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THE STUDY OF INNOVATION AND ABSORPTIVE CAPACITY OF BRICS COUNTRIES BY USING MULTIPLE REGRESSION ANALYSIS

O ESTUDO DA INOVAÇÃO E CAPACIDADE ABSORVENTE DOS PAÍSES DO BRICS USANDO A ANÁLISE DE REGRESSÃO MÚLTIPLA

EL ESTUDIO DE LA INNOVACIÓN Y LA CAPACIDAD DE ABSORCIÓN DE LOS PAÍSES DE BRICS MEDIANTE EL USO DE UN ANÁLISIS DE REGRESIÓN MÚLTIPLE

Khalid Usman[1]
Liu Zhiying[2]
Shen Huayan[3]
Xie Xin[4]
Jin Yujia[5]

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Abstract
Objective of the study: This research aims to explore the diverse impacts of national innovation systems of BRICS countries by indicating the key elements and systems aspect, how these aspects have committed to the running of the whole systems and interpreted inside the economic development of these nations.
Methodology/approach: Data were collected from the World Bank (WDI), United Nations Educational, Scientific and Cultural Organization (UNESCO), United State Patent and Trade office (USPTO), and World Intellectual Property Organization (WIPO) for Brazil, Russia, India, China and South Africa (BRICS) countries. Data used for following research are time series, annual data from 1999-2014. The multi-regression analysis was completed with utilizing the Statistical package for the Social Science (SPSS).
Originality/Relevance: We intend at devoting to the research literature and policy by producing quantitative based proof of the framework that connects the comprehensive element of innovation system to economic system for a longtime.
Main results: The findings showed the degree to which components of the National innovation system (NIS), depend on one another for Brazil, Russia, India, China and South Africa (BRICS) , in this regard, any changes in one indicator can effect on other indicators in the system.
Theoretical/methodological contributions: Our research is based on the conceptual analyses which draw from the existing literature. It is based on a model to evaluate the dynamics of innovation capacity, absorptive capacity impact and robustness of the economic development.
Social /management contributions: Our results have significant implication for policy makers.

Keywords: National Innovation System. Innovation Capacity. Absorptive Capacity. Economic Growth. Multi-Regression Analysis. Brazil, Russia, India, China and South Africa (BRICS).

[1]Associate Professor (PhD), School of Economics and Management, Guangzhou City Construction College (GZCCC). Guangzhou City, Guangdong Province, China. khalid@mail.ustc.edu.cn
[2]Professor (PhD), School of Management, University of Science and Technology of China (USTC). Hefei City, Anhui Province, China. liuzhiy@ustc.edu.cn
[3]Professor (PhD), School of Economics and Management, Guangzhou City Construction College (GZCCC). Guangzhou City, Guangdong Province, China. shenhuayan@hrbeu.edu.cn
[4]Lecturer (Master's Degree), School of Economics and Management, Guangzhou City Construction College (GZCCC). Guangzhou City, Guangdong Province, China. 765567473@qq.com
[5]Lecturer (Master's Degree), School of Economics and Management, Guangzhou City Construction College (GZCCC). Guangzhou City, Guangdong Province, China. 2315442063@qq.com

Resumo

Objetivo do estudo: Esta pesquisa tem como objetivo explorar os diversos impactos dos sistemas nacionais de inovação dos países BRICS, indicando os principais elementos e aspectos de sistemas, como esses aspectos se comprometeram com o funcionamento de todos os sistemas e interpretados dentro do desenvolvimento econômico dessas nações.
Metodologia / Abordagem: Foram recolhidos dados do Banco Mundial (WDI), da Organização Educacional, Científica e Cultural das Nações Unidas (UNESCO), do Gabinete de Patentes e Comércio dos Estados Unidos (USPTO) e da Organização Mundial de Propriedade Intelectual (OMPI) para o Brasil, Rússia, Índia, China e África do Sul (BRICS). Os dados utilizados para a investigação a seguir são séries cronológicas, dados anuais de 1999-2014. A análise de multi-regressão foi concluída com a utilização do pacote estatístico para a ciência social (SPSS).
Originalidade / relevância: pretendemos dedicar à literatura e política de pesquisa, produzindo prova quantitativa baseada no quadro que liga o elemento abrangente do sistema de inovação ao sistema econômico por um longo tempo.
Principais resultados: Os resultados mostraram até que ponto os componentes do NIS dependem um do outro para o Brasil, Rússia, Índia, China e África do Sul (BRICS) – a este respeito, qualquer mudança de um indicador pode afetar outros indicadores no sistema.
Contribuições teóricas / metodológicas: Nossa pesquisa é baseada nas análises conceituais que retiram da literatura existente. É baseado em um modelo para avaliar a dinâmica da capacidade de inovação, impacto de capacidade de absorção e robustez do desenvolvimento econômico.
Contribuições Sociais / Gestão: Nossos resultados têm implicação significativa para os formuladores de políticas.

