Global Journal of HUMAN-SOCIAL SCIENCE: H
Interdisciplinary
Volume 21 Issue 3 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-460x & Print ISSN: 0975-587X

The Linkage between Input and Output in the Innovation Ecosystem

By Diego Araujo Reis, Fábio Rodrigues De Moura & Iracema Machado De Aragão

Federal University of Sergipe

Abstract- An innovation ecosystem is characterized by numerous interactions between its various components. The proper functioning of an innovation ecosystem is a necessary condition to increase the chances of successful innovative activities. This research aims to investigate the relationship between input and output in the innovation ecosystem of countries. For the empirical evaluation, the Global Innovation Index (GII) was used as a proxy of the innovation ecosystem. This index tracks innovation inputs and innovation products in various countries. Using annual country data, an unconditional quantile regression model was estimated to identify the structural relationship between innovation input and output, including with lag application. Our findings show that innovation input has a significant and positive effect on innovation output in countries. These findings are useful for national innovation policies, since they emphasize the need to promote better innovation incentives.

Keywords: innovation ecosystem; global innovation index; innovation input; innovation output; innovation policies; innovation in countries; national innovation; quantile regression.

GJHSS-H Classification: FOR Code: 280107

The Linkage between Input and Output in the Innovation Ecosystem

Diego Araujo Reis [α], Fábio Rodrigues de Moura [σ] & Iracema Machado De Aragão [ρ]

Abstract- An innovation ecosystem is characterized by numerous interactions between its various components. The proper functioning of an innovation ecosystem is a necessary condition to increase the chances of successful innovative activities. This research aims to investigate the relationship between input and output in the innovation ecosystem of countries. For the empirical evaluation, the Global Innovation Index (GII) was used as a proxy of the innovation ecosystem. This index tracks innovation inputs and innovation products in various countries. Using annual country data, an unconditional quantile regression model was estimated to identify the structural relationship between innovation input and output, including with lag application. Our findings show that innovation input has a significant and positive effect on innovation output in countries. These findings are useful for national innovation policies, since they emphasize the need to promote better innovation incentives.

Keywords: innovation ecosystem; global innovation index; innovation input; innovation output; innovation policies; innovation in countries; national innovation; quantile regression.

I. Introduction

The result of new arrangements between the factors of production that lead to new goods, new production processes or new forms of industrial organization is associated with the notion of innovation introduced by Schumpeter (1934). Innovation is the key to a dynamic economy. Easterly and Levine (2001) and Helpmann (2004) argue that it is not so much the accumulation of more capital that determines the long-term economic growth, but how capital is used, i.e., the innovation process.

Innovation increases employment, income, and competitiveness, thereby leading to economic development. Countries need to create incentives for innovation in order to raise their standard of living (Moretti, 2004; Helpmann, 2004; Cooke, 2008; OCDE, 2010; Atkinson, 2013; Gogodze, 2016; Hernandez & González, 2017). However, the decision making of policy makers should be preceded by studies that qualify and quantify the specificities of innovation, in order to identify the state of the art and prepare adequate strategies to promote it.

The Global Innovation Index (GII), created in 2007, resulted from a collaboration between Cornell University, INSEAD (European Institute of Business Administration) and the World Intellectual Property Organization (WIPO). The goal was to create procedures and metrics to measure the different dimensions of innovation in a number of countries (SaiSana, 2011). The GII tracks innovation inputs, which are related to a favorable innovation environment (Institutions; Human Resources and Research; Infrastructure; Market Sophistication and Business Sophistication), and outputs, defined as the results of innovation (Knowledge and Technology-based Products; Creative Products). Innovation inputs and outputs are sub-indexes that generate the GII (Dutta & Benavente, 2011).

However, the methodology of GII does not empirically assess the possible linkage between innovation inputs and outputs over a particular time. The GII only synthesizes the final annual result for the status quo of innovation in several countries based on the mapped categories. GII methodology states that the direct relationship between inputs and innovation products should be viewed with caution, since the effect may not be automatic or contemporary.

Our research has identified a relative scarcity of scientific studies on the possible links between innovation inputs and outputs, and how this relationship can develop over time. As such, we aim to investigate the relationship between input and output in the innovation ecosystem. We test the hypothesis that innovation input affected output in the GII results between 2009 and 2019.

We estimate an unconditional quantile regression model with contemporaneous and lag adjustment to identify the (hypothetical) structural relationship between innovation input and output in countries. Our study proposes a different approach for analyzing the innovation ecosystem that may be useful for global innovation policies.

Author α: Ph.D. Program of Postgraduate in Intellectual Property Science, Federal University of Sergipe, São Cristóvão, Brazil. Campus São Cristóvão - Cidade Univ. Prof. José Aloísio de Campos. e-mail: diegoaraujoreis@hotmail.com

Author σ: Ph.D. Professor. Program of Postgraduate in Economics. Department of Economics, Federal University of Sergipe, São Cristóvão, Brazil. Campus São Cristóvão - Cidade Univ. Prof. José Aloísio de Campos. e-mail: fabiromoura@gmail.com

Author ρ: Ph.D. Professor. Program of Postgraduate in Intellectual Property Science. Department of Business Administration, Federal University of Sergipe, São Cristóvão, Brazil. Campus São Cristóvão - Cidade Univ. Prof. José Aloísio de Campos. e-mail: aragao.ufs@gmail.com

II. Innovation Ecosystem

Following Schumpeter (1934), other authors and organizations have proposed new innovation concepts (OECD, 1997; Edquist, 1997; Sundbo & Gallouj, 1998; OECD, 2005). To summarize, innovation is now understood as the implementation of something new or significantly improved (Product or Service, Process, Marketing Method; Business Organization Method, Commercial Models, Practices, Workplace Organization or Foreign Relations).

Leydesdorff and Etzkowitz (1996) and Etzkowitz and Leydesdorff (2000) proposed the Triple Helix innovation model to identify the role of companies, governments and universities. In this model, the university encourages the relationship with companies and government in generating, accumulating and applying new knowledge (technological innovations) in favor of economic development. Campbell, Carayannis and Rehman (2015) broaden the notion of Triple helix by introducing civil society as a fourth helix, emphasizing democracy and the importance of political and civil rights in the innovation system. Carayannis, Barth and Campbell (2012) and Carayannis and Rakhmatullin (2014) include sustainable development as another dimension in the helix models, resulting in a five-helix model.

