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Analysing the Bilateral Relationship between Technological Readiness and Innovation of Countries by Considering the Mediating Effect of GDP

Mohammad Reza Mehregan, Seyed Hamid Hashemi*, Mahdi Nik Neshan

Faculty of Management, University of Tehran, Tehran, Iran

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Abstract

During the past decade, the World Economic Forum has published its annual reports in which the Global Competitiveness Index is included. This paper aims to investigate the key factors for achieving an innovation-driven economy. In this paper, we used partial canonical correlation analysis (PCCA) to examine the relationships between key pillars in "efficiency enhancers" and "business sophistication" factors. The results of Pearson correlation showed that "technological readiness" and "innovation" are highly correlated. Then, the PCCA method was used to understand the relationships between their sub-pillars. Our findings showed that "availability of latest technologies" and "firm-level technology absorption" in the technological readiness pillar, and "quality of scientific research institutions", "university-industry collaboration in R&D" and "companies' spending on R&D" in the innovation pillar present the highest correlations. Furthermore, according to the canonical second root analysis, we analyse some other interrelations. Thus, policymakers can employ the results to prioritize their macro policies.

Keywords

Developed economy, National innovation, Partial canonical correlation analysis, Technological growth.

* Corresponding Author Email: s.hamidhashemi@ut.ac.ir

Introduction

In today's globalized world, competitiveness has become a milestone of both advanced and developing countries. Because of pressures introduced by globalization, it is important to have a framework for analysing a country's competitive position in the international market rather than simply focusing on measures of internal productivity. It is common knowledge that the marketplace is no longer restricted to a particular geographic location. A business can thus expect competition from neighbouring entities, and/or from similar operations within its region. The marketplace is now global, and even the smallest organizations compete on an international level. Many policymakers express serious concerns about national competitiveness. The competitiveness of a nation is defined as "the degree to which it can, under free and fair market conditions, produce goods and services that meet the standards of international markets while simultaneously expanding the real income of its citizens, thus improving their quality of life" (Artto, 1987).

Each year the World Economic Forum (WEF) publishes a report on the competitiveness of countries. These reports serve as benchmarks for national policymakers and interested parties to judge the relative success of their countries in achieving competitiveness as represented by accepted indices. A nation's competitiveness can be viewed as its position in the international marketplace compared to other nations of similar economic development levels. The capability of countries to survive and to have a competitive advantage in global markets depends on, among other things, the efficiency of their public institutions, the excellence of the educational, health and communications infrastructures, as well as on the nation's political and economic stability. Besides this, an outstanding macroeconomic environment alone cannot guarantee a high level of national competitive standing unless firms create valuable goods and services with a commensurately high level of productivity at the micro level (Onsel *et al*., 2008).

While the Global Competitiveness Report (GCR), which is reported yearly by the WEF, displays the results of the 12 pillars of global competitiveness separately (Table 1), it is important to keep in mind that these attributes are not independent: they tend to reinforce each other, and a weakness in one area often has a negative impact in others. For example, a strong innovation capacity (pillar 12) will be very difficult to achieve without a healthy, well-educated and trained workforce (pillars 4 and 5) that is adept at absorbing new technologies (pillar 9), and without sufficient financing (pillar 8) for R&D or an efficient goods market which makes it possible to take new innovations to market (Schwab, 2012).

Table 1. Global Competitiveness Index framework (Schwab, 2012)

Stages of development	Main sub-indexes	pillars
Factor-driven economy	Basic requirements	1.institutions 2.infrastructure 3.macroeconomic stability 4.health and primary education
Efficiency-driven economy	Efficiency enhancers	5.higher education and training 6.goods market efficiency 7.labor market efficiency 8.financial market development 9.technological readiness 10.market size
Innovation-driven economy	Innovation and sophistication factors	11.business sophistication 12.innovation

Technology development (TD) is the basic means by which companies, industries and countries can foster their competitive capabilities and increase their competitive advantages (Wang *et al*., 2007). The importance of technology development and investment in information technology has been studied thoroughly (Jafari, 2014). The central role played by technology in strategies for national competitiveness is further complicated by the presence of multinational enterprises in different countries (Porter, 1985). Furthermore, innovation in science and technology has been noted as an economic factor since the time of the classical economists. From the 1970s onwards, the public and private sectors began to focus on the use of innovation management strategies to gain economic advantages in the global market. Business interest in innovation management strategies had grown for a number of reasons. Two of them in particular provided the major impetus. The first reason was the general restructuring of international business away from resource-driven and towards knowledge-intensive industries. Secondly, there has been increasing emphasis on the role of innovation management in corporate competitive strategy (Roberts, 1998). As well as business, internationally, governments have become interested in innovation systems management. In the 1970s and 80s there was an economic expansion of countries who appeared to profit from the use of new innovation management policy at both government and business levels, such as Japan and Germany (Roberts, 1998).