Palavras-chave: Sistema nacional de inovação. Capacidade de inovação. Capacidade de absorção. Crescimento economic.análise multi-regressão. Países do Brasil, Rússia, Índia, China e África do Sul (BRICS).

Resumen

Objetivo del estudio: El objetivo de este estudio es explorar los diferentes efectos de los sistemas de innovación de los países BRICS señalando los elementos clave y los aspectos sistémicos de los sistemas de innovación de los países BRICS, as í como su compromiso con el funcionamiento de todo el sistema y su interpretación en el desarrollo económico de esos países.
Metodología/enfoque: Se recopilaron datos del Banco Mundial (WDI), la Organización de las Naciones Unidas para la educación, la Ciencia y la Cultura (UNESCO), la Oficina de patentes y comercio de los Estados Unidos (USPTO) y la Organización Mundial de la propiedad intelectual (OMPI) sobre el Brasil, Rusia, la India, China y Sudáfrica (BRICS). Los datos utilizados en el siguiente estudio son series temporales, es decir, datos anuales para 1999 - 2014. El análisis de regresión múltiple se realiza utilizando el paquete de software estadístico de Ciencias Sociales (SPSS).
Originalidad/relevancia: tenemos la intención de dedicar la literatura y la política de investigación al producir pruebas cuantitativas basadas en el marco que conecta el elemento integral del sistema de innovación al sistema económico durante un largo tiempo
Resultados principales: Los resultados muestran el grado en que los componentes de los sistemas de innovación en el Brasil, Rusia, la India, China y Sudáfrica (BRIC) son interdependientes y, a este respecto, cualquier cambio en un indicador puede afectar a otros indicadores del sistema.
Contribuciones teóricas/metodológicas: Nuestra investigación se basa en los análisis conceptuales que se extraen de la literatura existente. Se basa en un modelo para evaluar la dinámica de la capacidad de innovación, el impacto de la capacidad de absorción y la robustez del desarrollo económico.
Contribuciones sociales/de gestión: nuestros resultados tienen una implicación significativa para los responsables políticos.

Palabras clave: Sistema de innovación nacional. Capacidad de innovación. Capacidad de absorción. Crecimiento economic.análisis de múltiples regression. Países Brasil, Rusia, India, China y Sudáfrica (BRICS).

1 Introduction

This research study is built on the basis of evolutionary economics and systems of innovation ideas. The innovation system literature generally utilized either in academic and policy/Strategy contexts in 1980's (Balzat & Hanusch, 2004; Sharif, 2006). It was formulated to investigate economic growth, considering innovation and learning, when neoclassical economic contemplation was insufficient (B. A. Lundvall, 2007). The innovation system approach engaged historical and evolutionary perspectives. In spite of more than 20 years another critical flaw of innovation system approaches is that yet inadequate in its management of the influence characteristic of development (Charles Edquist, 1997).

The concept of National innovation system (NIS) first appeared in the work of Freeman on technological infrastructure in 1982 was referred to a system of innovation (Christopher Freeman, 2004). In 1987, system of innovation was first used in the Freeman's book on "technology policy and economic performance in Japan" in the form of publication (Freeman, C., 1987). The current literature on the national innovation systems (NIS) of developing economies such as Brazil, Russia, India, China and South Africa (BRICS),was bound to four kinds of research: (1) theoretical and historical research of the national innovation systems of the BRICS (Cassiolato & Vitorino, 2009; Sceri et al., 2010; Zaichenko, 2014), (2) examining the causality between national innovation systems (NIS) variables and their effect on economic growth or development (Alnafrah & Bogdanova, 2018; Alnafrah et al., 2018; Rao Nicholson et al., 2017), (3) practicing machine learning technology to assess the structural durability and flaws of national innovation systems (NIS) (Alnafrah, 2019; Alnafrah & Zeno, 2019), and (4) evaluating the performance of particular innovative industries or subsystems for example energy, insurance industry and ICT industry (Song et al., 2013; Tu et al., 2016; Huang & Eling, 2013; Biryukova & Matiukhina, 2019). Productivity growth path of national innovation system (NIS) and its linkage with technological progress in the process of catch-up (Zabala Iturriagagoitia et al., 2020)

