71	0.72	0.81	0.72	0.81	0.82	0.83	0.86	0.91	0.94	0.86
Canada	1.00	1.00	0.99	0.94	0.90	0.90	0.95	1.00	1.00	1.00	0.99	1.00	0.96	0.99
Czech Republic	0.56	0.57	0.70	0.72	0.74	0.61	0.65	0.76	0.70	0.72	0.76	0.82	0.79	0.76
Denmark	0.65	0.66	0.72	1.00	0.84	0.89	0.80	0.84	0.82	0.84	0.85	0.96	1.00	0.89
Finland	0.72	0.70	0.91	0.74	0.85	1.00	0.82	0.93	0.93	0.93	0.93	1.00	1.00	0.95
France	0.72	0.76	0.74	0.84	0.84	0.84	0.79	0.85	0.89	0.72	0.77	0.80	0.83	0.81
Germany	1.00	1.00	0.91	1.00	1.00	1.00	0.98	1.00	1.00	0.89	1.00	1.00	1.00	0.98
Greece	0.86	0.86	0.84	0.83	0.73	0.72	0.81	1.00	0.92	0.85	0.84	0.84	0.88	0.89
Hong Kong	0.68	0.66	0.68	0.63	0.64	0.62	0.65	0.85	0.83	0.85	0.86	0.84	0.81	0.84
Iceland	0.63	0.73	0.94	1.00	0.98	1.00	0.88	0.88	0.94	1.00	0.96	0.98	1.00	0.96
Ireland	0.74	0.69	0.74	0.79	0.76	0.70	0.74	0.91	0.82	0.87	0.88	0.95	0.95	0.90
Israel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	1.00	0.97	0.97
Italy	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
Japan	1.00	1.00	0.96	1.00	1.00	0.95	0.99	1.00	1.00	0.89	0.91	0.93	0.94	0.95
Luxembourg	1.00	0.46	0.64	0.96	0.82	0.86	0.79	0.54	0.56	1.00	0.78	0.91	0.97	0.79
Netherlands	0.99	0.91	0.93	1.00	1.00	1.00	0.97	0.93	1.00	0.86	0.91	1.00	1.00	0.95
New Zealand	1.00	0.87	0.90	0.88	0.86	0.87	0.89	1.00	0.96	0.95	0.96	1.00	1.00	0.98
Norway	0.64	0.65	0.73	0.73	0.77	0.79	0.72	0.70	0.71	0.77	0.77	0.82	0.82	0.77
Portugal	0.56	0.60	0.63	0.64	0.65	0.63	0.62	0.67	0.83	0.68	0.69	0.76	0.78	0.73
Singapore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slovenia	0.79	0.87	0.89	0.81	0.90	0.92	0.86	1.00	1.00	1.00	0.97	1.00	1.00	0.99
South Korea	0.95	0.94	0.87	1.00	1.00	1.00	0.96	0.99	1.00	0.83	1.00	1.00	1.00	0.97
Spain	0.81	0.84	0.79	0.81	0.77	0.87	0.82	0.85	0.84	0.75	0.76	0.73	0.79	0.79
Sweden	0.73	0.73	0.74	0.76	0.75	0.78	0.75	0.91	0.86	0.88	0.93	0.96	1.00	0.92
Switzerland	0.99	0.95	0.96	0.98	0.99	1.00	0.98	1.00	1.00	0.96	1.00	1.00	1.00	0.99
United Kingdom	0.80	0.82	0.88	0.88	0.94	0.93	0.88	0.88	0.89	0.88	0.93	1.00	1.00	0.93
United States	1.00	1.00	0.89	0.84	0.82	0.85	0.90	1.00	1.00	0.87	0.86	0.88	0.87	0.91
Average	0.82	0.80	0.83	0.87	0.85	0.86		0.95	0.97	0.91	0.91	0.94	0.95	

