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THE RELATIONSHIP BETWEEN NATIONAL INNOVATIVE CAPABILITY AND PERFORMANCE IN EUROPE

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ABSTRACT

Purpose: The aim of this study is to empirically investigate the relationships between capacity and performance indicators of National Innovation Systems in European countries over the period from 2000 to 2014.

Methodology: As an analytical tool in order to examine the dynamics of innovation process at macro level, we used National ınnovation System approach which has had a large scope in innovation literature over the last decades. In this analytical framework, we employed Canonical Correlation Method to empirically examine the relationships between two variable set of capacity and performance components. National innovation capacity is represented by the dimensions of Research and Development activities, Human Capital and Information and Communication Technology (ICT) infrastructure. Dimensions of invention and innovation are chosen the proxies for performance components of NIS. Thus, this study applies an empirical method to get different capability dimensions of system together in order to determine their effectiveness on innovation performance.

Findings: Results of the empirical study reveal that the most significant contribution to innovation performance comes from Human Capital while dimensions of ICT infrastructure and Research and Development take second and third place, respectively. In addition, it seems that educational attainment and ICT-using levels are better indicators for determining the impacts of Human Capital and ICT infrastructure on innovation performance rather than the levels of education spending and ICT investment.

Conclusion: As generally argued, increasing of R&D intensity at country level is not only sufficient condition for improving innovation system in Europe. Accordingly, innovation policies like European Union focusing on an R&D–to-GDP ratio 3% is not enough without providing the requirements for an appropriate human capital development in national innovation system.

Keywords: National innovative capability and performance, Europe.
JEL Codes: O11, O31, O52

1. INTRODUCTION

Over the past decades, the capacity for innovation has played significant role in determining of the countries` competitiveness in the global economy. Accordingly, both academic scholars and policymakers have paid increasing attention to innovation as a basic source of long term economic growth. It has been also recognized that systemic approach is essential to understand innovation process and thus produce better policy implication. From this perspective, National Innovation System (NIS) approach has also become the most popular analytical tool in the economics literature focusing on innovation analysis (Carlosson, 2007, 861). Today, there is a common consensus among innovation theory scholars on the significance of NIS approach to examine the basic dynamics of innovation process at the macro level. Beyond its spread among the academic community, the approach of NIS has also been increasingly used by international organizations as an analytical framework for the study of innovation (Teixeira, 2013, 2). Consequently, NIS approach gets diffused across the international and national organizations and academic world as a theoretical framework in order to analyse innovation process at national level.

NIS can be defined as the system consisting of “the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge” (Lundwall, 1992, 12). NIS approach argues that innovation exists in a system composed of different components and performs depending on interaction of these components and institution surrounding all of the system. Every component in NIS has a function to promote innovation capacity and performance of system. Thus, innovation system consists of different capability and performance components. In conclusion, NIS approach gives new insight to researches focusing to examine innovative capacity and performance of countries. In other words, this approach let us to interpret innovative capacity and performance of the countries by mapping various components in national system. It is also clear that how well innovation system dynamics can be identified is crucial to design policy aims and tools at national level. Consequently, NIS approach provides an analytical tool to examine dynamic of innovation process and thus provide a comprehensive guide for policy making.

Based on the frame of reference in development of innovation literature indicated above, the objective of this paper is to examine the relationship between innovative capability and performance of European countries. National innovative capacity refers the country’s ability to improve new technology leading long-term economic growth while national innovative performance here shows the success of innovative effort in a country. Accordingly, this paper aims to investigate the dynamic of innovation process and thus enhance policy design for better implication. The remainder of this paper is organized as follows: In the second part, we review the literature focusing on examining the dynamics of national innovation systems. In the third part, we present empirical analysis of innovation system of European countries and the findings. Final section concludes concerning with the basic dynamic of innovation process in Europe and makes some policy implications.