These two concepts, in many situations, are interrelated. For example, when we are discussing technology, we use the term "technological innovation" for innovations which are technology based. Nowadays, according to the fast changing technological environment, many technological innovations can be seen in different industries like automobile manufacture, mobile phones, learning technologies, etc., but the main question which remains is about the state of the interrelationship between them. We are interested in investigating this relationship in this paper.

According to the systematic literature review, it has been determined that a few papers have been published about the interrelationships between factors which affect countries' competitiveness levels. Therefore, in this paper we develop a framework to examine the relationship between technological readiness and the innovation state of countries, which are important pillars in measuring competitiveness at national and international level. The rest of the paper proceeds as follows. We begin with a brief outline of the competitiveness concept and Global Competitiveness Index in the next section. Research methodology, data analysis and research results constitute the other sections. Finally, in the last section, the paper concludes with a summary of the whole paper and some suggestions.

Literature review

Competitiveness

At the beginning of the 21st century, the world economy is governed by two strong forces: technology and globalization, both of which have an important impact on companies, economies and countries. Nowadays, as the globalization process is happening in significant ways, the main objective of any country and nation remains competitiveness (Bleotu, 2012). Porter believed that "the only meaningful definition of competitiveness at the national level is national productivity" (Porter, 1990). Furthermore, Heap pointed out that "improving productivity is the only way of baking a bigger cake - most other changes simply give us different sized slices" (Heap, 2007). For these reasons, many of the Global Competitiveness Index's (GCI) sub-pillars are the same as the productivity sub-indexes.

Global Competitiveness Index

For more than three decades, the World Economic Forum's annual Global Competitiveness Reports (GCRs) have studied and benchmarked the many factors underpinning national competitiveness. From the beginning, the goal has been to provide insight and impetus for the discussion among all stakeholders on the best strategies and policies to help countries overcome the barriers to improving competitiveness (Schwab, 2012). Since 2005, the World Economic Forum has based its competitiveness analysis on the GCI, a comprehensive tool that measures the microeconomic and macroeconomic foundations of national competitiveness.

As noted earlier, the WEF recently introduced the GCI to rank countries. While the GCI refers to macroeconomic determinants of productivity, the business competitiveness index (BCI) captures its microeconomic components. In addition, while the GCI is supposed to capture the "dynamic" determinants of productivity, the BCI captured the "static" determinants. In fact, however, the macro- and microeconomic determinants of competitiveness cannot truly be separated. The ability of firms to succeed depends on, among other things, the efficiency of public institutions, the quality of the educational system, and the overall macroeconomic stability of the country in which they operate. Productivity thus has both static and dynamic implications for a country's standard of living. Only by reinforcing each other can the micro- and macroeconomic characteristics of an economy jointly determine its level of productivity and competitiveness. To recall an earlier discussion, that is why, in the 2004 WEF report, the GCI was developed with the goal of unifying GCI and BCI (Onsel *et al*., 2008).

Many determining factors drive productivity and competitiveness.

Understanding the factors behind this process has occupied the minds of economists for many years, engendering theories ranging from Adam Smith's focus on specialization and the division of labour to neoclassical economists' emphasis on investment in physical capital and infrastructure, and more recently, to interest in other mechanisms such as education and training, technological progress, macroeconomic stability, good governance, firm sophistication and market efficiency, among other concerns. While all of these factors are likely to be important for competitiveness and growth, they are not mutually exclusive: two or more of them can be significant at the same time, and in fact that is what has been shown in the economic literature. This open-endedness is captured within the GCI by including a weighted average of many different components, each measuring a different aspect of competitiveness. These components are grouped into 12 pillars of competitiveness (Table 1). While all of the pillars described in Figure 1 will matter to a certain extent for all economies, it is clear that they will affect them in different ways; for example, the best way for Cambodia to improve its competitiveness is not the same as the best way for France to do so. This is because Cambodia and France are in different stages of development (Schwab, 2012).