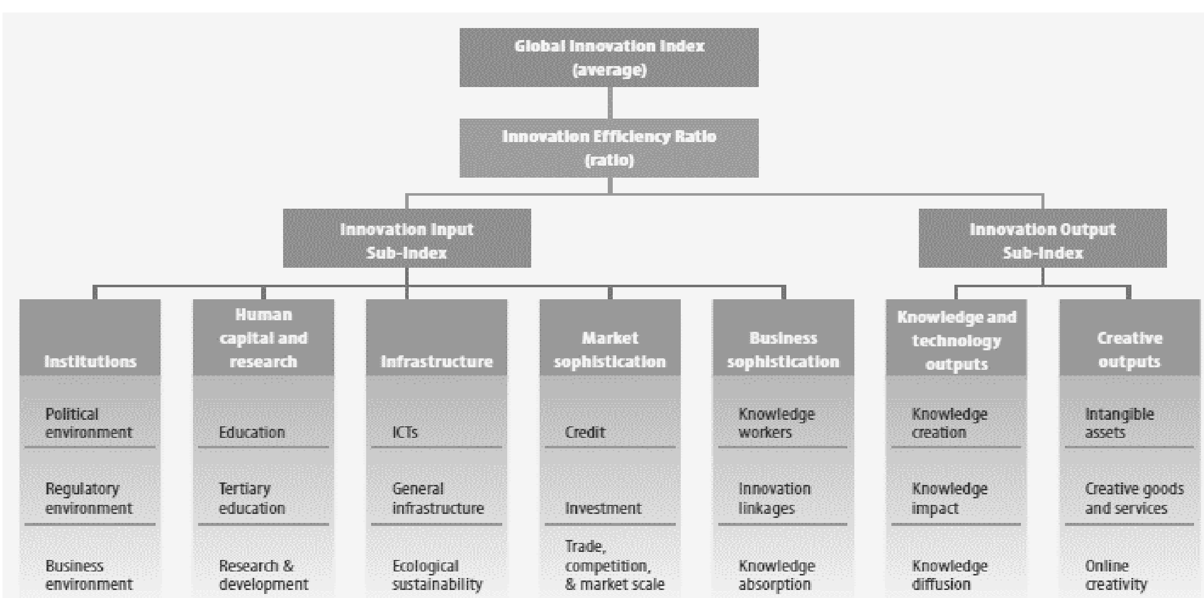
In addition, the innovation phenomenon has been systematically investigated and measured, under the open system and ecosystem approach (Dosi, 1988; Lundvall, 1992; Nelson, 1993; Freeman, 1995; Moore, 1996; Dahlander & Gann, 2010; Remneland Wikhamn & Wikhamn, 2013; Dedehayir & Seppänen, 2015; Brown, 2016; Adner, 2017; Dedehayir et al. 2017).

The innovation ecosystem has become an organizational paradigm and has served as the primary reference in formulating strategies for innovation (Teece, 2007). The functioning of the innovation ecosystem proposed for Moore (1996) is characterized by multiple interactions between its different components. In this respect, it is important to manage and expand the benefits of the ecosystem, which requires mapping and creating metrics to quantify and identify gaps in its performance, possibly correcting any bottlenecks (Jackson, 2010). The proper functioning of an ecosystem is needed to broaden the effectiveness of entrepreneurial and innovative activities, creating jobs and providing the conditions for economic prosperity.

III. Global Innovation Index (GII)

The GII was created based on the reasoning that innovation is important for driving competitiveness and economic progress in developed and developing economies. According to Saisana, Domínguez-Torreiro and Vertesy (2017), in 2017 the index was calculated for 127 countries based on 79 indicators; in that year, the index measured innovation ecosystems that covered 92.5% of the world's population and 97.6% of GDP (in USD).

The GII adopts the concept of innovation originally devised by the Oslo Manual and expanded by the European Community and the Organization for Economic Cooperation and Development (OECD). Figure 1 shows that the GII consists of seven large innovation areas divided into 21 sub-areas.



Source: Adapted by Authors (2019) based on Saisana, Domínguez-Torreiro and Vertesy (2017)

Figure 1: Composition of the Global Innovation Index (GII)

Input innovation is monitored by five large areas, which determine environmental aspects favorable to innovation, and two large areas monitor innovation output. The GII then aggregates the large areas into two sub-indices: Input and Output. Next, the Innovation Efficiency Ratio the ratio between the sub-indices of Innovation Input and Output, is calculated. Finally, the Global Innovation Index (GII) is calculated by arithmetic mean of the sub-indices.

The GII and its sub-indices are quantitative measures that range between 0 and 100; the higher the score, the more developed the innovation ecosystem. The complete GII methodology can be accessed in greater detail in the annual reports published jointly by Cornell University and WIPO.

SaiSana (2011), Saisana and Philippas (2012; 2013), Saisana and Saltelli (2014), Saisana and Domínguez-Torreiro (2015) and Saisana, Domínguez-Torreiro and Vertesy (2016; 2017) assessed the GII using the *Handbook on Constructing Composite Indicators: Methodology and User Guide*, produced by the Applied Statistics and Econometrics Unit of the Joint Research Centre (JRC) of the European Commission in Ispra (Italy) in partnership with the OECD. These authors tested the GII from two perspectives: conceptual and statistical coherence. They concluded that the multilevel structure of the GII is statistically coherent and has a stable structure, since it is not dominated by any of the sub-ind. The ranking obtained by a country is reasonably robust given the methodological assumptions (estimated lost data, weighting and aggregation formula).

IV. Literature Review

Studies that investigate the GII derive from a more specific approach reported in specialized journals, which analyzed the GII empirically. Al-Sudairi and Bakry (2014) explored the results of the GII for Saudi Arabia. Sohn, Kim and Jeon (2016) re-examined the GII using a structural equation model for 2013 data. These authors analyzed innovation input (institution, human capital and research, infrastructure, market sophistication and business sophistication) and output (knowledge and technology, and creative solutions). However, they did not consider the possible structural relationship between the factors that affect a country's innovation performance.

Crespo and Crespo (2016) assume that countries can achieve high innovation performance in the GII using various combinations of input. The authors discuss the internal sub-pillars of innovation input and establish two sub-samples (high and low-income countries). They find that several input combinations lead to high innovation performance in both groups, and that in the low-income group none of the individual conditions is sufficient to predict good innovation performance, while in the high-income group infrastructure, human capital and research conditions are sufficient to obtain a better innovation performance. Carpita and Ciavolino (2017) found evidence of a positive relationship between Business Sophistication (explanatory variable) and Innovation Input (response variable), using the GII data for 27 European Union (EU) countries in 2012.