2. LITERATURE REVIEW

It has still been a big issue to measure and assess innovation process although literature on innovation has a long history. Indeed, there is no agreement on what indicators are used for assessment and measurement of innovation process in literature today. However, it has been some classifications concerning with the stages of development of ideas about innovations and the corresponding changes in the metrics innovation. In the first stage, science has been perceived as the main driving force of innovation process. Therefore, economists have paid their attention to Research and Development activities. Later, innovation studies focused on the direct results of Research and Development activities like the number of scientific publications and patent. In the final stage from 1990s to now, systemic perception of innovation process has become important in order to analyse innovation dynamics. Thus economists used the range of indicators symbolising different factors of innovation system since it has been widely accepted that innovation exist in a system consisting of different components (Kravchenko, 2011, 63).

Indeed, looking at the literature, it seems that innovation process has been firstly analysed by the linear models based on the causality relation from scientific research to innovation. Firm has also been accepted as the basic actor of innovation process. In this model, innovation begins with basic research and advances through applied research until becoming invention. Later firms test invention in commercial market and lead to diffusion. Thus innovation is seen as an output of a linear process performing in a sequential and hierarchical order (Samara, et. al 2012, 624) Accordingly, the innovation analysis has been mainly made by using single indicator like R&D investment of firm. However, from the beginning of the 1990s, it has been recognised that systemic cooperation in innovation process has been essential. Thus, systemic perception became main approach to understand the innovation process. In the framework of systemic perception of innovation, it has been argued that innovation exists in a system consisting of different components and performs depending on interaction of these components. Consequently, focusing of the innovation studies evolves from linear concepts to non-linear concepts including complex interactive relationship among different factors (Fagerberg and Sapprasert, 2011, 42).

Under this line of view, the idea of thinking about innovation from a systemic perspective at the national level, called National Innovation System (NIS) approach, was developed by three main streams: C. Freeman at Science Policy Research Unit (SPRU) in the United Kingdom, B. A. Lundwall at the IKE Group in Denmark and R. Nelson at Columbia University in the United States. Firstly, Freeman (1987) brought the concept of NIS into the literature by his book titled “Technology Policy and Economic Performance: Lessons from Japan”. Later, Lundvall (1992) published as an editor a book titled “National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning”. Final seminal book named “National Innovation Systems: A Comparative Study” have been edited by Nelson (1993). These economists can also be divided into two groups in terms of their definition of NIS. Nelson considers with the narrow definition of NIS covering only organizations involved in research institutions and firms. On the other hand, Freeman and Lundwall consider the broad definitions of NIS covering all aspects of the economic structure and the institutional set-up (Varblane and Tamm, 2007, 5).

The idea of NIS has been rapıdly expanded in the literature. Accordingly, economists have started to develop a methodology for assessment and measurement of national innovation systems. Different composite indicators producing scoreboards and indices have been developed to measure and compare different national innovation system. Economists found the method of composite indicators to measure innovation process of national system. Thus, they combine a number of factors effecting innovation process in a single figure by attaching different weights to the relative importance of the indicators. Indeed, in the recent decades, the role of composite indicators of innovation remarkably increased in assessment of innovation process. International economic organisations have also elaborated different composite indicators to classify their member countries in terms of innovative capability and performance.

World Bank has developed Knowledge Assessment Methodology (KAM) to measure innovative maturity of nations. This methodology combined the indicators under four sub-title: Economic Incentive and Institutional Regime, Education, Innovation and Information and Communications Technologies (ICT). Thus two indices were produced: Knowledge Index (KI) and Knowledge Economy Index (KEI) (Karahan, 2012, 23). Organization for Economic Co-operation and Development (OECD) has also published Science, Technology and Industry (STI) Scoreboard. Analyses concerning with the member countries in the Scoreboard are summarized in five thematic sub-titles: Investing in Knowledge, Talent and Skills, Connecting to Knowledge, Unlocking Innovation in Firms, Competing in the Global Economy, Empowering Society with Science and Technology (OECD, 2015, 3). European Union has also proposed a composite indicator called "European Innovation Scoreboard" to measure and assess national innovation system in European countries. This scoreboard combines different system indicators into three dimensions: enablers, firm activities and outputs. Thus, national innovation system in European countries are categorized in terms of performance as Modest Innovators, Moderate Innovators, Strong Innovators and Leader Innovators (European Union, 2015, 7).