Table 42continued

DMU	Base Model CCR							Lag Model CCR						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 2														
Argentina	0.87	0.83	0.53	0.46	0.45	0.46	0.60	0.98	0.85	0.49	0.46	0.47	0.46	0.62
Brazil	1.00	1.00	0.98	1.00	1.00	0.99	0.99	1.00	1.00	0.89	1.00	1.00	0.98	0.98
Chile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00
Estonia	0.91	0.81	0.96	1.00	1.00	1.00	0.95	1.00	0.95	1.00	1.00	1.00	1.00	0.99
Hungary	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.94	1.00	1.00	0.99
Latvia	0.72	1.00	1.00	1.00	1.00	1.00	0.95	0.99	1.00	1.00	0.94	1.00	1.00	0.99
Lithuania	0.65	0.87	0.90	1.00	0.99	1.00	0.90	0.70	0.94	0.85	0.86	0.94	0.98	0.88
Poland	0.85	0.88	0.93	0.92	0.96	1.00	0.92	0.88	0.89	0.91	0.93	1.00	1.00	0.93
Russian Federation	0.89	0.89	1.00	0.98	0.87	1.00	0.94	1.00	1.00	1.00	1.00	0.97	1.00	1.00
Slovakia	0.96	1.00	0.97	0.98	1.00	1.00	0.98	0.94	1.00	0.88	0.95	1.00	1.00	0.96
Turkey	1.00	0.98	1.00	0.99	0.97	0.93	0.98	1.00	1.00	1.00	0.98	1.00	0.98	0.99
Average	0.90	0.94	0.97	0.99	0.98	0.99		0.95	0.97	0.91	0.91	0.94	0.95	
Group 3														
Bulgaria	1.00	0.97	1.00	1.00	0.99	1.00	0.99	0.98	0.85	0.49	0.46	0.47	0.46	0.62
China	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89	1.00	1.00	0.98	0.98
Colombia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00
Malaysia	1.00	0.88	1.00	1.00	1.00	1.00	0.98	1.00	0.95	1.00	1.00	1.00	1.00	0.99
Mexico	0.78	0.75	0.69	0.71	0.73	0.78	0.74	1.00	1.00	0.99	0.94	1.00	1.00	0.99
Romania	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.94	1.00	1.00	0.99
South Africa	1.00	1.00	1.00	0.78	0.85	0.88	0.92	0.70	0.94	0.85	0.86	0.94	0.98	0.88
Thailand	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88	0.89	0.91	0.93	1.00	1.00	0.93
Average	0.97	0.95	0.96	0.94	0.95	0.96		1.00	1.00	1.00	1.00	0.97	1.00	
Group 4														
Egypt	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
India	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Indonesia	1.00	1.00	1.00	1.00	0.77	0.87	0.94	1.00	1.00	0.96	1.00	0.83	0.88	0.95
Nigeria	1.00	1.00	1.00	1.00	1.00	0.86	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pakistan	0.65	0.71	0.83	0.92	1.00	1.00	0.85	1.00	0.72	0.75	0.88	1.00	1.00	0.89
Philippines	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.88	0.98	1.00	1.00	0.97
Ukraine	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.93	1.00	1.00	0.98
Average	0.95	0.96	0.98	0.99	0.97	0.96		1.00	0.96	0.93	0.97	0.98	0.98	

Table 43 shows the input-oriented BCC model results according to GDP per capita groups. It is important to note that Group 1 has the lowest average scores both in the base model and the lag model, whereas Group 2 and Group 3 achieved full efficiency for 3 to 4 years respectively in the six year period.