Innovation system has evolved broadly recognized in to two reasons in innovation research studies, First, in view of the fact that, it departs away from the predictable linear approached and second, research & development to describe the transformations during innovation among the countries (Radosevic, 1998). Although, this approach is also have some weaknesses like other approaches. The weaknesses those are associated with the system structure and its capabilities (Nilsson, 2011). When analyzing the system these weaknesses are also creates problems either they are in physical/conceptual and the problem of system frontiers as well as institutional variety of innovation system (Radosevic, 1998). According to the (Carlsson et al., 2002), the deficiencies which are related to the level of analysis can be handling through the identification of components or actors, their crucial association and assessment of the performance of the innovation system.

For the assessment of association between economic growth and technology; Jan Fagerberg (1994), demonstrated a review of empirical research articles for last two decades; selected variables about the economic growth and technology are integrate the share of human capital, International trade, and technology capabilities. The dynamic approaches could be found in Schumpeterian multiple equilibria models and the empirical exercise are closely related to the dynamic approaches, which investigate how the model of technology gap association differ beyond the countries cluster and what the innovation role and absorptive capacity for nations at diverse phase of technological development (Castellacci, F., Archibugi, 2008; Castellacci, F., Natera, 2011; Jan Fagerberg et al., 2007; Jan Fagerberg & Verspagen, 2002; Lee & Kim, 2009; Filippetti & Peyrache, 2011).

Concisely, they lies in a multiple equilibria model classification of the association between innovation, absorptive capability and economic growth; in which threshold in different convergence country's ability to incorporate the technological innovation and the imitation capabilities as well as the shift from a given development stage to a more advance one(Azariadis, C., Drazen, 1990; Galor & Weil, 2000; Howitt & Mayer-Foulkes, 2005; Howitt, P., 2000; Acemoglu, Zilibotti, & Aghion, 2006). If multiple equilibria model associations matters, then economies classified by distinct intensity of per capita income, may describe the emergence of different country groups, and how they growth performance of these differ overtime (Durlauf, S.N., Johnson, P.A., 1995).

This study evaluates the capabilities of innovation system of BRICS countries, shows facts of the process and achievement to development and comprehends the lesson for other developing nations on the national system of innovation of BRICS countries. Particular consideration will be given to policy implementation. This research aims to explore the diverse impacts of national innovation systems of BRICS countries by indicating the key elements and systems aspect, how these aspects have committed to the running of the whole systems and interpreted inside the economic development of these nations. The facts and figures from this study might likewise be a perspective for policy/strategy makers in different countries in their endeavor to draw up science and technology strategies/policies, in view of the correlation between components of the national system of innovation and system variation involving the BRICS countries.

The rest of the paper is structured as follows. Section two; literature review and hypothesis development relevant to the research, basis of innovation capacity, absorptive capacity and national innovation systems. Section three; data collection and research methodology. Section four, depicts the results and discussion from the empirical analysis and Section five illustrates the conclusion, limitation of research and suggestions.

2 Literature review and hypothesis development

According to Suarez-Villa, determining the innovation capacity may present the major information regarding the changes of innovation in the manufacturing and industrial commotion (Suarez-Villa, 1990). The concept of NIC has been investigated in the work of (Porter, M and Stern, 1999; Porter and Stern, 2001; Furman et al., 2002). The expansion of the national innovation capacity model projected by Furman et al. (2002), was accomplished by Furman & Hayes (2004). However, in their sample size, they just considered the developed nations instead of developing economies. Concerning to segregate the outcomes from the consequences of Furman & Hayes, 2004; Furman et al., 2002; Hu & Mathews, 2005), investigated the NIC of East Asian economies(late comer nations), on the premise of Furman et al. (2002), framework and data resources.