Gogodze (2016) analyzed the relationships among the components of GII, employing the Structural Equation Modeling (SEM) techniques in 77 countries, between 2011 and 2015. Gogodze (2016) found results that support the existence of a causal link among the various sub-indexes of the GII. The author concluded that the efficient management of institutional capital in high-income countries is essential to innovation success.

Vlasova, Kuznetsova and Roud (2017) investigated the GII results for Russia between 2013 and 2016. The authors analyzed the strengths and weaknesses regarding progress in science, technology and innovation in the country. Jankowska, Matysek-Jedrych and Mroczek-Dabrowska (2017) used the GII to explain how national innovation systems can transform innovation input into output in different countries. The authors assume that more innovation input generates more innovation output in a country. They used cluster analysis with 228 countries. Subsequent results obtained for Poland and Bulgaria contradicted the initial results. The authors then try to explain how and why national innovation systems fail (or succeed) in creating innovation.

There is also a series of studies available in the GII reports that discuss its theoretical-methodological concept and results (Dutta & Benavente, 2011; SaiSana, 2011; Dutta, Benavente & Wunsch-Vincent, 2012; Saisana & Philippas, 2012; Wunsch-Vincent, 2012; Slater and Wruuck, 2012; Saisana and Philippas, 2013; Hollanders, 2013; Xiangjiang, Peng & Kelly, 2013; Dutta et al, 2014; Saisana & Saltelli, 2014; Scott & Vincent-Lancrin, 2014; Dutta et al, 2015; Saisana & Domínguez-Torreiro, 2015; Reynoso et al, 2015; Goedhuys, Hollanders & Mohnen, 2015; Atkinson & Ezell, 2015; Chen, Zheng & Guo, 2015; Chaminade & Moskovko, 2015; Gopalakrishnan & Dasgupta, 2015; Ecuru & Kawooya, 2015; Dutta et al, 2016; Saisana, Domínguez-Torreiro & Vertesy, 2016; Poh, 2016; Gokhber & Roud, 2016; Dutta et al, 2017; Andrade & Domingos, 2017; and Lybbert et al, 2017).

Dutta and Benavente (2011), Dutta, Benavente and Wunsch-Vincent (2012), Dutta, Benavente and Wunsch-Vincent (2013), Dutta et al (2014), Dutta et al (2015), Dutta et al (2016) and Dutta et al (2017) report that, although the scores for Input and Output in the GII may differ substantially, leading to important changes in a country's classification, there is a positive relationship between them. To summarize, based on the data available for the respective years, these authors infer that the efforts made for better innovation input are rewarded with improved innovation results. On the other hand, the GII methodology warns that the relationship between inputs and innovation products should be viewed with caution, since the direct effect may not be automatic or contemporary.

Along these same lines, the present study sought to confirm whether innovation inputs statistically affect the products of innovation in the GII results. One of the differences, however, is to make an assessment over an extended period (2009 to 2019), through the quantile econometric method, including the use of lags.

V. Sample Design

The sample was based on the availability of the GII sub-indices (innovation input and output) and the data were obtained from the annual GII reports. The other control variable selected was Gross Domestic Product Per Capita based on Purchasing Power Parity (GDP) in 2011 USD, obtained from the World Bank.

The sample includes all the available years of the GII between 2009 and 2019. However, the current year GII is based on country data from the previous two years. In order to estimate the empirical model, we consider that the results of the GII always refer to the two years prior to publication.

Table 1: Number of countries mapped by the GII

Countries	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
GII	130	132	125	141	142	143	141	128	127	126	129
GDP PPP per capita	128	130	123	140	141	143	141	128	127	126	129

Source: Authors (2019). 1- Note: The GII data for 2009 to 2010 correspond to the previous version, which varied between 0 and 1. To reconcile the earlier version with the current one, the data for 2009 to 2010 were multiplied by 100. For more information on the methodology, see the annual reports.

As can be observed, the non-homogeneous number of countries mapped each year by the GII requires some specific methodological treatment.

VI. Empirical Model

The GII sub-indices use a variety of information on a country's innovation ecosystem (see Figure 1). However, since the index covers several countries with varying economic performance, it is important to consider the possible high heterogeneity in the structural relationship between input and output in the innovation ecosystem environment. As such, we propose estimating a quantile regression model with fixed effects in a panel data setting in order to test the possible relationship between innovation input and output.

The quantile regression model with fixed effects is credited to different authors (Koenker, 2004; Bache et al., 2013; Powell, 2017). In this study, we use quantile regression with fixed effects, as proposed by Bache et al. (2013):

$$y_{it} = x_{it}\beta\,(\tau) + s_i\pi + \varepsilon_{it}, \qquad (1)$$

We estimated a Correlated-Random-Effects (CRE) model (unconditional) according to Bache et al. (2013):

$$OUTPUT_{It} = \beta_0(\tau) + INPUT_{it}(\tau)\beta_1 + GDP_{it}(\tau)\,\beta_2 + D_k + s_i\pi + \varepsilon_{it}, \qquad (2)$$

where i is the index for countries and t is the index for years. The time-invariant unobserved effects are controlled by the covariate vector si, constructible from repeated measurements of the time-varying covariates in xit (time-invariant covariates, such as geographic region, are not used to construct si). In general, si is constructed using the t-means (averages over time) of the time-varying covariates in xit. This allows for unobserved characteristics to correlate with xit. In addition, the unobserved effects can affect both the scale and location of the response distribution. The si vector enters linearly in the criterion function and the unobserved effects are allowed to vary with each quantile. Nevertheless, the estimator proposed by Bache et al. (2013) allows the use of unbalanced panels (si is constructed using the years available for each country). The model was estimated using log variables (coefficients are elasticities), and Dk are dummies to capture the particular effect of different regions on innovation output. The regions are labeled based on United Nations criteria, as follows: EUR = Europe; NAC = North America; LCN = Latin America and the Caribbean; CSA = Central and Southern Asia; SEAO= Southeast Asia, East Asia, and Oceania; NAWA = Northern Africa and Western Asia; SSF = Sub-Saharan Africa. We selected CSA as the base region. The response variable and the covariates are in logs, except for the dummies.