Table 43. Input-oriented BCC model according to GDP per capita group

DMU	Base Model BCC							Lag Model BCC						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 1														
Australia	0.95	0.94	0.96	0.97	0.95	0.93	0.95	1.00	0.97	0.97	0.99	1.00	1.00	0.99
Austria	0.84	0.80	0.78	1.00	0.75	0.75	0.82	0.85	0.82	0.79	0.77	0.78	1.00	0.84
Belgium	0.99	0.98	0.96	0.95	0.94	0.96	0.96	1.00	0.99	0.97	0.98	0.99	1.00	0.99
Canada	1.00	1.00	1.00	0.99	0.95	0.93	0.98	1.00	1.00	1.00	0.99	1.00	0.97	0.99
Czech Republic	1.00	0.98	1.00	1.00	1.00	0.98	0.99	1.00	1.00	0.98	0.99	1.00	1.00	0.99
Denmark	0.91	0.90	0.89	1.00	0.93	0.95	0.93	0.97	0.94	0.93	0.94	1.00	1.00	0.96
Finland	0.91	0.87	1.00	0.86	0.90	1.00	0.92	1.00	1.00	0.98	0.96	1.00	1.00	0.99
France	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.95	0.98	0.97	0.98
Germany	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.99
Greece	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.94	0.97	1.00	0.98
Hong Kong	0.87	0.88	0.87	0.86	0.85	0.82	0.86	0.94	0.94	0.95	0.95	0.94	0.93	0.94
Iceland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ireland	0.98	0.95	1.00	1.00	1.00	1.00	0.99	0.97	0.94	0.96	0.95	1.00	1.00	0.97
Israel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.98	1.00	0.97	0.99
Italy	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
Japan	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	0.94	0.97	0.99	0.96	0.98
Luxembourg	1.00	0.85	0.90	1.00	0.95	0.95	0.94	1.00	1.00	1.00	0.87	0.92	1.00	0.96
Netherlands	1.00	0.97	0.98	1.00	1.00	1.00	0.99	1.00	1.00	0.94	0.95	1.00	1.00	0.98
New Zealand	1.00	0.95	0.96	0.96	0.94	0.93	0.96	1.00	0.98	0.96	0.98	1.00	1.00	0.99
Norway	0.87	0.86	0.87	0.85	0.87	0.86	0.87	0.83	0.82	0.83	0.82	0.84	0.85	0.83
Portugal	1.00	1.00	1.00	0.99	0.99	0.99	0.99	1.00	1.00	0.99	0.99	1.00	1.00	1.00
Singapore	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slovenia	1.00	1.00	1.00	0.98	0.99	0.99	0.99	1.00	1.00	1.00	0.97	1.00	1.00	1.00
South Korea	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
Spain	1.00	1.00	1.00	0.99	0.98	1.00	1.00	1.00	0.99	0.96	0.97	0.99	1.00	0.98
Sweden	0.89	0.84	0.87	0.89	0.87	0.86	0.87	0.94	0.89	0.91	0.94	0.97	1.00	0.94
Switzerland	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
United Kingdom	0.95	0.94	0.96	0.93	0.96	0.95	0.95	1.00	0.99	0.98	0.98	1.00	1.00	0.99
United States	1.00	1.00	1.00	0.96	0.92	0.92	0.97	1.00	1.00	0.93	0.92	0.93	0.92	0.95
Average	0.97	0.96	0.96	0.97	0.96	0.96		0.98	0.97	0.96	0.96	0.98	0.98	

Table 43 continued

DMU	Base Model BCC							Lag Model BCC						
	2007	2008	2009	2010	2011	2012	Aver	2007	2008	2009	2010	2011	2012	Aver
Group 2														
Argentina	1.00	0.98	0.97	0.94	0.92	0.91	0.95	1.00	1.00	0.97	0.92	0.93	0.90	0.95
Brazil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00
Chile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00
Estonia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hungary	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.95	1.00	1.00	0.99
Latvia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	1.00	1.00	0.99
Lithuania	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.94	1.00	1.00	0.98
Poland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00
Russian Federation	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00
Slovakia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.97	1.00	1.00	0.99
Turkey	1.00	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00
Average	1.00	1.00	1.00	0.99	0.99	0.99		1.00	1.00	0.99	0.97	0.99	0.99	
Group 3														
Bulgaria	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	1.00	0.98
China	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Colombia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
Malaysia	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00	0.99
Mexico	1.00	1.00	1.00	0.97	0.94	1.00	0.98	1.00	0.96	0.92	0.93	0.92	0.90	0.94
Romania	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
South Africa	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Thailand	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00
Average	1.00	0.99	1.00	1.00	0.99	1.00		1.00	0.99	0.99	0.99	0.98	0.99	
Group 4														
Egypt	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
India	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Indonesia	1.00	1.00	1.00	1.00	0.84	0.87	0.95	1.00	1.00	0.96	1.00	0.88	0.90	0.96
Nigeria	1.00	1.00	1.00	1.00	1.00	0.93	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pakistan	0.99	0.97	1.00	1.00	1.00	1.00	0.99	1.00	0.82	0.76	0.88	1.00	1.00	0.91
Philippines	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.92	1.00	1.00	1.00	0.99
Ukraine	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.94	1.00	1.00	0.98
Average	1.00	1.00	1.00	1.00	0.98	0.97		1.00	0.97	0.94	0.97	0.98	0.99	

It is also important to note that, in Group 1, Austria, Hong Kong, Norway and Sweden have the lowest efficiency ratios. When the results are compared with BCCI model according to GDP Groups, Sweden is less efficient in the BCCI model according to the GDP per capita groups while Austria, Hong Kong and Norway are

inefficient under that grouping. It is also surprising that the efficiency range in the average ratios are smaller than any previous result.