Looking at the literature, in order to examine national innovation system, it seems that composite indicators are also used widely among economists besides international economic organizations. Most popular one called "The ARCO Technology Index" belongs to Archibugi and Coco (2004). They have taken three dimensions of technology into account in order to develop composite indicators: Innovative Activity, Human Capital and Technology Infrastructure. They have examined 162 countries using the data for the period from 1990 to 2000. Finally, Bashir (2013) presented a study for measuring innovation capability and Innovation Index Ranking of top 15 most efficient innovative Islamic Countries. His innovation index consists of two input sub-index including the variables related to Human Capital and Research and Business Sophistication. Innovation output sub-index also consists of two input sub-index including Knowledge and Technology Outputs and Creative Outputs. In conclusion, although scoreboard methodology creates some problems, like single number cannot provide comprehensive information of the whole innovation process, it seems that this methodology continues to be used widely to examine the national innovation system. However, it is clear that scoreboard methodology lacks any systemic analysis to make further interpretation of the relations between different components of national innovation system.

Besides the studies using the scoreboard methodology based on composite indicators, some studies have applied different econometric methods in order to assess and measure the dynamics of innovation process in the framework of NIS approach. Griffith et al. (2004) examined the dynamics of innovation process by using panel data analysis of twelve OECD countries from 1974 to 1990. They tried to investigate the impacts of R&D and human capital on total factor productivity. The findings revealed the two impacts of R&D on the productivity growth of OECD countries. R&D stimulates growth directly through innovation and also indirectly through technology transfer. The results of study also indicated that human capital effects productivity by stimulating innovation and absorptive capacity. Thus they indicated the significance of R&D and human capital as the basic dynamics of national innovation system. Castellacci and Natera (2013) aimed to investigate the dynamics of innovation system for a panel of 87 countries in the period 1980-2007. For this aim, they examined the co-evolution of two main dimensions: innovative capability and absorptive capacity. The results indicated that innovative capability symbolising by innovative input, scientific output and technological output and absorptive capacity consisting of the variable of infrastructures, international trade and human capital are linked by a set of long-term structural relationships. They concluded that it should be taken the complementary between the variables relating to innovative capability and absorptive capacity into account for a better understanding of the dynamics of complex evolving system of innovation process.

Finally, it can be argued that Data Envelopment Analysis (DEA) as a statistical method is also quite popular to measure the efficiency of national innovation system. Sharma and Thomas (2008) examined the relationship between input variables consisting of R&D expenditure and researchers per million population and output variables including patents granted to residents and the number of publication for 22 countries. They found that both R&D expenditure and number of researcher have significant impact on output variables. Pan et al. (2010) measured the performance of the National Innovation system in 33 Asian and European Countries by using bilateral DEA model. Total expenditure on education and R&D, total R&D personnel and imports of goods and services are accepted as input factors while number of patent and scientific articles are chosen output factors. Besides finding of effectiveness of input factors on output, by making the bilateral comparison analysis, they indicated that the input factors of Asian group is a better performer than the ones of European group.

3. DATA AND METHODOLOGY

As can be seen from the literature review, a lot system identification method has been proposed to examine innovation process. This study also aimed to develop an assessment for national innovation process in European countries. We know that National Innovation System consists of different components and the dynamics of the system arises from the interactions among these components. Accordingly, our system identification methods will be based on examining the interactions among capacity and performance components of national innovation system. In other words, while assessing and measuring the innovation process, we will examine the relationships among the data that belongs to capacity and performance components of systems in Europe. Thus, depending on the most recent and available annual data from EUROSTAT under the thematic subtitle of Science and Technology over the period from 2000 to 2014, we have considered 12 European countries which are Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and, United Kingdom.