In the study of NIC of convergence or catching up economies (Furman et al., 2002; Hu & Mathews, 2005; Nasierowski & Arcelus, 1999), are trying to find the answer of the question, “Why is there a huge difference between rich and catching up nations, poor economies? On the other hand, these research articles did not manage or capture the question of how developing countries can convergence or divergence between them and developed countries. Abramovitz & David (1996), introduce a new term “absorptive capacity” to answer the above question. Jan Fagerberg et al. (2007) were the scholars who introduced the term national innovation capacity and absorptive capacity of catching up economies together. Castellacci & Natera (2013), include catching up economies in their countries panel data analysis, by demonstrating their outcomes in the light of income groups’ economies,(advanced nations, income groups and less developed countries), which gives impression to have deal with the weakness in the research work of Furman & Hayes (2004) and Jan Fagerberg et al. (2007). They treated with the NIS dynamics by using the victor auto-regression, through the co-evolution between innovation capacity and absorptive capacity as well as their inter-relationship with income level (per capita GDP). At different stages of development, their results could be pertained to all economies.

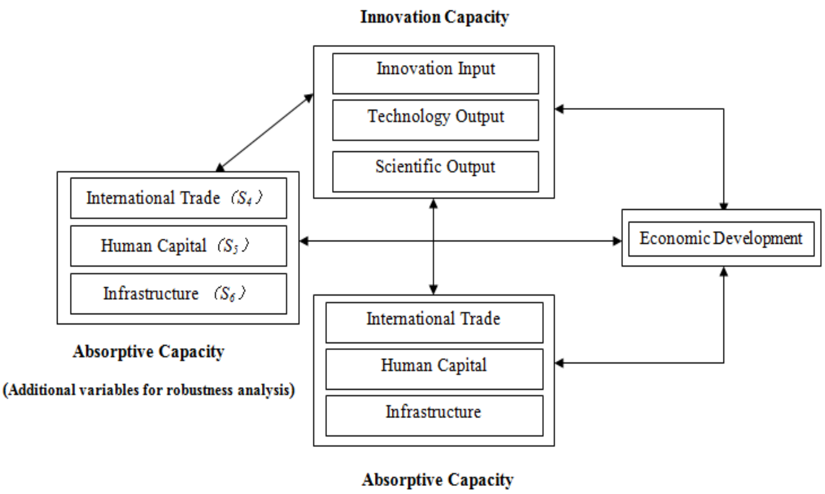
According to the Castellacci & Natera (2013),the analysis of internal dynamics of innovation capacity, technology output (patent) in addition to scientific output are negative relationship but mutually having optimistic as well as significant associated to per capita GDP income level of middle income countries/economies. On the other hand, there is no negative association between research & development expenditure, science& technical articles as well as patents of developed economies; however the patent were the significant predictor of per capita GDP and research & development expenditure (R&D expenditures).

The dynamics of absorptive capacity the results of Granger causality test showed there is two-way causality relationship has exist between the variables like infrastructure and human/personal capital, as well as between infrastructure and international trade of middle income economies. On the other hand the results of Furman & Hayes (2004), and Jan Fagerberg et al. (2007),established infrastructure, trade and human capital are the important/significant indicator of NIS, even they do not analyzed the bi-causal correlation among their variables. Moreover, according to Castellacci & Natera (2013), the income level reasons the international trade growth and between the infrastructure and income level the two-directional causality has existed. On the other side, the results of human capital and infrastructure, having unidirectional causality of less developed countries and income level resulting the growth of human capital and further two-directional causality between income level and international trade. For developing countries there is no significant correlation between the income level and trade (Jan Fagerberg et al., 2007).When Castellacci & Natera (2013), tackle the interaction between the innovation capacity absorptive capacity indicators, the findings shows that innovation input (R&D expenses), on Infrastructure (electricity consumption per capita), there had causal effect, in addition to in the context of East Asian Economies the two-directional causal correlation presents between scientific output and infrastructure as well as between technological outputs and infrastructure. Furthermore, the results pointed out that scientific output and infrastructure having two-directional causal correlation furthermore one-way causal relationship between international trade and innovation input for developing countries moreover the innovation input resulting the expansion of FDI/international trade.

Our research findings are based on the conceptual analyses which draw from the existing literature. Figure 1 demonstrates the dynamics of innovation capacity and absorptive capacity furthermore their entire relationship through the economic growth. This empirical research is based on a model to evaluate the dynamics of innovation capacity, absorptive capacity impact and robustness of the economic development intensity on such variables in NIS of BRICS nations.

Figure 1

Dynamics and Co-evolution of innovation capacity and absorptive capacity



Source: The Authors.