Figure 17 gives a brief visualization of efficiency averages under CCRI for the base model and the graph shows that highest GDP per capita does not lead higher efficiency although those countries are innovation-driven. This shows that scarce resources are wasted compared to Group 2 countries, which are in the transition period from efficiency-driven to innovation-driven.

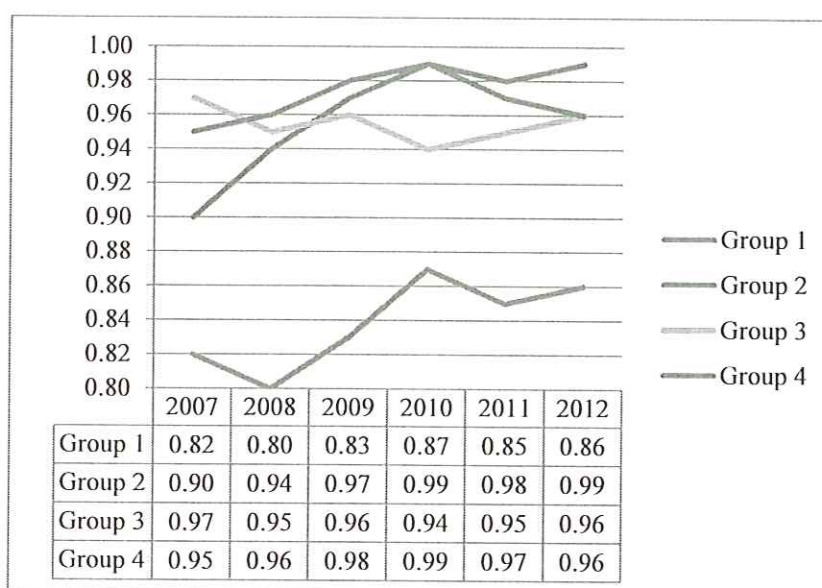


Figure 17. Base model input oriented CCR according to GDP per capita group

Figure 18 shows the average ratios under CRRI for the time lag period, and the decrease in the efficiency averages of Groups 1, 2 and 4 in the year 2009 is substantial. Group 3 has a sharp decrease due to the decrease in Bulgaria and China's efficiency in 2009.

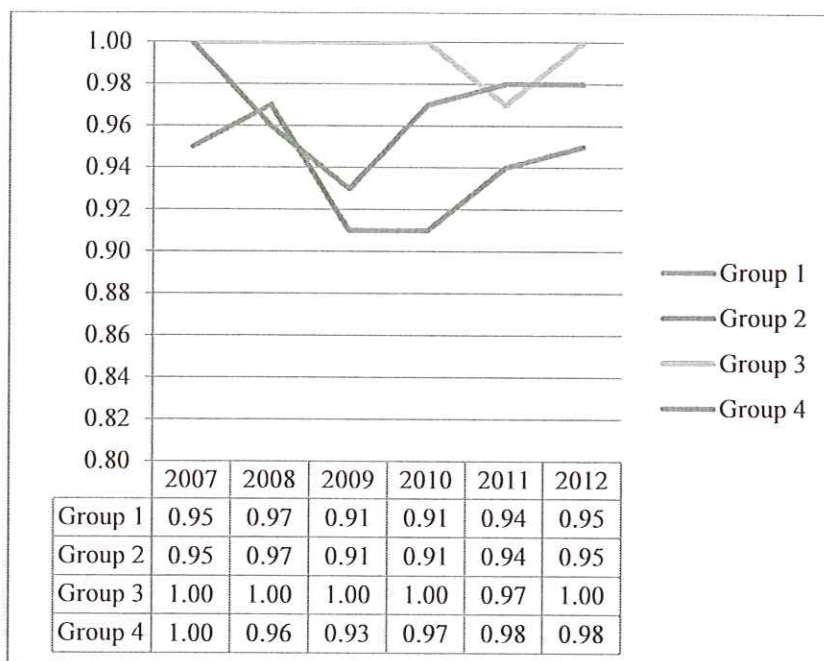


Figure 18. Lag model input oriented CCR according to GDP per capita group

Figure 19 shows the BCCI base model under GDP per capita and it reveals that the lowest efficiency belongs to Group 1 for all years, whereas Group 4 faces a significant drop in its average due to Indonesia's and Nigeria's decreasing efficiency.