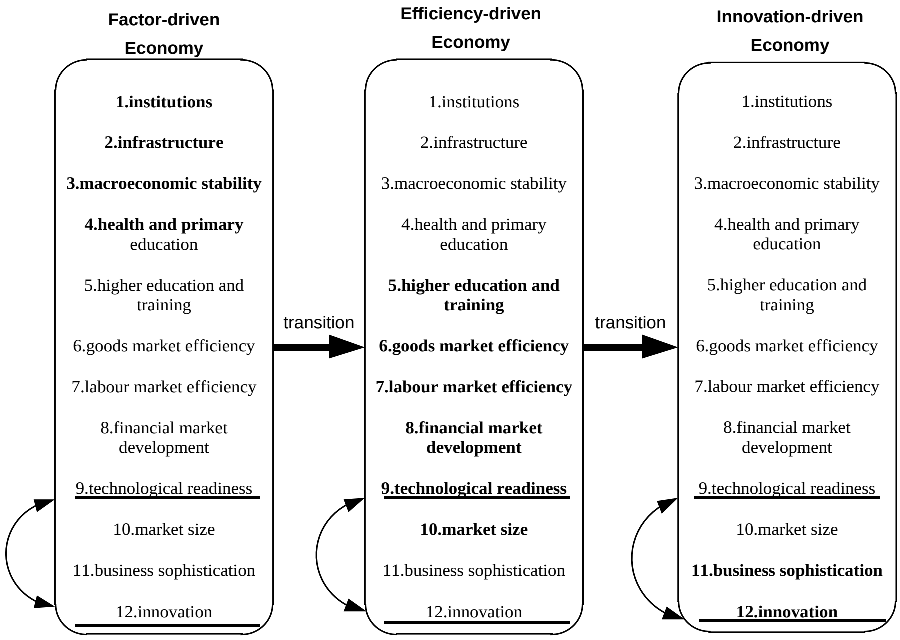

Fig. 1. Conceptual framework of this research

Our conceptual model is presented in Figure 1. As seen in Figure 1, we consider the interrelationship between technological readiness and innovation of countries, while simultaneously controlling the impacts of GDP and GDP per capita on them in all stages of economic development. This relationship may be stronger in developing and developed countries, but we should not ignore it in factor-driven economies. The bold pillars in each stage represent the key factors in that stage.

To answer the above question, researchers utilized the PCCA method, which has been explained previously.

Stages of economic development

According to Schwab (2012), two criteria are used to allocate countries into stages of development. The first is the level of GDP per capita at market exchange rates. This widely available measure is used as a proxy for wages, because internationally comparable data on wages are not available for all countries covered. The thresholds used are also shown in Table 1. A second criterion is used to modify for those countries that are wealthy, but where prosperity is based on the extraction of resources. This is measured by the share of exports of mineral goods in total exports (goods and services), and assumes that countries that export more than 70 percent of mineral products (measured using a five-year average) are to a large extent factor-driven.

In accordance with the economic theory of stages of development, the GCI assumes that economies in the first stage are mainly *factor-driven* and compete based on their factor endowments: primarily low-skilled labour and natural resources. Key pillars at the first stage are shown in Figure 1. As a country becomes more competitive, productivity will increase and wages will rise with advancing development. Countries will then move into the *efficiency-driven* stage of development, when they must begin to develop more efficient production processes and increase product quality because wages have risen and they cannot increase prices. Key pillars for an efficiency-driven economy are also shown in Figure 1. Finally, as countries move into the *innovation-driven* stage, wages will have risen by so much that they are able to sustain those higher wages and the associated standard of living only if their businesses are able to compete with new and/or unique products, services, models and processes. At this stage, companies must compete by producing new and different goods through new technologies (pillar 12), and/or the most sophisticated production processes or business models (pillar 11). Any countries falling between two of the three stages are considered to be "in transition". Therefore, there are five stages created by adding two "in transition" stages, one between the first and second stages, and one between the second and third stages of development.

The GCI takes the stages of development into account by assigning higher relative weights to those pillars that are more relevant for an economy given its particular stage of development.