Considering that the possible relationship between innovation inputs on outputs may not be automatic, we still apply a lag one-year quantile model, where, for example, 2018 inputs will be contrasted with their 2019 counterparts, while inputs from 2019 are also modeled. This is because both 2018 and 2019 inputs can simultaneously affect 2019 innovation products. In addition, we take into account that this lag models may be endogenous, since innovation outputs may include innovations that are be correlated with innovation inputs, such as process innovations. To overcome this possible problem, we have included a last quantile model whose input will be lagged by one year and contrasted exclusively with innovation outputs.

VII. Results and Discussion

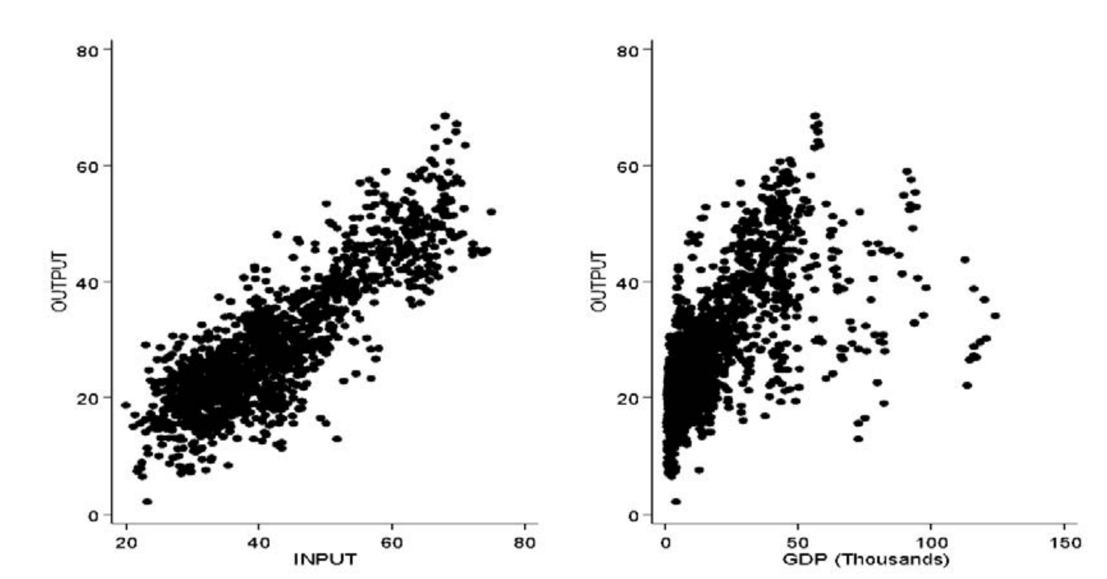
Table 2 presents the descriptive statistics of the variables (Innovation Input, Innovation Output, GDP Per capita) in the period. With the exception of the standard deviation, note that the statistical values of innovation inputs and outputs differ substantially, suggesting that the average and median effort of innovation inputs is greater than innovation results. The minimum and maximum values demonstrate that innovation results are significantly lower than innovation inputs. However, the standard deviation between these variables is relatively similar.

Table 2: Descriptive statistics for the inputs, outputs and GDP variables (2009 to 2019)

STATISTIC	INPUT	OUTPUT	GDP
Average	42.49	29.43	20,704.56
Median	40.49	26.97	13,776.03
Standard Deviation	11.82	11.45	20,578.98
Minimum	19.90	2.10	670.78
Maximum	74.90	68.60	12,4024.57
Observations	1464.00	1464.00	1,456.00

Source: Authors (2019)

The average GDP was above the median, with high standard deviation, and its minimum and maximum values show the wide variability of economic performance between countries. In general, the distribution of all observed variables is heterogeneous. Figure 2 shows the scatter plots for inputs, outputs and GDP, where It is possible to observation that the variables inputs and GDP are linearly associated with innovation outputs. As expected, the distribution of innovation input data is better matched with innovation product observations.



Source: Authors (2019).

Figure 2: Dispersion of the inputs, outputs and GDP in the period (2009 to 2019)

It is important to note that the more than 120 countries present in the sample are markedly different in their own characteristics, from economic and social to political, cultural, and territorial aspects, among others. Thus, to properly investigate the wide variability in data distribution of the sample variables, Table 3 presents a statistical description by quantiles, which organizes the distribution of countries monotonically according to the median.

Table 3: Quantile median of the variables (2009 to 2019)

VARIABLES	INPUT	OUTPUT	GDP
10%	28.85	16.90	1,848.24
20%	32.00	19.90	3,470.13
30%	34.70	22.03	6,058.04
40%	37.80	24.38	8,689.13
50%	40.49	26.97	12,400.89
60%	43.01	29.90	16,684.51
70%	46.90	33.84	23,505.04
80%	53.08	39.38	33,411.80
90%	62.20	46.60	44,315.39

Source: Authors (2019).

Nine quantiles were established for the sample hierarchy. This procedure enabled the formation of groups of countries with lower standard deviation. The 10% quantile value, for example, is represented by the lowest values in the distribution of input and innovation product and economic performance data. However, the countries with the highest values are above the 90% quantile.

Table 4 summarizes the results of quantile regression no lag for countries between 2009 and 2019. Innovation input has a significant positive effect on innovation output, except for the 10% quantile. As such, this result confirms our hypothesis and partially corroborates that of Dutta and Benavente (2011), Dutta, Benavente and Wunsch-Vincent (2012), Dutta, Benavente and Wunsch-Vincent (2013), Dutta et al (2014), Dutta et al (2015), Dutta et al (2016) and Dutta et al (2017), which claims there is a positive relationship between the sub-indexes.

However, countries located in the initial quantile seem unable to translate their innovation efforts into innovation products. Another important finding is that, the farther we move to the right tail of the innovation output distribution, the greater the effect of innovation input. In the 90% quantile, the magnitude of the coefficient is smaller, compared to the 80% quantile.

