

The Linkage between Input and Output in the Innovation Ecosystem

Iracema Machado de Aragão

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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.

Index terms— innovation ecosystem; global innovation index; innovation input; innovation output; innovation.

1 Introduction

he 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 longterm 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 T 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

46 between input and output in the innovation ecosystem. We test the hypothesis that innovation input affected
47 output in the GII results between 2009 and 2019.

48 We estimate an unconditional quantile regression model with contemporaneous and lag adjustment to identify
49 the (hypothetical) structural relationship between innovation input and output in countries. Our study proposes
50 a different approach for analyzing the innovation ecosystem that may be useful for global innovation policies.
51 (Moretti, 2004; Helpmann, 2004; Cooke, 2008)

52 2 Innovation Ecosystem

53 Following Schumpeter (1934), other authors and organizations have proposed new innovation concepts (OECD,
54 1997; Edquist, 1997; Sundbo & Gallouj, 1998; OECD, 2005). To summarize, innovation is now understood as the
55 implementation of something new or significantly improved (Product or Service, Process, Marketing Method;
56 Business Organization Method, Commercial Models, Practices, Workplace Organization or Foreign Relations).
57 Leydesdorff and Etzkowitz (1996) and Etzkowitz and Leydesdorff (2000) proposed the Triple Helix innovation
58 model to identify the role of companies, governments and universities. In this model, the university encourages
59 the relationship with companies and government in generating, accumulating and applying new knowledge
60 (technological innovations) in favor of economic development. Campbell, Carayannis and Rehman (2015) broaden
61 the notion of Triple helix by introducing civil society as a fourth helix, emphasizing democracy and the importance
62 of political and civil rights in the innovation system. Carayannis, Barth and Campbell (2012) and Carayannis
63 and Rakhmatullin (2014) include sustainable development as another dimension in the helix models, resulting in
64 a five-helix model.

65 In addition, the innovation phenomenon has been systematically investigated and measured, under the open
66 system and ecosystem approach (Dosi, 1988; Lundvall, 1992; Nelson, 1993; Freeman, 1995). The innovation ecosystem
67 has become an organizational paradigm and has served as the primary reference in formulating strategies for
68 innovation (Teece, 2007). The functioning of the innovation ecosystem proposed for Moore (1996) is characterized
69 by multiple interactions between its different components. In this respect, it is important to manage and expand
70 the benefits of the ecosystem, which requires mapping and creating metrics to quantify and identify gaps in its
71 performance, possibly correcting any bottlenecks (Jackson, 2010). The proper functioning of an ecosystem is
72 needed to broaden the effectiveness of entrepreneurial and innovative activities, creating jobs and providing the
73 conditions for economic prosperity.

74 3 III.

75 4 Global Innovation Index (GII)

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

80 The GII adopts the concept of innovation originally devised by the Oslo Manual and expanded by the European
81 Community and the Organization for Economic Cooperation and Development (OECD). Figure 1 shows that the
82 GII consists of seven large innovation areas divided into 21 sub-areas. Input innovation is monitored by five large
83 areas, which determine environmental aspects favorable to innovation, and two large areas monitor innovation
84 output. The GII then aggregates the large areas into two sub-indices: Input and Output. Next, the Innovation
85 Efficiency Ratio the ratio between the sub-indices of Innovation Input and Output, is calculated. Finally, the
86 Global Innovation Index (GII) is calculated by arithmetic mean of the sub-indices.

87 The GII and its sub-indices are quantitative measures that range between 0 and 100; the higher the score, the
88 more developed the innovation ecosystem.

89 5 Literature Review

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

96 Crespo and Crespo (2016) assume that countries can achieve high innovation performance in the GII using
97 various combinations of input. The authors discuss the internal sub-pillars of innovation input and establish two
98 sub-samples (high and low-income countries). They find that several input combinations lead to high innovation
99 performance in both groups, and that in the low-income group none of the individual conditions is sufficient to
100 predict good innovation performance, while in the high-income group infrastructure, human capital and research
101 conditions are sufficient to obtain a better innovation performance. Carpita and Ciavolino (2017) found evidence
102 of a positive relationship between Business Sophistication (explanatory variable) and Innovation Input (response
103 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 ?? The Linkage between Input and Output in the Innovation Ecosystem 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.