Finally, it should be taken into account that the GCR is a kind of secondary data. Survey-based secondary data refers to data collected using a survey strategy, usually by questionnaires that have already been analysed for their original purpose (Sauders *et al*., 2007). They are made available as compiled data tables or, increasingly frequently, as a downloadable matrix of raw data for secondary analysis. Unlike data that one collects oneself, secondary data generally provide a source of data that is both permanent and available in a form that may be checked relatively easily by others. This means that both the data and the research findings are more open to public scrutiny.

Partial canonical correlation analysis

CCA is a multi-variable statistical approach for measuring linear relationships between different groups of variables. This approach can play an important role in an exploratory mean when multi-attribute variables have some relationship to an analytical category (Lima et al., 2004). CCA obtains a linear composition of predicting variables that have the most correlation with a linear combination of criteria variables. These combinations are shown as follows (LeClere, 2006):

$$W_1 = a_{11}X_1 + a_{12}X_2 + \cdots + a_{1p}X_p$$
$$V_1 = b_{11}Y_1 + b_{12}Y_2 + \cdots + a_{1p}Y_p \qquad (1)$$

The number of dependent variables (six) or the number of independent variables (two), whichever is smaller, determines the maximum number of canonical functions. Thus, the analysis is based upon the derivation of four canonical functions. Table 2 represents some researches that employed the CCA method.

Table 2. Some previous researches that applied CCA technique

Author(s)	Methodology
(Byrd and Turner, 2001)	They used CCA to offer an exploratory analysis into the relationship between flexible IT infrastructure and competitive advantage.
(Takane et al., 2006)	They proposed an improved method for generalized constrained canonical correlation analysis.
(Jang and Ryu, 2006)	This study examined the interdependencies in investing and financing decisions of restaurant firms.
(Liow and Webb, 2009)	Their study investigates the presence of common factors in the securitized real estate markets of the United States (US), United Kingdom (UK), Hong Kong (HK) and Singapore (SG).
(Droge et al., 2012)	They used CCA and effect decomposition to demonstrate that customer integration mediates the linkages from product modularity and process modularity to delivery performance, as well as mediating the relationship between process modularity and support performance.
(Sohn and Lee, 2012)	They used CCA in order to investigate the relationship between multiple process control monitoring variables and various probe bin variables.

Reinsel (1984) suggested estimating firstly the regression of Y on a small number of “preferred” predictor variables, which are expected to yield canonical correlations that are a large portion of the total correlations due to all predictors, in the usual least squares method. Then, the preceding multivariate shrinkage methods are applied to the residuals, whereby the methods can be represented in terms of partial canonical correlation analysis (Reinsel, 1999). In fact, PCCA finds the correlation between X and Y after removing “partialling out” of the linear effect of the confounding variables Z (Cubaddaa and Hecq, 2001).

In accordance with the discussions mentioned above, the main questions of this paper are:

Question 1: Is there any meaningful relationship between “Efficiency Enhancers” sub-indexes and “Innovation and Sophistication” factors?

Question 2: Which correlations between “Efficiency Enhancers” pillars and “Innovation and Sophistication” factors are the strongest?

There are several sub-questions, but the most important one is as follows:

Based on the answers to the above questions, which are examined in later sections, which sub-pillars of “technological readiness” and “innovation” are strongly interrelated in controlling the impact of countries’ GDP and GDP per capita?

Methods

Research design

The research method used for this study is descriptive correlation. Pearson correlation and partial CCA have been used for our secondary analysis. The statistical population of this study is 144 countries which were included in the GCR 2012-2013. According to the Pearson correlation results in the first step, the partial canonical correlation between innovation and technological readiness, two sets of competitiveness pillars, was considered.

Data analysis

Descriptive analysis

Descriptive analyses of all countries categorized into five economic development stages are presented in Table 3.