The key set of variables related to capability and performance components in our model are shown in Table-1. Variables related to capability components can be seen from the left column of Table-1 while the right column of Table-1 presents variables related to performance components. National innovation capacity is represented by the dimensions of Human Capital, Research and Development (R&D) activities and Information and Communication Technology (ICT) infrastructure. Dimensions of Human Capital consists of total expenditure on education (X_1), graduates in upper secondary education per 1000 population aged 25–34 (X_2) and doctorate graduates per 1000 population aged 25–34 (X_3). R&D activities include R&D performed by Business (X_4), R&D performed by Government (X_5) and R&D personnel (X_6). ICT infrastructure covers the variables like Internet access of household (X_7), share of the ICT sector (X_8) and share of ICT sector investment in total investment (X_9). Performance variables consist of dimensions of invention and innovation. Dimension of invention includes the variables like number of scientific publication (Y_1) and patent applications to European Patent Office (Y_2). Dimension of innovation includes the variables like medium and high-tech manufacture exports (Y_3) and sales of new market and new to firm innovation (Y_4).

Table-1: Model of Canonical Correlation Analysis for Capacity and Performance of National Innovation System

	Capacity Variables of National Innovation System	Canonical Variables of Capacity	Canonical Coefficient	Canonical Variables of Performance	Performance Variables of National İnnovation System	
	Human Capital					
X_1	Total expenditure on Education (%GDP)					
X_2	Graduates in upper secondary education per 1000 population aged 25–34				**Invention**	
					Number of scientific publication in scientific journal	Y_1
X_3	Doctorate graduates per 1000 population aged 25-34				Patent Applications to EPO (per million inhabitants)	Y_2
	Research and Develop.					
X_4	R&D performed by Business (% GDP)	U_1 U_2	R_1 R_2	V_1 V_2	**Innovation**	
X_5	R&D performed by Government (% GDP)	U_3	R_3	V_3	Medium and high-tech manufacture exports (% of total)	Y_3
X_6	R&D personnel (% of the labour)				Sales of new market and new to firm inno. (% of total turnover)	Y_4
	ICT Structure					

X_7	Internet access of household (% of all household)
X_8	Share of the ICT Sector (% of GDP)
X_9	Share of ICT Sector Investment (% of total Investment)

A number of system identification methods based on the focusing on interaction among components of system have been developed in the last decades. From the point of view of our analysis, we need an empirical methodology that takes account the interactions among all capacity and performance components of system. Accordingly, it can be argued that Canonical Correlation Analysis (CCA) is the best empirical method to satisfy the needs for this kind of system analysis. Indeed, CCA is a powerful method used to measure the relationship between two multidimensional variables. Thus it enhances our understanding of the system dynamics arising from interaction among capacity and performance components of NIS. In other words, system dynamics arising from the NIS capacity and performance components are easily obtained by CCA. This method has the ability to deal with variable pair of sets simultaneously to produce both structural and spatial meaning. That means it provides an effective technic to evaluate the causal relationship between several variables belonging to capacity and performance components of NIS.

Canonical correlation Analysis was first introduced by Hotelling (1936). This empirical model can be described briefly like below (Johnson and Wichern, 2007, 539-541). Assume that, there are original two data set: X-Variable Set (X1, X2,.......Xp) and Y-Variable Set (Y1, Y2,.......Yq). Dual canonical variables U_i and V_i are derived by the linear combination of observed original data set indicated below.

$$U_i = a_{i1} X_1 + a_{i2} X_2 + ... + a_{ip} X_p$$

$$V_i = b_{i1} Y_1 + b_{i2} Y_2 + ... + b_{2ip} Y_p$$

The criteria for determining the number of dual canonical variables (s); (U_i, Vi) s = Min (p, q) and (a_{i1}, a_{i2}, ... a_{i1p}) and (b_{i1}, b_{i2}, ... b_{i1q}) are called canonical vectors. Thus, linear components of the data set can be redefined as follows:

$$U_i = a^{'} X$$

$$V_i = b^{'} Y$$

Then the variance and covariance of canonical variables can be calculated as follows:

$$\text{Var } (U_i) = a\text{` Cov } (X)\ a = a\text{` } \Sigma_{11}\ a$$

$$\text{Var } (V_i) = b\text{` Cov } (Y)\ b = b\text{` } \Sigma_{22}\ b$$

$$\text{Var } (U_i\ , V_i) = a\text{` Cov } (XY)\ b = a\text{` } \Sigma_{12}\ b$$

Thus highest correlation coefficients (**R_i**) for canonical vectors a and b and therefore the canonical variables U_i and V_i can be obtained from the following formula;

$$R_i\ (U_i\ , V_i\ ) = \frac{a\text{` } \Sigma_{12}\ b}{\sqrt{a\text{`}\Sigma_{11}\ a}\ \sqrt{b\text{`}\Sigma_{22}\ b}}$$

In the framework of canonical correlation analysis also produces “Canonical Loadings of the Original Variables with their Canonical Variables” and “Canonical Loadings of the Original Variables with opposite Canonical Variables” in order to indicate the impact of original variables on own and other canonical variables.