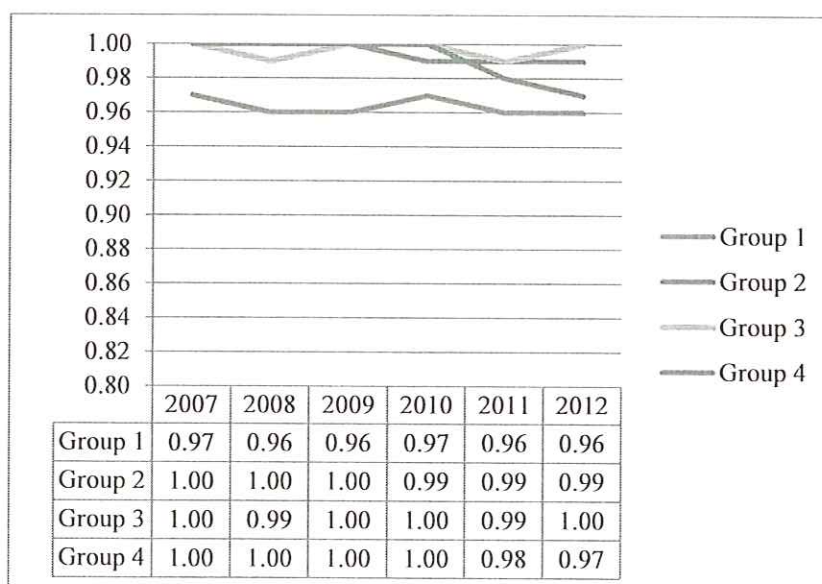


Figure 19. Base model input oriented BBC according to GDP per capita group

Figure 20 shows BCCI in the base model and indicates that Group 4 faces a significant decrease in its average during the years 2008 and 2009 due to Pakistan, the Philippines and Indonesia. Group 1, with the lowest efficiency score after 2010, faces the lowest average due to Norway and Austria's low efficiencies.

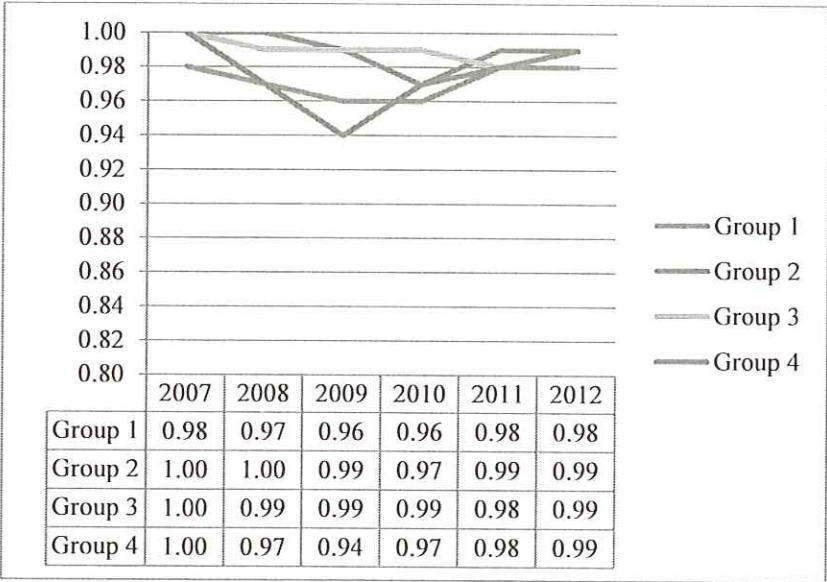


Figure 20.Lag model input oriented BBC according to GDP per capita grou

CHAPTER VII

CONCLUSION

The aim of this study was to give detailed information about knowledge based economy and how innovation became so crucial for sustainable growth after the 2007 crisis. This study also shows how countries' innovation efficiency was affected by the 2007 financial crisis and how the trend of innovation efficiency changed according to country between 2007 and 2012. By grouping these countries according to GDP and GDP per capita, the study underlines how countries in the same GDP or GDP per capita group could have different innovation efficiency ratios.

After the 2007 crisis, with decreasing demand and vitality in the market, countries and firms started giving necessary importance and allotting budget to increase their research and development with the aim of increasing innovation and fostering economic growth. Considering innovation as the only exit from the crisis, countries implemented policies to deepen their ICT infrastructure, ICT use and skill, and networks that could be established in the Triple Helix. The countries which got maximum output with minimum input or vice versa gained innovation efficiency without wasting its resources.