Table 3. Descriptive analysis of countries’ statistics considering five stages of development

Stage of development	Number of countries	Mean of GDP per capita	Mean of HET[1]	Mean of GME[2]	Mean of LME[3]	Mean of FMD[4]	Mean of TR[5]	Mean of MS[6]	Mean of BS[7]	Mean of In[8]
Factor-driven	38	879.7368	2.9974	3.9158	4.2342	3.5974	2.8816	2.8816	3.4421	2.8342
In transition from 1st to 2nd stage	18	15429.3889	3.9111	4.0167	3.9611	3.8389	3.5722	3.7000	3.7944	3.0111
Efficiency-driven	32	5349.0312	3.9750	4.1750	4.1812	4.0219	3.6719	3.4062	3.7812	2.9875
In transition from 2nd to 3rd stage	21	13864.2381	4.6667	4.3429	4.3667	4.2190	4.3714	3.9333	4.0524	3.3000
Innovation-driven	35	44373.20	5.3514	4.8714	4.7514	4.7171	5.4686	4.5829	4.9714	4.6514

Note: scores are in a scale of 1 to 7.

1. Higher Education and Training
2. Goods Market Efficiency
3. Labour Market Efficiency
4. Financial Market Development
5. Technological Readiness
6. Market Size
7. Business sophistication
8. Innovation

Table 3 shows that, when countries grow and develop to higher stages, their sub- pillars' scores develop almost smoothly. This analysis can be understood by considering any column of Table 3. Yet the question remains: which efficiency enhancer pillars better predict the changes in the innovation and sophistication pillars? This question will be answered in later sections.

Pearson correlation analysis

To understand the strongest correlations between EE pillars and ISF pillars, the Pearson correlation has been used. Correlation analysis is shown in Table 4.

Table 4. Correlations between EE pillars and ISF pillars

		HET	GME	LME	FMD	TR	MS
BS	Pearson correlation	.829**	.868**	.580**	.787**	.840**	.579**
	Sig(2-tailed)	.000	.000	.000	.000	.000	.000
In	Pearson correlation	.808**	.796**	.630**	.718**	.840**	.546**
	Sig(2-tailed)	.000	.000	.000	.000	.000	.000

** Correlation is significant at 0.01 level (2-tailed)

Table 3 presents the correlations between pillars. Based on Table 3, business sophistication has the highest correlation with goods' market efficiency (0.868), and also with technological readiness (0.84). On the other hand, innovation is highly correlated with technological readiness (0.84) and higher education and training (0.808). So, technological readiness, out of the EE pillars, and innovation, out of the ISF pillars, were selected for further analysis, although BS and GME are also highly correlated. Technological readiness is the 9th pillar of national competitiveness and is a key driver for an efficiency-driven economy in stage 2 of development. It has the following composition: availability of latest technologies; firm-level technology absorption; FDI and technology transfer; individuals using the Internet; broadband internet subscribers; Int'l Internet bandwidth; mobile broadband subscriptions (GCR, 2012). Innovation is the 12th pillar of national competitiveness and is key for an innovation-driven economy in stage 3 of development. It has the following composition: capacity for innovation; quality of scientific research institutions; company spending on R&D; university-industry collaboration in

R&D; government procurement of advanced technology products; availability of scientists and engineers; PCT patents and applications.

Some of the sub-pillars of innovation and technological readiness are strongly affected by countries' gross domestic production (GDP) and GDP per capita, and factors such as availability of latest technology, technology absorption and company spending on R&D. So, to investigate the relationships between these two pillars, we control the impacts of GDP and GDP per capita. Now we can discuss the second part of the research, but before that, the sub-question of this paper should be addressed. By considering the above comments, the sub-question is:

Is there any meaningful relationship between "technological readiness" and "innovation" when controlling two variables, "GDP" and "GDP per capita"? And which variables in the sub-pillars have the most impact on predicting the other set behaviours?

Partial canonical correlation analysis results

To answer the established question, we first used canonical correlation to analyse the data, and then, using partial canonical correlation, data were analysed and compared with the first output.

Based on Table 5, in both analyses the correlation was meaningful and interpretable. According to Table 5, all significant coefficients are smaller than 0.001, so the linearity of relations between the two sets of variables can be supposed for utilizing the PCCA method.

Table 5. Multivariate test of significance

CAA					PCCA				
Test	**Value**	**F Stat**	**Df**	**Sing.**	**Test**	**Value**	**F stat**	**Df**	**Sign.**
Pllais	1.663	6.054	49	0.000	Pllais	1.43719	5.019	49	0.000
Hotlilings	6.0519	15.844	49	0.000	Hotlilings	2.73199	7.15255	49	0.000
Wilks	0.8249	9.9088	49	0.000	Wilks	0.14547	6.26287	49	0.000

According to Table 6, the first and second canonical variables are statistically meaningful for CCA, but due to the weakness of the second root in explaining variance, we refrained from using it in our analysis. Furthermore, in PCCA the third canonical variable is statistically significant, but due to the weakness in explaining variance, we ignore it for interpretation.