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

7 VI.

8 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} = \alpha + \beta_1 x_{it} + \beta_2 x_{it}^2 + \beta_3 x_{it}^3 + \beta_4 x_{it}^4 + \beta_5 x_{it}^5 + \beta_6 x_{it}^6 + \beta_7 x_{it}^7 + \beta_8 x_{it}^8 + \beta_9 x_{it}^9 + \beta_{10} x_{it}^{10} + \beta_{11} x_{it}^{11} + \beta_{12} x_{it}^{12} + \beta_{13} x_{it}^{13} + \beta_{14} x_{it}^{14} + \beta_{15} x_{it}^{15} + \beta_{16} x_{it}^{16} + \beta_{17} x_{it}^{17} + \beta_{18} x_{it}^{18} + \beta_{19} x_{it}^{19} + \beta_{20} x_{it}^{20} + \beta_{21} x_{it}^{21} + \beta_{22} x_{it}^{22} + \beta_{23} x_{it}^{23} + \beta_{24} x_{it}^{24} + \beta_{25} x_{it}^{25} + \beta_{26} x_{it}^{26} + \beta_{27} x_{it}^{27} + \beta_{28} x_{it}^{28} + \beta_{29} x_{it}^{29} + \beta_{30} x_{it}^{30} + \beta_{31} x_{it}^{31} + \beta_{32} x_{it}^{32} + \beta_{33} x_{it}^{33} + \beta_{34} x_{it}^{34} + \beta_{35} x_{it}^{35} + \beta_{36} x_{it}^{36} + \beta_{37} x_{it}^{37} + \beta_{38} x_{it}^{38} + \beta_{39} x_{it}^{39} + \beta_{40} x_{it}^{40} + \beta_{41} x_{it}^{41} + \beta_{42} 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164 that are be correlated with innovation inputs, such as process innovations. To overcome this possible problem,
165 we have included a last quantile model whose input will be lagged by one year and contrasted exclusively with
166 innovation outputs. The average GDP was above the median, with high standard deviation, and its minimum
167 and maximum values show the wide variability of economic performance between countries. In general, the
168 distribution of all observed variables is heterogeneous. Figure 2 shows the scatter plots for inputs, outputs
169 and GDP, where It is possible to observation that the variables inputs and GDP are linearly associated with
170 innovation outputs. As expected, the distribution of innovation input data is better matched with innovation
171 product observations. Source: Authors (2019). It is important to note that the more than 120 countries present
172 in the sample are markedly different in their own characteristics, from economic and social to political, cultural,
173 and territorial aspects, among others. Thus, to properly investigate the wide variability in data distribution of
174 the sample variables, Table 3 presents a statistical description by quantiles, which organizes the distribution of
175 countries monotonically according to the median. Nine quantiles were established for the sample hierarchy. This
176 procedure enabled the formation of groups of countries with lower standard deviation. The 10% quantile value,
177 for example, is represented by the lowest values in the distribution of input and innovation product and economic
178 performance data. However, the countries with the highest values are above the 90% quantile.

179 9 VII.

180 10 Results and Discussion

181 Table 4 summarizes the results of quantile regression no lag for countries between 2009 and 2019. Innovation input
182 has a significant positive effect on innovation output, except for the 10% quantile. As such, this result confirms
183 our hypothesis and partially corroborates that of Dutta and Benavente (2011) However, countries located in the
184 initial quantile seem unable to translate their innovation efforts into innovation products. Another important
185 finding is that, the farther we move to the right tail of the innovation output distribution, the greater the effect of
186 innovation input. In the 90% quantile, the magnitude of the coefficient is smaller, compared to the 80% quantile.
187 The Linkage between Input and Output in the Innovation Ecosystem

188 Table 5 shows the results of contemporaneous and lagged variables. The cumulative effect, that is, when we
189 add the contemporary and lagged result of innovation inputs, we observe a positive and significant effect on the
190 30%, 40%, 50%, 60%, 70% and 90% quantiles of the response variable (results innovation). This indicates that
191 more innovation inputs positively affect innovation output in countries located in the right tail of the response
192 distribution, especially in countries with the highest GII output sub-index scores, with the exception of the 80%
193 quantile. The cumulative effect of innovation inputs on innovation output in the 10% and 20% quantiles is non-
194 significant. Once again, these findings are evidence that countries with a relatively weak innovation ecosystem
195 cannot translate their innovation efforts into product innovation. We further tested in Table 6 whether the shift in
196 production input lag only affects innovation output in subsequent years. We found evidence that innovation inputs
197 (Institutions; Human Resources and Research; Infrastructure; Market Sophistication and Business Sophistication)
198 positively and significantly impact innovation outputs (Knowledge and Technology-based Products; Creative
199 Products), except in the 10% and 20% quantiles. This result corroborates the previous findings, especially at the
200 higher quantiles. Our analysis also includes GDP per capita as control variable. Interestingly, GDP per capita
201 shows a negative and meaningful relationship with innovation outcomes across the quantiles (Tables 4, 5 and 6).
202 The effect of accumulated GDP also remains negative and significant. However, these results may be attributed
203 to three reasons: i) a decline in the economic growth rate in many countries during the period; ii) GDP per
204 capita may be affecting innovation output differently in the short, medium and long run; and iii) the relevant
205 information for explaining innovation output is already contained in the innovation input sub-index.