Table 4: Results of quantile regressions for countries between 2009 and 2019

OUTPUT	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
INPUT	-0.0501	0.2263***	0.2642***	0.5363***	0.6146***	0.8100***	0.846***	1.418***	1.0713***
	(0.085)	(0.037)	(0.060)	(0.096)	(0.088)	(0.082)	(0.129)	(0.174)	(0.301)
GDP	-0.8089***	-0.4725***	-0.3203***	-0.1038***	-0.1879***	-0.0946***	-0.1574*	-0.5245***	-0.3589***
	(0.119)	(0.046)	(0.070)	(0.027)	(0.030)	(0.033)	(0.093)	(0.082)	(0.103)
EUR	-0.1116**	0.088**	0.1719***	0.2178***	0.2494***	0.3236***	0.2270***	0.0289	0.0022
	(0.043)	(0.039)	(0.054)	(0.028)	(0.030)	(0.037)	(0.063)	(0.054)	(0.024)
LCN	0.088***	0.1471***	0.0755***	0.0333*	-0.0011	-0.0235	-0.1157***	-0.1551***	-0.0933***
	(0.032)	(0.035)	(0.020)	(0.019)	(0.015)	(0.017)	(0.043)	(0.023)	(0.030)
NAC	-0.2886***	-0.0355	0.0598	0.0962***	0.1402***	0.2874***	0.3164***	0.2721***	0.3662***
	(0.052)	(0.037)	(0.046)	(0.021)	(0.039)	(0.044)	(0.036)	(0.061)	(0.100)
NAWA	-0.0988**	0.1204***	0.1473***	0.104***	0.0706***	0.0416**	-0.0532	-0.1611***	-0.0951***
	(0.044)	(0.036)	(0.036)	(0.020)	(0.012)	(0.020)	(0.062)	(0.020)	(0.034)
SEAO	-0.1291***	0.0824**	0.1634***	0.1780***	0.1849***	0.2489***	0.1233**	0.0087	-0.1587***
	(0.043)	(0.038)	(0.049)	(0.015)	(0.028)	(0.033)	(0.058)	(0.023)	(0.048)
SSF	-0.1599***	-0.0301	-0.0359	-0.0471***	-0.0221	0.0099	0.0246***	0.0479***	0.0164*
	(0.034)	(0.029)	(0.021)	(0.010)	(0.020)	(0.014)	(0.006)	(0.010)	(0.008)

*Source: Authors (2019). Asterisks denote the significance level: * 10%; ** 5%; *** 1%. Bootstrapped standard errors are given in parentheses.*

Table 5 shows the results of contemporaneous and lagged variables. The cumulative effect, that is, when we add the contemporary and lagged result of innovation inputs, we observe a positive and significant effect on the 30%, 40%, 50%, 60%, 70% and 90% quantiles of the response variable (results innovation). This indicates that more innovation inputs positively affect innovation output in countries located in the right tail of the response distribution, especially in countries with the highest GII output sub-index scores, with the exception of the 80% quantile. The cumulative effect of innovation inputs on innovation output in the 10% and 20% quantiles is non-significant. Once again, these findings are evidence that countries with a relatively weak innovation ecosystem cannot translate their innovation efforts into product innovation.

Table 5: Results of quantile regressions for countries between 2009 and 2019

OUTPUT	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
INPUT	-0.0125	-0.4430***	-0.1238	0.1259**	0.1669*	0.5315***	0.7253***	1.4693***	0.9386***
	(0.102)	(0.077)	(0.091)	(0.055)	(0.091)	(0.092)	(0.224)	(0.222)	(0.350)
LAGINPUT	-0.4999***	0.0857	0.2615***	0.3146***	0.5176***	0.3083***	0.3720***	0.0854	0.2200*
	(0.082)	(0.102)	(0.052)	(0.092)	(0.057)	(0.057)	(0.078)	(0.103)	(0.115)
GDP	0.8961***	0.8264***	0.3598***	0.407***	-0.0521	0.1414	0.3331**	-0.2249	0.2107
	(0.308)	(0.127)	(0.112)	(0.138)	(0.167)	(0.176)	(0.165)	(0.145)	(0.143)
LAGDP	-1.8926***	-1.5918***	-0.8329***	-0.6517***	-0.2462	-0.4101*	-0.8104***	-0.3016*	-0.5891***
	(0.318)	(0.176)	(0.129)	(0.133)	(0.162)	(0.209)	(0.157)	(0.157)	(0.181)
EUR	-0.0054	0.2006***	0.3301***	0.3473***	0.3139***	0.39***	0.1862**	-0.0261	0.0342*
	(0.076)	(0.035)	(0.058)	(0.032)	(0.043)	(0.056)	(0.084)	(0.037)	(0.020)
LCN	0.1360***	0.1923***	0.1991***	0.1170***	0.0037	0.0112	-0.1541***	-0.1704***	-0.0814***
	(0.050)	(0.037)	(0.030)	(0.033)	(0.017)	(0.035)	(0.047)	(0.037)	(0.025)
NAC	-0.1625**	0.1057***	0.2341***	0.219***	0.1977***	0.337***	0.2543***	0.1913***	0.3792***
	(0.082)	(0.034)	(0.047)	(0.022)	(0.050)	(0.038)	(0.045)	(0.050)	(0.089)
NAWA	0.0151	0.2345***	0.2934***	0.2007***	0.0753***	0.0552	-0.1499**	-0.2267***	-0.0972***
	(0.073)	(0.034)	(0.044)	(0.033)	(0.022)	(0.046)	(0.072)	(0.045)	(0.028)
SEAO	-0.0833	0.1558***	0.2831***	0.2446***	0.2133***	0.2903***	0.0984	0.0007	-0.198***
	(0.079)	(0.031)	(0.049)	(0.021)	(0.042)	(0.053)	(0.061)	(0.031)	(0.044)
SSF	-0.1545***	-0.02	0.0636**	0.014	-0.0384*	0.005	-0.0299***	-0.0085	-0.0019
	(0.049)	(0.025)	(0.026)	(0.016)	(0.019)	(0.014)	(0.010)	(0.010)	(0.002)

*Source: Authors (2019). Asterisks denote the significance level: * 10%; ** 5%; *** 1%. Bootstrapped standard errors are given in parentheses.*

We further tested in Table 6 whether the shift in production input lag only affects innovation output in subsequent years. We found evidence that innovation inputs (Institutions; Human Resources and Research; Infrastructure; Market Sophistication and Business Sophistication) positively and significantly impact innovation outputs (Knowledge and Technology-based Products; Creative Products), except in the 10% and 20% quantiles. This result corroborates the previous findings, especially at the higher quantiles.