Table 6. Eigenvalues and canonical correlation

CCA					PCCA				
Root	**Eigen value**	**Canonical correlation**	**Squared CC**	**Contribution percentage**	**Root**	**Eigen value**	**Canonical correlation**	**Squared CC**	**Contribution percentage**
1	4.71137	0.908	0.82491	77.8487	1	1.354	0.758	0.57524	49.5708
2	0.88406	0.685	0.46923	14.607	2	0.892	0.686	0.47173	32.6859
					3	0.328	0.497	0.24713	12.0153

When controlling the two variables “GDP” and “GDP per capita”, the amount of variance explained using the first canonical variable reduces. Through this action, the second canonical variable and its equations acquire meaning, and hidden relationships between some of the sub-indexes are uncovered. The relationship between these variables was hidden by the fact that 77.84 percent of the variance in canonical variables was explained by this root. Using PCCA, the importance of the second root that by itself explains 32 percent of the variance between canonical variables is taken into consideration.

According to Table 7, the canonical cross-loading in canonical correlation and PCCA can be compared accurately. GDP and GDP per capita have a massive effect on correlation between these sets of variables, and cause decreasing internal validity and overstatement of the correlation between two variable sets.

Table 7. Canonical loadings and cross-loadings

Variance in technological readiness variables explained by canonical variables for PCCA				
Canonical var.	**Canonical loading**	**Cumulative**	**Canonical cross loading**	**cumulative**
1	41.8	41.8	24.04	24.048
2	Resume 14.23	56.03	6.71	30.76
Variance Innovation variables explained by canonical variables for PCCA				
Canonical var.	**Canonical loading**	**Cumulative**	**Canonical cross loading**	**cumulative**
1	59.2490	59.2490	34.08	34.08
2	13.07	72.32	6.1662	40.2486
Variance in technological readiness variables explained by canonical variables for CCA				
Canonical var.	**Canonical loading**	**Cumulative**	**Canonical cross loading**	**cumulative**
1	62.89	62.89	51.88	51.88
2	11.67	74.56	5.47	57.35
Variance in Innovation variables explained by canonical variables for PCCA				
Canonical var.	**Canonical loading**	**Cumulative**	**Canonical cross loading**	**cumulative**
1	74.29	74.29	61.28	61.28
2	9.10	83.69	4.41	65.69

According to Table 8, all variables in both sets are correlated except variable “International Internet bandwidth”, the correlation of which is not statistically meaningful. In the technological readiness pillar, the highest correlations between original variables and canonical variables are related to the variables of availability of latest technologies and firm-level technology absorption with their own canonical variable, with canonical correlation coefficients of 0.8331 and 0.8283, respectively. In the innovation pillar, too, quality of scientific research institutions has the highest correlation with its canonical variable (0.9147), followed by university-industry collaboration in R&D (0.8702), company spending on R&D (0.8568) and capacity for innovation (0.8553), which have significant correlation coefficients. The second-most important relationships between variables based on second canonical correlation (second root) are FDI and technology transfer (0.7172), broadband Internet subscriptions (0.454), and, also in the innovation pillar, government procurement of advanced tech products (0.6328) and PCT patents and applications (0.6228). The first root and second root can be interpreted separately as two separate equations.

Table 8. Correlation between canonical variables and original variable in PCCA

Var\root	1	2	Var\root	1	2
Availability of latest technologies	0.8331	-0.2798	Capacity for innovation	0.8553	0.1257
Firm-level technology absorption	0.8283	-0.3508	Quality of scientific research institutions	0.9147	-.08855
FDI and technology transfer	0.5800	-0.7172	Company spending on R&D	0.8568	-0.1015
Individuals using Internet	0.5167	.08565	University-industry collaboration in R&D	0.8702	-0.2832
Broadband Internet subscriptions	0.6700	0.4540	Government procurement of advanced tech products	0.5061	-0.6328
Int’l Internet bandwidth	0.2871	-0.1038	Availability of scientists and engineers	0.6602	-0.1116
Mobile broadband subscriptions	0.6409	0.2369	PCT patents, applications	0.6287	0.6228