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

216 11 VIII.

217 12 Conclusion

218 This study presents evidence that innovation input positively affects innovation output, as measured by the GII,
219 especially in the high quantiles. The results show that the effect of innovation input on innovation production
220 occurs from both the contemporary point of view and the lagged variables. The effect seems to decline the more
221 we move to the left tail, which would corroborate, to a certain extent, literature studies supporting the theory
222 that that more efforts directed to innovation input are always rewarded with better innovation results. This

223 argument seems to be more plausible at high quantiles, whereas encouraging more input when we are at the right
 224 tail might only moderately affect innovation results.

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

231 We should also consider the limitations of using GII. Although the index methodology considers a variety of
 232 innovation dimensions, we know that the innovation process is multifaceted, and impossible to be faithfully
 233 reproduced. There are therefore a variety of blind spots in assessing innovation performance in countries.
 234 However, the GII provides coverage of important data that is useful for scientific research and decision-making
 in innovative ecosystem management.¹

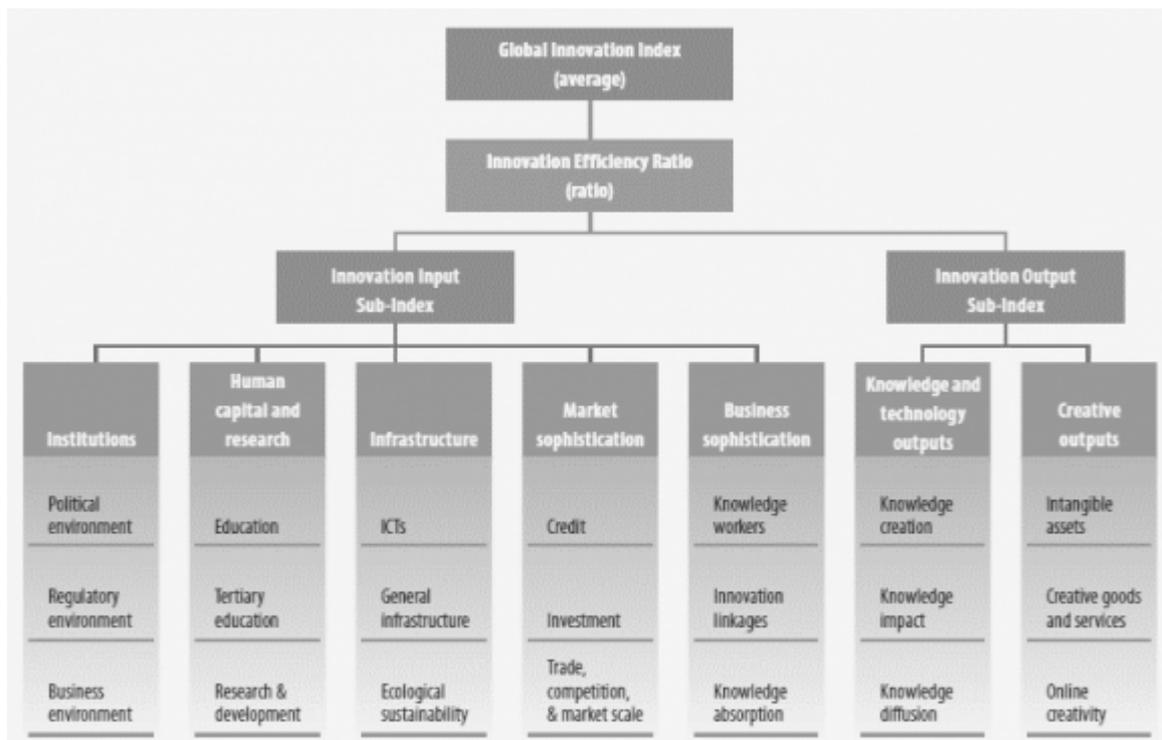


Figure 1:

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¹. 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.