Table 6: Results of quantile regressions for countries between 2010 and 2019

OUTPUT	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
LAGINPUT	-0.4087***	-0.0388	0.2407***	0.4197***	0.5927***	0.5808***	0.7591***	0.7717***	0.6969***
	(0.052)	(0.082)	(0.084)	(0.082)	(0.060)	(0.089)	(0.101)	(0.125)	(0.144)
LAGGDP	-1.0839***	-0.8879***	-0.5197***	-0.2715***	-0.2771***	-0.2307***	-0.4388***	-0.3621***	-0.3074***
	(0.116)	(0.080)	(0.097)	(0.045)	(0.043)	(0.067)	(0.079)	(0.103)	(0.093)
EUR	-0.0714	0.1455***	0.2902***	0.3156***	0.2961***	0.3755***	0.1807**	-0.0358	0.0048
	(0.073)	(0.034)	(0.057)	(0.031)	(0.044)	(0.053)	(0.077)	(0.048)	(0.024)
LCN	0.084*	0.1502***	0.1691***	0.0938***	-0.0073	0.0071	-0.1480***	-0.1666***	-0.0948***
	(0.049)	(0.035)	(0.028)	(0.032)	(0.016)	(0.032)	(0.042)	(0.029)	(0.028)
NAC	-0.2393***	0.0432	0.1895***	0.1841***	0.1806***	0.3289***	0.2603***	0.1936***	0.3567***
	(0.083)	(0.032)	(0.046)	(0.020)	(0.053)	(0.037)	(0.041)	(0.056)	(0.083)
NAWA	-0.0934	0.1488***	0.2332***	0.1552***	0.0574***	0.0594	-0.1193**	-0.1989***	-0.1084***

	(0.078)	(0.029)	(0.041)	(0.030)	(0.015)	(0.036)	(0.059)	(0.029)	(0.028)
SEAO	-0.0736	0.1622***	0.2871***	0.247***	0.2119***	0.2826***	0.0854	-0.0131	-0.2066***
	(0.076)	(0.031)	(0.049)	(0.021)	(0.041)	(0.054)	(0.062)	(0.029)	(0.044)
SSF	-0.2277***	-0.0766***	0.0244	-0.015	-0.0477**	0.0147	0.0002	0.0207***	-0.0004
	(0.056)	(0.025)	(0.026)	(0.017)	(0.023)	(0.011)	(0.009)	(0.008)	(0.003)

*Source: Authors (2019). Asterisks denote the significance level: * 10%; ** 5%; *** 1%. Bootstrapped standard errors are given in parentheses.*

Our analysis also includes GDP per capita as control variable. Interestingly, GDP per capita shows a negative and meaningful relationship with innovation outcomes across the quantiles (Tables 4, 5 and 6). The effect of accumulated GDP also remains negative and significant. However, these results may be attributed to three reasons: i) a decline in the economic growth rate in many countries during the period; ii) GDP per capita may be affecting innovation output differently in the short, medium and long run; and iii) the relevant information for explaining innovation output is already contained in the innovation input sub-index.

In general, the results of the region dummies (relative to CSA) in Tables 4, 5 and 6 reveal that on the European continent, innovation results seem to increase from the left to right intermediate quantiles. In Latin America, significant positive results are found in the lower quantiles, while the countries of North America show significant positive results in the right tail of the quantiles. The NAWA and SEAO regions exhibit significant positive results in the intermediate positions between the 20% and 60% quantiles. The Sub-Saharan Africa region produced varying results. The non-significant or negative significant and s effect in quantiles may be associated with stagnant innovation results. All regions had divergent effects across the quantiles. No significant effect was found for some regions likely because they are located in emerging countries with low innovation levels. Moreover, there are specific variables in emerging economies that affect innovation input such as high levels of informal competition, and low levels of inter-organizational cooperation.

VIII. Conclusion

This study presents evidence that innovation input positively affects innovation output, as measured by the GII, especially in the high quantiles. The results show that the effect of innovation input on innovation production occurs from both the contemporary point of view and the lagged variables. The effect seems to decline the more we move to the left tail, which would corroborate, to a certain extent, literature studies supporting the theory that that more efforts directed to innovation input are always rewarded with better innovation results. This argument seems to be more plausible at high quantiles, whereas encouraging more input when we are at the right tail might only moderately affect innovation results.

The relationship between input and innovation output in the GII has already been recognized, but we have attempted to broaden the discussion by monitoring all countries included in the GII. Furthermore, we observed a longer period than that of past studies. We also included regional dummies in order to capture more information on the behavior of innovation output. The non-significant or significant and negative effects found demonstrates the need for more efficient policies, in order to reverse the stagnation trend in some quantiles, and enhance the effectiveness of input in materializing innovation products in countries with developing economies.

We should also consider the limitations of using GII. Although the index methodology considers a variety of innovation dimensions, we know that the innovation process is multifaceted, and impossible to be faithfully reproduced. There are therefore a variety of blind spots in assessing innovation performance in countries. However, the GII provides coverage of important data that is useful for scientific research and decision-making in innovative ecosystem management.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. We are grateful for the support given by the State Agency to support Research and Technological Innovation of Sergipe (FAPITEC/SE/BRAZIL), Program of Postgraduate in Intellectual Property Science (PPGPI/UFS) and Program of Postgraduate in Economic (NUPEC/UFS).

References Références Referencias

1. Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. *Journal of Management*, 43 (1), 39-58.
2. Andrade, R.B. & Domingos, G.A. (2017). Policies and Institutions Fostering Innovation and Agriculture Technologies in Brazil. In: *The Global Innovation Index 2017: Innovation Feeding the World*, Cornell University, INSEAD, and the WIPO.
3. Atkinson, R.D. (2013). Innovation in cities and innovation by cities. In: *Creating Competitiveness: Entrepreneurship and Innovation Policies for Growth*, Ed. Audretsch, D.B and Walshok, M.L.