The variables in preliminary analysis for every model are:

(i) Innovation Inputs:- (x_1) denotes Agriculture Value added (% of GDP), Research &Development expenditure(% of GDP),

(ii) Technology output:- (x_2)denotes number of patents applications,

(iii) Scientific Output:- (x_3) denotes number of scientific and technical journal,

(iv) International Trade:- (x_4) denotes trade % of GDP,

(v) Human Capital:- (x_5) denotes school enrollment, tertiary (% of gross),

(vi) Infrastructure :-(x_6) denotes mobile cellular subscriber (per 100 people).

On the other hand the variables to check the robustness of models to examine to what extent results would change when the variables change with the:

(i) International Trade:-(s_4) denotes FDI, net inflow (% of GDP) ,

(ii) Human Capital:- (s_5) denotes secondary school enrollment,(% gross),

(iii) Infrastructure:- (s_6)denotes electric power consumption (kWh per capital).

γ: denotes economic development: - GDP per capita 2005

We can also write it as. Following equation is the main model of this research.

$$(1)\ \gamma = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \varepsilon_1 \text{(Main Model)}$$

The indicators which are shown in Fig. 1, tested separately to know how they interact with each other. We further divided the main model into different categories to investigate the impact of different variables on economic development as well as also analyzed their entire relationships among the indicators in term of degree they forecast with each other's. According to the equation, the following three hypotheses will be tested in our empirical analysis.

Hypothesis 1:- *The dynamics of innovation capacity*

1. To examining the relationship, between the variables of innovation capacity and economic development.

Regarding the hypothesis 1, we suppose to examining the relationship, between the variables of innovation capacity (innovation input, scientific output and technology output), and economic development (GDP per capita), of BRICS countries. We aim to find that the bidirectional relationship between these variables in the model. The uniqueness of this hypothesis is that we assume the eternity of bidirectional relationship that spins the growth of innovation capacity over time. According to Castellacci, F., Archibugi (2008), innovation input and threshold level affects the technology and scientific output, which in turn influence the dynamics on innovation input.

Hypothesis 2:- *The dynamics of absorptive capacity*

2. To investigative the relationship between the variables of absorptive capacity and economic development.

The purpose of hypothesis 2, is to investigative the relationship between absorptive capacity (human capital, international trade, and infrastructure) and economic development (per capita GDP) of BRICS nations that drives the development of absorptive capacity in long term. Such kind of relationship has already been explored in the field of research as well as in the field of applied research plus development literature.

Hypothesis 3:- *Relationship between innovation capacity and absorptive capacity*

3. Investigate the relationships between innovation capacity and absorptive capacity.

Under the hypothesis 3, relationships between innovation capacity and absorptive capacity, we predict that how innovation capacity and absorptive capacity are linked together. Under this hypothesis, we predict bidirectional relationship between innovation capacity (innovation input, scientific output and technology output), and absorptive capacity (human capital, international trade and infrastructure).

3 Data collection and Research methodology

In this study, secondary data are utilized as a unique basis, which is one of the three primary operations of secondary data (Emory, C. W., & Cooper, 1991). At the point, when exploit secondary data, the biggest critical problem is the aptness of the data to the research questions (E. Smith, 2008). Secondary data can provide this constraint excellent than primary data. Additionally, the official documents and statistics utilized in this research have good advantages. Official statistics are perpetual (Emory, C. W., & Cooper, 1991; Bryman, A., & Bell, 2003). They can likewise bring about unexpected revelations (Saunderset al., 2003). Likewise essential is they are attainable for panel studies (Bryman, A., & Bell, 2003; Saunders et al., 2003), and they can utilized to make effective comparison between various countries, groups and societies (E. Smith, 2008).

In particular, the concepts and findings of different authors were utilized to shape the premise of the conceptual framework and model utilized as a component of the study of BRICS national innovation systems (J. L. Furman & Hayes, 2004; J. L. Furman, Porter, & Stern, 2002; Jan Fagerberg, Srholec, & Knell; 2007, Castellacci & Natera, 2013).

In this study, the data for most of the variables except for the patent counts were collected from the World Bank (WDI) and UNESCO. The data about patent statistics of BRICS countries is acquired from the United State Patent and Trade office (USPTO), and World Intellectual Property Organization

(WIPO) websites. Data used for following research are time series annual data from 1999-2014 of BRICS countries along with a group of seven selected indicators shown in figure 1. In addition, it is generally recognizes that developing nations began inventing their national innovation capabilities not very long within a period of previous two eras Hu & Mathews,(2005). We practiced Multiple Linear Regression Model to figure out the level of reliance of our dependent/response variable by utilizing the SPSS software and the indicators demonstrating statistical significant relationship were measured as well as particularly those that demonstrated statistical significant relationships within the economic development were significance preference in the analysis.