Conclusion and suggestions

This paper intended to examine the relationships between efficiency-driven pillars and innovation-driven pillars. Based on the Pearson correlation between them, we conducted a partial canonical correlation analysis on the relationship between technological readiness and innovation, which had the highest correlation. We used PCCA to overcome the effects of the control variables, GDP and GDP per capita, and through comparison with CCA one more interpretable relation was discovered by PCCA. It could be valuable to add a further point that to our knowledge there is no research in previous works in the field of management and economics which has utilized the PCCA method for considering interrelationships between elements by controlling some variables.

Based on the results obtained in the previous section, availability of latest technologies and firm-level technology absorption from the technological readiness pillar, and quality of scientific research institutions, university-industry collaboration in R&D and company spending on R&D from the innovation pillar are highly correlated. On the other hand, based on canonical second root analysis, FDI and technology transfer, broadband Internet subscriptions, and, also in the innovation pillar, government procurement of advanced technology products, and PCT patents and applications are highly correlated. It is interesting to note that the GCR’s authors (Schwab, 2012), when introducing innovation, used “technological innovation” to describe innovation. It must be said that innovation affects the level of technology; on the other hand, we must consider technology a comprehensive definition, as it is technology which creates innovation. Innovation is particularly important for economies as they approach the frontiers of knowledge, and the possibility of generating more value by only integrating and adapting exogenous technologies tends to disappear (Aghion and Howitt, 1992). As shown in the descriptive analysis, there are 32 countries in the efficiency-driven economy stage, and 21 countries in transition from this stage to an innovation-driven economy. Less advanced countries in these two stages can still improve their productivity by adopting the latest technologies or making incremental improvements in their technologies; for those that have reached the innovation stage of development, this is no longer sufficient for increasing productivity. Firms in these countries must design and develop cutting-edge products and processes to maintain a competitive edge and move toward higher value-added activities. On the other hand, for countries in stage 2 and in transition from stage 2 to 3, the creation and development of bilateral cooperation between research institutes, universities and industries to invest in research and development to promote innovation is recommended. Researchers highlight the following actions for politicians and policymakers in order to improve their national competitiveness and transition from the efficiency-driven to the innovation-driven stage of development:

Supporting the bilateral collaboration of local researchers and universities with industries. Governments should support local researchers, the scientific community and industries to obtain and absorb new firm-level technologies and also create a climate for increasing the innovation capacity of academic researchers in practice (based on the first canonical root analysis).

Restructuring and supporting scientific research and development (SRD) institutes. To better commercialize R&D outputs, policymakers should focus on the real potential of each SRD institution. Policymakers should provide a supportive environment with rules and guidelines, such as financial support instruments through which institutions can maximize their ability to conduct scientific research and the development process. It would help the development and emergence of new technologies at national and firm levels to increase the country's competitiveness level (based on the first canonical root analysis).

Preparing the conditions for direct foreign investment and knowledge-sharing in the country. Policymakers should pay attention to foreign relations with advanced and developed countries and try as much as possible to attract foreign investments and knowledge-sharing into the country. Indeed, we noticed the importance of trade openness, FDI, human capital, R&D and knowledge flows for innovation and absorption in less advanced countries. Thus, encouraging innovation will first require improving the investment climate for innovative firms, which includes reinforcing the regulatory reform agenda, removing barriers to competition and fostering skills development. In parallel, policymakers should adopt policies to spur participation in world R&D, as collaboration with researchers and multinational corporations abroad is an effective way to tap into the global knowledge pool, enabling both technological and intellectual transfer of know-how (based on second canonical root analysis).

The findings of this research increased our knowledge about the relationship between the pillars of “technology readiness” and “innovation”. Finally, we should remember that we predicted some relations of the GCI pillars using PCCA. It should be noted that other factors are surely required for the transition from an efficiency-driven economy to an innovation-driven economy. As previously mentioned, the pillars are all interrelated and intertwined. For example, a researcher may investigate the relationship between GME and BS for transiting from stage two to third stage. We propose that researchers investigate the relationships between pillars by the decision-making trial and evaluation laboratory (DEMATEL) method, which considers relationships between elements of a system and prioritizes them by their influencing power.