In this study countries are grouped according to two indicators, specifically, GDP and GDP per capita. After grouping the countries according to GDP, CCRI, BCCI and BCCO analyses were applied to the base model and the time lag model with 2 years of lag. In all cases, countries like Argentina, Brazil and Turkey faced the lowest efficiency ratios whereas Russia and Egypt got the lowest efficiency ratios in the CCRI and BCCO analyses.

When countries were grouped according to their GDP per capita, in the CCCI model, Australia, Belgium, Norway, Ireland, Argentina, Mexico, Bulgaria and Pakistan achieved low efficiency scores. On the other hand, in the BCCI model, all BRICS countries and Turkey faced very low efficiency in their groups.

As underlined previously, since countries have more power to control their inputs rather than their outputs, input-oriented models are preferred. In addition, since applying constant returns to scale in the DEA model ignores country-specific scale differences, various returns to scale reflect more practical results. Applying the same model with a time lag assumption of two years creates a chance to see how the inputs in previous years turned into output in a period of time. As a result of all these arguments, an input-oriented BCC base and lag model is suggested for further analysis.

According to this model, in grouping according to GDP, Brazil and France in Group 1, Turkey in Group 2, Argentina, Austria, Hungary, Poland, Portugal and Egypt in Group 3, and Estonia and Bulgaria in Group 4 face low efficiency scores. Especially Turkey, falling from 0.87 in 2007 to 0.72 in 2010 in the lag model performs as the lowest innovation-efficient country while Mexico, Russia and Indonesia are almost efficient.

In the comparison based on comparison with GDP per capita, Austria, Norway and Sweden have lower efficiency scores in the group with the highest GDP per capita. On the other hand, unlike the countries in the GDP grouping, Turkey seems fully efficient in comparison with Slovakia, Argentina and Lithuania. Brazil and Russia are also fully efficient.

Turkey, spending only 0.53% of its GDP for R&D in 2002, reached almost 1% of GDP spending in R&D in 2013. R&D expenditure per inhabitant rose from 46PPP US\$ in 2002 to 166 PPP US\$ in 2012, according to the Turkish Statistical Institute (TSI). GERD, HERD and especially BERD keep increasing for the last 9 years starting from 2013 with the exception of the year 2009, when the BERD faced the negative effects of the crisis after two years (TSI). Full-time employed R&D personnel reached 105.000 in 2012, up from 29.000 in 2002. According to data gathered from Thomson Reuters, the number of academic journal articles increased to 25.018 in 2012, up from 8.975 in 2002. In addition to all these indicators, according to the Turkish Patent Institute, total patent applications done to TPI reached 11.599 in 2012, and increase of 600% since 2002.

Although all these indicators show that Turkey increased its investments in R&D and got positive outcomes and returns, the innovation efficiency ratio in the empirical data shows that, in comparison with other countries, Turkey still has a low innovation-efficiency ratio. This result reveals that Turkey could produce more output with the same input, or that Turkey should minimize its inputs and still produce same amount of output. For a middle-income country like Turkey, innovation and efficient use of resources are the only ways to avoid the middle income trap, as has been pointed out earlier, and to upgrade from the group of transition countries to the innovation-driven group.

Generating clusters and encouraging networks in the Triple Helix will definitely enhance the efficient use of resources because cluster effects and networks will minimize iteration in research and maximize knowledge diffusion. Furthermore, grant programmes offered by national and international institutions and government bodies should be gathered under an umbrella organization so that every researcher or

each organizational body can access and learn about ongoing research groups and projects. Transforming published articles or patents taken, into added value for the economy and the society should be a priority since research that is left behind closed doors leads neither to a multiplier effect or to best practices that the country needs.

This study contributes to the literature in the following ways:

- By examining the years from 2007 to 2012 under two models, the base model and the 2-year lag model;
- By analyzing 58 countries and grouping them according to their GDP and GDP per capita;
- By presenting a study of 58 countries conducted with CCCI, BCCI and BCCO.

For future studies, much can be done. In order to find the fundamental reasons for the low efficiency ratio in Turkey, a NUTS 2 region base study can be conducted. After the establishment of regional innovation agencies in 26 NUTS 2 regions in 2009, Turkey took a step towards concrete and permanent solutions to regional inequalities. Since each and every region's inputs differ from one another, it is extremely important to conduct regional development and innovation system plans.