4 Results and discussion

4.1 Data screening and test assumptions of the model

Based on the framework developed above, we explain the statistical data on the indicators about the innovation capacity and absorptive capacity along with the Economic development of BRICS countries that was examined in the research study. Here we presented the problems/issues regarding the data screening and the test assumption of the model about BRICS countries, in order to illustrate the condition of differences. Subsequently, screening the time series data for this research , it was found that there was some missing values for the variables School enrollment tertiary (%gross) and School enrollment Secondary (% gross) for Brazil and South Africa, and might be possible removed from the analysis. The remaining variables of Brazil, South Africa and other countries had no missing value. Therefore, we have used liner regression analysis as an imputation method for these variables. In statistic, imputation method is the process of missing with proxy value. Imputation method is referred as a method to prevent the drawback involved with list wise deletion of cases that have missing value. Basically, the multiple liner regressions analysis is required to be addressed the necessary assumptions and conclusion as suggested in the model. As indicated by Field, (2005), “every indicator variables must be quantitative or explicit, as well as the dependent variables must be quantitatively persistent plus limitless”. The data about each variables used in this research is quantitative through the optimistic dissimilarity, which already meet the above assumptions, and do not have a negative variation. See Appendix1, Table 4.1, illustrates the descriptive statistics of the data set for BRICS countries correspondingly.

An additional inherent hypothesis of multi linear regressions is the presumption that there is linear correlation between the dependents as well as the indicator/independent variables. Utilizing the logarithmic transformation of statistical data was made to recognize nonlinear pattern in the statistical data, and then the partial regression plots were calculated between the dependent variable as well as all indicator/independent variables.

The Homoscedasticity implies that the fluctuation about the regression line is the similar for all estimates of the independent/predictor variables and also called homogeneity of variance. This implies that the fluctuation of the predicator/indicator variables at each stage ought to be the same Field, (2005). Multicollinearity, which happens when regression models incorporate profoundly related independent variables, can cause to irrational regression coefficients and complexity in depicting the individual significance of a predictor (Cohen et al, 2003; Field, 2005).

4.2 Results for national innovation capacity of BRICS countries

Our basic model for BRICS countries evaluates the effect of the variables for innovation capacity, technology output, scientific output, international trade, human capital and infrastructure on the variable for economic development.

$$(1)\ \gamma = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \varepsilon_1 \text{(Main Model)}$$

Table 1, indicates the summary of findings for BRICS countries as a solution to the probability of multicollinearity, most of the variables for BRICS countries are highly correlated, and there is no issue of multicollineaty in the model. (See Appendix 2, Table 1)

4.3 The dynamics of innovation capability of BRICS

The finding for BRICS countries extracted in Table 2illustrates that economic development put positive affect on technology output and scientific output for all BRICS countries.

Here is breaking down the main model into different sub- categories to examining the impact of dynamics of innovation capacity variables on economic development when assessed separately.

$$(1)\ \gamma = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 \text{(Model 1)}$$

$$(2)\ x_1 = \beta_0 + \beta_1 \gamma + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 \text{(Model 2)}$$

$$(3)\ x_2 = \beta_0 + \beta_1 \gamma + \beta_2 x_1 + \beta_3 x_3 + \varepsilon_1 \text{(Model 3)}$$

$$(4)\ x_3 = \beta_0 + \beta_1 \gamma + \beta_2 x_1 + \beta_3 x_2 + \varepsilon_1 \text{(Model 4)}$$