One limitation of this paper was the use of a method which is based on linear relationships, when we know in the real world that most of the relations are nonlinear. It can also be proposed that in future researchers perform a correlation analysis by considering the nonlinear relationships between pillars, and compare their results with those of this paper.

References

Artto, E. (1987). "Relative total costs—an approach to competitiveness measurement of industries". *Management International Review*, 27(2), 47-58.

Bleotu, V. (2012). "Comparative analysis of Romanian competitiveness evolution". 4th WORLD CONFERENCE ON EDUCATIONAL SCIENCES. holded in Barcelona, Spain. *Procedia - Social and Behavioral Sciences*, 46, 5382-5386.

Byrd, T. A. & Turner, D. E. (2001). "An exploratory examination of the relationship between flexible IT infrustructure and competitive advantage". *Information & Management*, 39(1) 41-52.

Cubaddaa, G. & Hecq, A. (2001). "On non-contemporaneous short-run co-movements". *Economics Letters*, 73(3), 389-397.

Droge, C.; Vickery, S. & Jacobs, M. A. (2012). "Does supply chain integration mediate the relationships between product/process strategy and service performance? An empirical study". *International Journal of Production Economics*, 137(2), 250-262.

Heap, J. (2007). "Stormy productivity weather ahead?". *International Journal of Productivity and Performance Management*, 56(2), 170-177.

Jafari, S. (2014). "Strategic Cost-Cutting in Information Technology: toward a Framework for Enhancing the Business Value of IT". *Iranian Journal of Management Studies*,7(1), 21-39.

Jang, S. & Ryu, K. (2006). "Cross-balance sheet interdependencies of restaurant firms: a canonical correlation analysis". *International Journal of Hospitality Management*, 25(1), 159-166.

Leclere, J. (2006). "Bankruptcy studies and ad hoc variable selection: a canonical correlation analysis". *Review of Accounting and Finance*, 5(4), 410-422.

Lima, M.; Resende, M. & Hasenclever, L. (2004). "Skill enhancement efforts and firm performance in the Brazilian chemical industry: An exploratory canonical correlation analysis research note". *International Journal of Production Economics*, 19(2), 149-155.

Liow, K. H. & Webb, J. R. (2009). "Common factors in international securitized real estate markets". *Review of Financial Economics*, 18(2), 80-89.

Onsel, S.; Ulengin, F.; Ulusoy, G.; Aktas, E., Kabak, O. & Topcu, Y. I. (2008). "A new perspective on the competitiveness of nations". *Socio-Economic Planning Sciences*, 42(4), 221–246.

Philippe, Aghion & HOWITT, Peter. (1992). "A Model of Growth through Creative Destruction". *Econometrica LX*, 60(2), 323-351.

Porter, M. E. (1985). *Competitive Advantage: Creating and Sustaining Superior Performance*. New York, Free Press.

Porter, M. E. (1990). *The Competitive Advantage of Nations*. New York, free press.

Reinsel, G. C. (1999). "On multivariate linear regression shrinkage and reduced-rank procedures". *Journal of Statistical Planning and Inference*, 81(2), 311-321.

Roberts, R. (1998). "Managing innovation: The pursuit of competitive advantage and the design of innovation intense environments". *Research Policy*, 27(2), 159-175.

Rugman, A. M. (1987). "Strategies for national competitiveness". *Long Range Planning*, 20(3), 92-97.

Sauders, M.; Lewis, P. & Thornhill, A. (2007). *Research methods for business students.* Harlow, Prentice Hall.

Schwab, K. (2012). *The Global Competitiveness Report 2012-2013*. Geneva: World Economic Forum.

Sohn, S. Y. & Lee, S. G. (2012). "Probe test yield optimization based on canonical correlation analysis between process control monitoring variables and probe bin variables". *Expert Systems with Applications*, 39(4), 4377-4382.

Takane, Y., Yanai, H. & Hwang, H. (2006). "An improved method for generalized constrained canonical correlation analysis". *Computational Statistics & Data Analysis*,50(1), 221-241.

Wang, T.-Y.; Chien, S.-C. & Kao, C. (2007). "The role of technology development in national competitiveness — Evidence from Southeast Asian countries". *Technological Forecasting and Social Change*, 74(8), 1357-1373.