In conclusion, in the framework of Canonical Correlation Analysis, we will make three different calculation concerning with the original capacity and performance variables of NIS in Table-1.

- Canonical Correlation Analysis of Canonical Variables relating to Original Variables: The observed original variables in each component of NIS are combined together into one synthetic variable called Canonical Variable.

After determining a set of canonical variables relating to component of system, to evaluate the interaction or simultaneous relationship between system components, we measure the associations among pair of canonical variables.

- Canonical Loadings of the Original Variables with own Canonical Variables: These canonical loadings inform interpretation by helping to define the structure of the own canonical variable, that is, what observed variables can be useful in creating the canonical variable and therefore may be much more useful to explain the relationships among components.
- Canonical Loadings of the Original Variables with opposite Canonical Variables: These canonical loadings inform how certain variable related to one component of NIS effect other component by interacting with the other canonical variable belonging to opposite components of NIS.

4. FINDINGS AND DISCUSSIONS

In the framework of Canonical Correlation Analysis, the relationship among the variables relating to capability and performance components of innovation system indicated in Table-1 have been examined. Thus we tried to indicate both the whole impact of capability components and the relative importance of each variable in capability components on performance components.

The results of canonical correlation coefficients for data set of capacity and performance of innovation system are presented in Table-2. It seems that all coefficients are statistically significant. This result indicates that capacity components consist of the dimensions of Human Capital, R&D and ICT structure have the positive effects on innovation performance. Thus, it can be concluded that capacity components of national innovation system perform well in Europe.

For further analysis, following the criteria advised by the Canonical Correlation Analysis, first and the biggest significant correlation (0.819) sourced from the first pair of canonical variables (U_1 V_1) has been used to produce the Loadings and Cross-Loading of the Original Variables. Accordingly, in terms of the first pair of canonical variables (U_1 V_1), Table-3 and Table-4 present loadings and cross-loadings of original variables respectively to show the relative importance of each observed variable related to components. While loadings in Table-3 indicate the relationship between original variable and the own canonical variables, cross-loadings in Table-4 measure the impact of original variable on opposite canonical variables.

It seems from the values of both loadings and cross-loadings in Table-3 and Table-4 that all variables related to Human Capital (X_1, X_2, X_3) have the biggest effect on innovation performance compared to other capability variables related to R&D and ICT except the internet access of household (X_7) belonging to ICT component. The impact of internet access of household (X_7) on innovation performance is only bigger than the total expenditure on education (X_1) in Human Capital component. However, it can be generally concluded that the component of Human Capital is the most dominant factor determining the innovation performance in European countries. Second most effective group of variables concerning with the capability component are related to ICT structure while the least effective variables on innovation performance belong to R&D component in the national innovation systems of Europe.

We can also compare the relative impact of each components variables in their own component by looking at the values of loadings and cross-loadings in Table-3 and Table-4. Among the variables relating to human capital components, the loading value (0,718) and cross-loading value (0,679) of doctorate graduates have the biggest weights while loading value (0,616) and cross-loading value (0,578) of graduates from upper secondary school have the second weights compared to the share of total expenditure on education. The variable of expenditures on education has the least loading value (0,454) and cross-loading value (0,417) in Human capital component. These show that indicators relating to the level of graduates from education effect the dynamic of innovation performance much more compared to expenditures on education.

Looking at the ICT, the loading value (0,598) and cross-loading value (0,551) of internet access of household has much more weights than both the loading value (0,447) and cross-loading value (0,409) of share of the ICT sector and the loading value (0,418) and cross-loading value (0,383) of share of ICT sector investment in total investment. Thus, ICT-using comes out as a most effective measure o innovation performance in comparison to the indicators relating to volumes of ICT sector and investment.