4. Atkinson, R.D. & Ezell, S. (2015). Principles for National Innovation Success. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
5. Al-Sudairi, M. & Bakry, S.H. (2014). Knowledge issues in the global innovation index: Assessment of the state of Saudi Arabia versus countries with distinct development. *Innovation-Management Policy & Practice*, 16 (2), 176-183.
6. Bache, SHM., Dahl, CM. & Kristensen, JT. (2013). Headlights on tobacco road to low birthweight outcomes: Evidence from a battery of quantile regression estimators and a heterogeneous panel. *Empirical Economics*. 44 (3), 1593–1633.
7. Brown, R. (2016), Mission impossible? Entrepreneurial universities and peripheral regional innovation systems. *Industry and Innovation*, 23 (2), 189-205.
8. Campbell, D.F.J., Carayannis, E.G. & Rehman, S.S. (2015). Quadruple helix structures of quality of democracy in innovation systems: the USA, OECD countries, and EU member countries in global comparison. *Journal of the Knowledge Economy*, 6 (3), 467–493.
9. Carayannis, E.G., Barth, T.D. & Campbell, D.F.J. (2012). The quintuple helix innovation model: global warming as a challenge and driver for innovation. *Journal of Innovation and Entrepreneurship*, 1 (2).
10. Carayannis, E.G. & Rakhmatullin, R. (2014). The quadruple/quintuple innovation helixes and smart specialisation strategies for sustainable and inclusive growth in Europe and beyond. *Journal of Knowledge Economy*, 5 (2), 212–239.
11. Carpita, M. & Ciavolino, E. (2017). A generalized maximum entropy estimator to simple linear measurement error model with a composite indicator. *Advances in Data Analysis and Classification*, 11 (1), 139–158.
12. Chaminade, C. & Moskovko, M. (2015). Radical Institutional Change: Enabling the Transformation of Georgia's Innovation System. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
13. Chen, D., Zheng, S. & Guo, L. (2015). The Impact of Science and Technology Policies on Rapid Economic Development in China. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
14. Cooke, P. (2008). Regional Innovation Systems, Clean Technology and Jacobian Cluster-Platform Policies. *Regional Science Policy and Practice*, 1 (1), 23-45.
15. Crespo, N.F. & Crespo, C.F. (2016). Global innovation index: Moving beyond the absolute value of ranking with a fuzzy-set analysis. *Journal of Business Research*, 69 (11), 5265-5271.
16. Dahlander, L. & Gann, D. (2010). How Open is Innovation? *Research Policy*, 39 (6), 699-709.
17. Dedehayir, O., & Seppänen, M. (2015). Birth and Expansion of Innovation Ecosystems: A Case Study of Copper Production. *Journal of Technology Management & Innovation*, 10 (2), 145-153.
18. Dedehayir, O., Ortt, R., & Seppänen, M. (2017). Disruptive change and the reconfiguration of innovation ecosystems. *Journal of Technology Management & Innovation*, 12 (3), 9-21.
19. Dosi, G. (1988). The nature of the innovative process. In: DOSI, G. et al (Eds.). *Technical change and economic theory*. London: Pinter.
20. Dutta, S. & Benavente, D. (2011). Measuring Innovation Potential and Results: The Best Performing Economies. In: *The Global Innovation Index 2011: Accelerating Growth and Development*, Dutta, S. INSEAD.
21. Dutta, S., Benavente, D. & Wunsch-Vincent, S. (2012). The Global Innovation Index 2012: Stronger Innovation Linkages for Global Growth. In: *The Global Innovation Index 2012: Stronger Innovation Linkages for Global Growth*, INSEAD and WIPO.
22. Dutta, S., Benavente, D. & Wunsch-Vincent, S. (2013). The Global Innovation Index 2013: Local Dynamics Keep Innovation Strong in the Face of Crisis. In: *The Global Innovation Index 2013: The Local Dynamics of Innovation*, Cornell University, INSEAD, and the WIPO.
23. Dutta, S., Benavente, Reynoso, R.E., Bernard, A.L., Lanvin, B. & Wunsch-Vincent, S. (2014). The Global Innovation Index 2014: Nurturing New Sources of Growth by Developing the Human Factor in Innovation. In: *The Global Innovation Index 2014: The Human Factor in Innovation*, Cornell University, INSEAD, and the WIPO.
24. Dutta, S., Bernard, A.L., Reynoso, R.E., Lanvin, B. & Wunsch-Vincent, S. (2015). The Global Innovation Index 2015: Effective Innovation Policies for Development. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development,* Cornell University, INSEAD, and the WIPO.
25. Dutta, S., Reynoso, R.E., Litner, J., Lanvin, B., Wunsch-Vincent, S. & Saxena, K. (2016). The Global Innovation Index 2016: Winning with Global Innovation. In: *The Global Innovation Index 2016: Winning with Global Innovation*, Cornell University, INSEAD, and the WIPO.
26. Dutta, S., Reynoso, R.E., Litner, J., Lanvin, B., Wunsch-Vincent, S. & Guadagno, F. (2017). The Global Innovation Index 2017: Innovation Feeding the World. In: *The Global Innovation Index 2017: Innovation Feeding the World*, Cornell University, INSEAD, and the WIPO.