Taking a step further and deepening this study at the regional level will enable policymakers to measure the innovation efficiency of regions and compare various regions with high income per capita to low income per capita to set their programme calls for projects in the areas predetermined by the deficiencies of innovation efficiency. Transferring resources between sectors and organizing the strategic priorities of the region accordingly will definitely enhance the knowledge and the innovation led by the region and strengthen the regional welfare.

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APPENDIX A Global Innovation Index

Input Pillar	Sub-pillar	Individual Indicator
Institutions	Political Environment	Political stability
		Government effectiveness
	Press freedom	
Institutions	Regulatory Environment	Regulatory quality
		Rule of law
	Cost of redundancy dismissal, salary weeks	
Institutions	Business Environment	Ease of starting a business
		Ease of resolving insolvency
		Ease of paying taxes
Human Capital and Research	Education	Current expenditure on education, % GNI
		Public expenditure/pupil, % GDP/cap
		School life expectancy, years
PISA scales in reading, maths, & science		
Pupil-teacher ratio, secondary		
Human Capital and Research	Tertiary Education	Tertiary enrollment, % gross
		Graduates in science & engineering, %
		Tertiary inbound mobility, %
Gross tertiary outbound enrollment, %		
Human Capital and Research	R&D	Researchers, headcounts/Mn Pop
		Gross expenditure on R&D, % GDP
		QS iniversity ranking, average score top 3
Infrastructure	ICT	ICT access
		ICT use
Government's online service		
E-participation		
Infrastructure	General Infrastructure	Electricity output, kWh/cap
		Electricity consumption, kWh/cap
		Logistics performance
		Gross capital formation, % GDP

	Ecological Sustainability	GDP/unit of energy use, 2000 PPP\$/kg oil eq Environmental performance ISO 14001 environmental certificates/bn PPP\$ GDP
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Market Sophistication	Credit	Ease of getting credit Domestic credit to private sector, % GDP Microfinance gross loans, % GDP
	Investment	Ease of protecting investors Market capitalization, % GDP Total value of stocks traded, % GDP Venture capital deals/tr PPP\$ GDP
	Trade and Competition	Applied tariff rate, weighted mean, % . Non-agricultural mkt access weighted tariff, % Intensity of local competition
Business Sophistication	Knowledge Workers	Knowledge-intensive employment, % Firms offering formal training, % firms R&D performed by business, % GDP R&D financed by business, % GMAT mean score GMAT test takers/mn pop. 20–34
	Innovation linkages	University/industry research collaboration State of cluster development R&D financed by abroad, % JV–strategic alliance deals/tr PPP\$ GDP Patent families filed in 3+ offices/bn PPP\$ GDP
	Knowledge Absorption	Royalty & license fees payments, % service imports High-tech imports less re-imports, % Comm., computer & info. services imports, % FDI net inflows, % GDP

Output Pillar	Sub-pillar	Individual Indicator
Knowledge and Technology Outputs	Knowledge Creation	Domestic resident patent ap/bn PPP\$ GDP PCT resident patent ap/bn PPP\$ GDP Domestic res utility model ap/bn PPP\$ GDP Scientific & technical articles/bn PPP\$ GDP Citable documents H index
	Knowledge Impact	Growth rate of PPP\$ GDP/worker, % New businesses/th pop. 15–64 Computer software spending, % GDP ISO 9001 quality certificates/bn PPP\$ GDP High- & medium-high-tech manufactures, %
	Knowledge Diffusion	Royalty & license fees receipts, % service exports High-tech exports less re-exports, % Comm., computer & info. services exports, % FDI net outflows, % GDP
Creative Outputs	Intangible Assets	Domestic res trademark reg/bn PPP\$ GDP Madrid trademark registrations/bn PPP\$ GDP ICT & business model creation ICT & organizational model creation
	Creative Goods and Services	Audio-visual & related services exports, % National feature films/mn pop. 15–69 Paid-for dailies, circulation, % pop. 15–69 Printing & publishing manufactures, % Creative goods exports, %
	Online Creativity	Generic top-level domains (TLDs)/th pop. 15–69 Country-code TLDs/th pop. 15–69 Wikipedia monthly edits/mn pop. 15–69 Video uploads on YouTube/pop. 15–69