Considering with the variables of R&D component, the loading value (0,423) and cross-loading value (0,387) of the number of personnel employed in R&D have the biggest weights compare to same values of private (0.311 and 0.271) and public (-0.152 and -0.103) performed R&D. That means the effectiveness of the number of R&D personnel on innovation performance is much bigger than the effectiveness of private and public performed R&D. By the way, the effect of public performed R&D, which is negative, is naturally also lower than private performed R&D.

Finally, looking at the relative importance of performance components, it seems from the Table -3 and Table-4 that invention values (Y_1 and Y_2) of loading and cross-loading are bigger than the related values of innovation (Y_3 and Y_4). This revealed that performance of European innovation systems is dominated by invention rather than innovation, which indicated that capacity components have the impacts on invention much more.

Table-2: Canonical Correlation Analysis

Pair of Canonical Variables	Canonical Correlation	Squared Canonical Correlation	Wilk`s Lambda	Chi-Square	df	P value
U_1 V_1	0.819	0.671	0.168	111.851	36	0.000
U_2 V_2	0.701	0.491	0.214	41.950	24	0.011
U_3 V_3	0.490	0.240	0.724	27.672	14	0.172
U_4V_4	0.299	0.089	0.897	6.831	6	0.374

Table-3: **Loadings of the Original Variables with their Canonical Variables**

	X – Variable Set (Capability)								
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
U_1	0.454	0.616	0.718	0.311	-0.152	0.423	0.598	0.477	o.418
	Y – Variable Set (Performance)								
	Y_1	Y_2	Y_3	Y_4					
V_1	0.668	0.545	0.337	0.218					

Table-4: Cross- Loadings of the Original Variable with opposite Canonical Variable

	X – Variable Set (Capability)								
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
U_1	0.417	0.578	0.679	0.271	-0.103	0.387	0.551	0.409	o.383
	Y – Variable Set (Performance)								
	Y_1	Y_2	Y_3	Y_4					
V_1	0.614	0.511	0.297	0.177					

5. CONCLUSION

A lot of empirical studies have been proposed in the framework of systemic perception to examine the dynamics of innovation process after National Innovation System (NIS) approach became popular as analytical tool. In our study we also aimed to measure and assess the dynamics of national innovation systems in European countries. Accordingly, by applying Canonical Correlation Analysis for the annual data from 2010 to 2014, we examined the impact of capability components on the performance of innovation system. We indicate whole impact of capability components and the relative impact of variables in every component on the performance of national innovation systems.

The results of canonical correlation coefficient reveal that variables related to capacity components like Human Capital, ICT structure and R&D have generally the positive effects on innovation performance in Europe. Among the capability components, empirical findings also indicate that variables related to Human Capital have the biggest effect on innovation performance of innovation systems in Europe. Variable belonging to ICT structure have the second significant effect on innovation performance while variables of R&D component have the latest impact on innovation process. Concerning with the variables related to human capital, the findings also indicated that the level of graduates from education effect the dynamic of innovation performance much more compared to variable of expenditures on education. Looking at the relative impact of variables belonging to ICT component, ICT-using comes out as a most effective measure for innovation performance in comparison to the indicators relating to volumes of ICT sector and investment. Finally, relating to variables of R&D component, the number of R&D personnel has a much more impact on innovation performance compared to private and public performed R&D.

Concerning with the policy design and implication process, it can be argued that policy makers in Europe firstly focus on the increasing number of people graduated from higher level education to promote innovation performance. They should also give importance to increasing the number of people using ICT and making R&D to reach better innovation performance. In conclusion, basic dynamic of innovation system in Europe comes mostly from the different aspects of human capital such as the number of people graduated from higher level education, using ICT and making R&D. Thus, as generally argued, increasing of R&D intensity at country level is not only sufficient condition for improving innovation system. Accordingly, innovation policies like European Union focusing on an R&D–to-GDP ratio 3% is not enough without providing the requirements for an appropriate human capital development in national innovation system.

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