27. Ecuru, J. & Kawooya, D. (2015). Effective Innovation Policies for Development: Uganda. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
28. Easterly, W. & Levine R. (2001). It's not factor accumulation: stylized facts and growth models. World Bank *Economic Review*, 15 (2), 177–219.
29. Edquist, C. (1997). *Systems of Innovation: technologies, institutions and organizations*. Londres: Printer Publisher.
30. Etzkowitz, H. & Leydesdorff, L. (2000). The dynamics of innovation: from national systems and Mode 2 to Triple Helix of university-industry-government relations. *Research Policy*, 29 (2), 109-123.
31. Freeman, C. (1995). The national system of innovation in historical perspective. *Cambridge Journal of Economics*, 19 (1), 5-24.
32. Goedhuys, M., Hollanders, H. & Mohnen, P. (2015). Innovation Policies For Development. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
33. Gokhberg, L. & Roud, V. (2016). How to Design a National Innovation System in a Time of Global Innovation Networks: A Russian Perspective. In: *The Global Innovation Index 2016: Winning with Global Innovation*, Cornell University, INSEAD, and the WIPO.
34. Gogodze, J. 2016. Mechanisms and Functions within a National Innovation System. Journal of Technology Management & Innovation, 11 (4), 12-21.
35. Gopalakrishnan, S.K. & Dasgupta, J. (2015). Policies to Drive Innovation in India. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
36. Helpmann, E. (2004). *The Mystery of Economic Growth*, Cambridge, MA: Belknap Press, 32.
37. Hernandez, C., & González, D. (2017). Study of the Start-Up Ecosystem in Lima. Peru: Analysis of Interorganizational Networks. *Journal of Technology Management & Innovation*, 12 (1), 71-83.
38. Hollanders, H. (2013). Measuring Regional Innovation: A European Perspective. In: *The Global Innovation Index 2013: The Local Dynamics of Innovation*, Cornell University, INSEAD, and the WIPO.
39. Jackson, D.J. (2010). *What is an Innovation Ecosystem?* Arlington, VA: National Science Foundation.
40. Jankowska, B., Matysek-Jedrych, A. & Mroczek-Dabrowska, K. (2017). Efficiency of National Innovation Systems - Poland and Bulgaria in The Context of the Global Innovation Index. *Comparative Economic Research-Central and Eastern Europe*, 20 (3), 77-94.
41. Koenker, R. (2004). Quantile regression for longitudinal data. *Journal of Multivariate Analysis*, 91 (1).
42. Lundvall, B.A. (1992). *National systems of innovation: towards a theory of innovation and interactive learning*. Londres: Frances Pinter.
43. Leydesdorff, L. & Etzkowitz, H. (1996). Emergence of a triple helix of university–industry–government relations. *Science and Public Policy*, 23 (5), 279–286.
44. Lybbert, T., Saxena, K., Ecuru, J., Kawooya, D. & Wunsch-Vincent, S. (2017). Enhancing Innovation in the Ugandan Agri-Food Sector: Progress, Constraints, and Possibilities. In: *The Global Innovation Index 2017: Innovation Feeding the World*, Cornell University, INSEAD, and the WIPO.
45. Moore, J.E. (1996). *The death of competition: leadership and strategy in the age of business ecosystems*. New York: Harper Business.
46. Moretti, E. (2004). Estimating the social return to higher education: evidence from longitudinal and repeated cross- sectional data. *Journal of Econometrics*, 121 (1-2), 175–212.
47. Nelson, R. (1993). *National innovation systems: a comparative analysis*. Nova York: Oxford University Press. OECD. (1997). *Manual de Oslo: Diretrizes para coleta e interpretação de dados sobre inovação*. 3ª Ed, Organization for Economic Co-Operation and Development.
48. OECD. (2005). *Promoting innovation in services. Paris: Organization for Economic Co-Operation and Development.*
49. OECD. (2010). *The OECD Innovation Strategy, Paris: Organization for Economic Co-Operation and Development*.
50. Poh, L.C. (2016). From Research to Innovation to Enterprise: The Case of Singapore. In: *The Global Innovation Index 2016: Winning with Global Innovation*, Cornell University, INSEAD, and the WIPO.
51. Powell, D. (2017). *Quantile Treatment Effects in the Presence of Covariates*. RAND Working Paper.
52. Remneland Wikhamn, B., & Wikhamn, W. (2013). Structuring of the Open Innovation Field. Journal of Technology Management & Innovation, 8 (3), 173-185.
53. Reynoso, R.E., Bernard, A.L., Saisana, M. Schaaper, M. Wunsch-Vincent, S. & Guadagno, F. (2015). Benchmarking Innovation Outperformance at the Global and Country Levels. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
54. SaiSana, M. (2011). Statistical tests on the Global Innovation Index. In: *The Global Innovation Index*

2011: Accelerating Growth and Development, Dutta, S. INSEAD.
55. Saisana, M. & Philippas, D.T. (2012). Statistical tests on the Global Innovation Index. In: *The Global Innovation Index 2012: Stronger Innovation Linkages for Global Growth*, INSEAD and WIPO.
56. Saisana, M. & Philippas, D.T. (2013). Joint Research Centre Statistical Audit of the 2013 Global Innovation Index. In: *The Global Innovation Index 2013: The Local Dynamics of Innovation*, Cornell University, INSEAD, and the WIPO.
57. Saisana, M. & Saltelli, A. (2014). Joint Research Centre Statistical Audit of the 2014 Global Innovation Index. In: *The Global Innovation Index 2014: The Human Factor in Innovation*, Cornell University, INSEAD, and the WIPO.
58. Saisana, M. & Domínguez-Torreiro, M. (2015). Joint Research Centre Statistical Audit of the 2015 Global Innovation Index. In: *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Cornell University, INSEAD, and the WIPO.
59. Saisana, M., Domínguez-Torreiro, M. & Vertesy, D. (2016). Joint Research Centre Statistical Audit of the 2016 Global Innovation Index. In: *The Global Innovation Index 2016: Winning with Global Innovation*, Cornell University, INSEAD, and the WIPO.
60. Saisana, M., Domínguez-Torreiro, M. & Vertesy, D. (2017). Joint Research Centre Statistical Audit of the 2016 Global Innovation Index. In: *The Global Innovation Index 2017: Innovation Feeding the World*, Cornell University, INSEAD, and the WIPO.
61. Schumpeter, J. A. (1934). *The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle.* Cambridge, MA: Harvard University Press.
62. Scott, R. & Vincent-Lancrin, S. (2014). Educating Innovators and Entrepreneurs. In: *The Global Innovation Index 2014: The Human Factor in Innovation*, Cornell University, INSEAD, and the WIPO.
63. Slater, D. & Wruuck, P. (2012). We Are All Content Creators Now: Measuring Creativity and Innovation in the Digital Economy. In: *The Global Innovation Index 2012: Stronger Innovation Linkages for Global Growth*, INSEAD and WIPO.
64. Sohn, S.Y., Kim, D.H. & Jeon, S.Y. (2016). Re-evaluation of global innovation index based on a structural equation model. *Technology Analysis & Strategic Management*, 28 (4), 492-505.
65. Sundbo, J. and Gallouj, F. (1998). Innovation in Service. Manchester, 1998. *Policy Research in Engineering*, Sciense & Technology - PREST. Project Report.
66. Vlasova, V., Kuznetsova, T. & Roud, V. (2017). Drivers and limitations of Russia's development based on the evidence provided by the Global Innovation Index. *Voprosy Ekonomiki*, (8), 24-41.
67. Wunsch-Vincent, S. (2012). Accounting for Science-Industry Collaboration in Innovation: Existing Metrics and Related Challenges. In: *The Global Innovation Index 2012: Stronger Innovation Linkages for Global Growth*, INSEAD and WIPO.
68. Teece, D.J. (2007). Explicating dynamic capabilities: The nature and micro foundations of (sustainable) enterprise performance. Strategic Management Journal, 18 (13), 1319-1350.
69. Xiangjiang, Q., Peng, J. & Kelly J. (2013). Open Innovation: The View of an ICT Leader in Distributed Global Innovation. In*: The Global Innovation Index 2013: The Local Dynamics of Innovation*, Cornell University, INSEAD, and the WIPO.