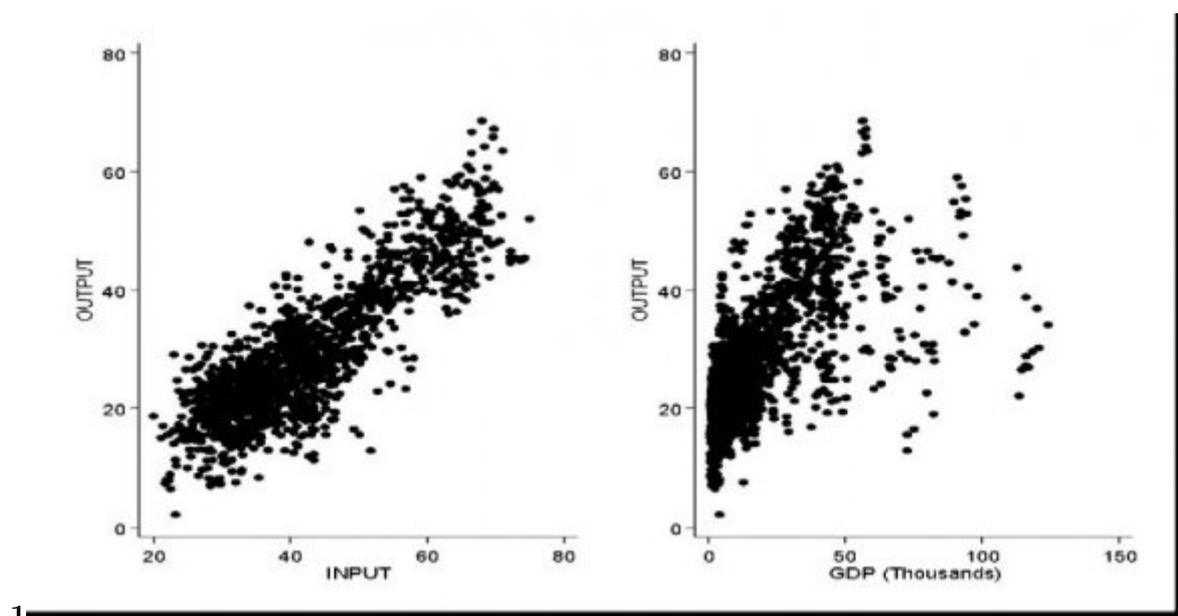


Figure 2: Figure 1 :

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),

Figure 3:

1

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

[Note: 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.]

Figure 4: Table 1 :

2

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

[Note: Source: Authors (2019)]

Figure 5: Table 2

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Global Journal of Human Social Science -

Figure 6: Table 2 :

3

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).

Figure 7: Table 3 :

12 CONCLUSION

4

	0.2	0.3	0.4	0.5	0.6				
OUTPUT									
INPUT0501 (0.085)	0.2263***	0.2642***	0.5363***	0.6146***	0.8100***	0.846***	(0.037)		
GDP-0.8089*** -0.4725*** -0.3203*** -0.1038*** -0.1879*** -0.0946*** -0.1574* -0.5245*** -0.3589*** (0.11116)** (0.043)	0.088**	0.1719***	0.2178***	0.2494***	0.3236***	0.2270***	(0.05)		
LCN0.088*** 0.1471*** 0.0755*** (0.032) (0.035) (0.020)			0.0333*	-	-				
			(0.019)	0.0010235					
				(0.015)	(0.017)				
NAC-0.2886*** (0.052)	-0.0355	0.0598	0.0962***	0.1402***	0.2874***	0.3164***	0.272		
	(0.037)	(0.046)							
NAWA0.0988** 0.1204*** 0.1473*** 0.104*** 0.0706*** 0.0416** (0.044) (0.036) (0.036) (0.020) (0.012) (0.02)									
SEA0.1291*** 0.0824** 0.1634*** 0.1780*** 0.1849*** 0.2489*** 0.1233** (0.043) (0.038) (0.049) (0.015) (0.01)									
SSF -0.1599*** (0.034)	-0.0301	-0.0359	-	-	0.0099				
	(0.029)	(0.021)	0.0471***	0.022	(0.014)				
			(0.010)	(0.020)					

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

Figure 8: Table 4 :

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Figure 9: Table 5 :

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	0.2	0.3	0.4	0.5	0.6	0.7			
OUTPUT									
LAGINPUT087*** (0.052)	-0.0388 (0.082)	0.2407***	0.4197***	0.5927***	0.5808***	0.7591***	0.77		
LAGGDP0839*** -0.8879*** -0.5197*** -0.2715*** -0.2771*** -0.2307*** -0.4388*** -0.3621*** -0.3074*** (0.11116)** (0.073)	0.1455***	0.2902***	0.3156***	0.2961***	0.3755***	0.1807**	(0.034) (0.057) (0.034) (0.057) (0.034) (0.057) (0.034) (0.057) (0.034) (0.057)		
LCN 0.084* (0.049)	0.1502***	0.1691***	0.0938***	(0.035) (0.028) (0.032)	-	0.0070.1480*** -0.1			
					0.0070.1480*** -0.1				
					(0.016)				
NAC-0.2393*** (0.083)	0.0432 (0.032)	0.1895***	0.1841***	0.1806***	0.3289***	0.2603***	0.19		
NAWA0.0934	0.1488***	0.2332***	0.1552***	0.0574***		0.0590.1193** -0.1			

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

Figure 10: Table 6 :

.1 Acknowledgments

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