Table 2, in case of Russia, economic development has positive effect on technology output but negative effect on scientific output. On the other hand, there is no significant relationship between economic development and innovation input for BRICS countries (except India) which proceeds opposite to the linear model. The results for Model 2, indicate that a significant positive relationship exist between technology output and innovation input with R^2 value as 60% for Brazil. The scientific outputs and innovation input for India have significant relation where beta 4.696 and R^2 as 85%. In case of Russia the innovation input showed negative relationship between all the independent variables. On the other hand, the results for China and South Africa have also demonstrated significant positive correlation between the innovation input and technology output, where the R^2 value were 91% for China and R^2 value were 27% for South Africa. On the other hand, Model 2 for South Africa illustrated that the coefficients is not significant as well as the F-value, so this model is not applicable perhaps. The results for Model 3 illustrate that there exist a positive correlation between technology output and economic development, scientific output and innovation input for all countries. However, Model 3 for Russia, India, China and South Africa show that a significant as well as positive two directional relationship satisfies between technology output and economic development. The results for model 4, applied on BRICS countries, demonstrate that the scientific output and economic development having significant positive relationship with R^2 ranging 94%for Brazil, 99 % for India, 82% for China and 94% for South Africa. Model 4 shows that the scientific output and innovation input also have positive and significant positive relationship for Russia where the beta is 0.513. Moreover, the results for BRICS countries pointed out two directional significant negative relationships between economic development and innovation inputs (see Model 1 and 2). TheR^2 outcomes for model 1 and model 4 in table 2 illustrates significantly positive relationship between economic development and scientific output for Brazil (90% and 94%), India (85% and 99%), China (91% and 82%), and South Africa (92% and 94%).

Table 1

Results for dynamics of innovation capability of BRICS

Model 1

Dependent Variables	Independent Variables					
	Countries	x_1	x_2	x_3	R^2	*F Ratio*
	beta/t-statistic					
γ	Brazil	-0.206 (1.347)	0.238* (0.631)	0.611*** (1.458)	0.908	26.376***
	Russia	-0.878 (-5.468)	0.103 (0.675)	-0.001 (-0.016)	0.938	50.386***
	India	0.104 (2.937)	0.562*** (3.914)	0.525*** (3.459)	0.997	952.818***
	China	-0.236 (-4.023)	0.706*** (16.377)	0.158 (3.611)	0.992	437.456***
	South Africa	-0.114 (-0.822)	0.160 (0.742)	1.031*** (4.552)	0.921	19.528***

Model 2

Dependent Variables	Countries	γ	x_2	x_3	R^2	*F Ratio*
	beta/ t-statistic					
x_1	Brazil	-0.896 (-1.347)	1.360*** (2.103)	-0.955 (-1.035)	0.601	4.016***
	Russia	-0.854 (-5.468)	-0.106 (-0.705)	0.043 (0.478)	0.940	51.909***
	India	4.696*** (2.937)	-2.264 (-1.627)	-3.265 (2.942)	0.859	18.210***
	China	-2.624 (-4.023)	1.660*** (3.024)	0.215* (1.021)	0.916	36.227***
	South Africa	-1.047 (-0.822)	0.037 (0.054)	0.609*** (0.397)	0.277	0.638

Model 3

Dependent Variables	Countries	Independent variables			R^2	*F Ratio*
		γ	x_1	x_3		
		beta/ t-statistic				
x_2	Brazil	0.199 (0.631)	0.262* (2.103)	0.888*** (3.003)	0.923	32.035***
	Russia	0.423*** (0.675)	-0.447 (-.705)	-0.003 (-.014)	0.746	9.778***
	India	1.122*** (3.914)	-0.100 (-1.627)	-0.208 (-0.649)	0.994	475.599***
	China	1.365*** (16.377)	0.288* (3.024)	-0.224 (-3.792)	0.985	224.751***
	South Africa	0.622*** (0.742)	0.016 (0.054)	-1.394 (-1.743)	0.694	3.774***

Model 4

Dependent Variables	Countries	Independent variables			R^2	*F Ratio*
		γ	x_1	x_2		
		beta/ t-statistic				
x_3	Brazil	0.344** (1.458)	-0.124 (-1.035)	0.0597 (3.003)	0.948	48.947***
	Russia	-0.017 (-0.016)	0.513** (0.478)	-0.008 (-0.014)	0.287	1.344**
	India	1.088*** (1.088)	-0.150 -2.942	-0.216 -0.649	0.993	458.165***
	China	3.592*** (3.611)	0.439* (1.021)	-2.638 (-3.792)	0.828	16.006***
	South Africa	0.781** (4.552)	0.050 (0.397)	-0.271 (-1.743)	0.940	26.294***

Note: Number in parentheses are t-statistic, beta *,**,***, denotes significant at 1%. 5% and 10% level respectively
Source: The Authors.

4.4 The dynamics of absorptive capability of BRICS

The models 1 to model 4 for dynamics of absorptive capability of BRICS countries are used in this section to establish the association between economic development, international trade, human capital and infrastructure. These models also established relationship among human capital, international trade and infrastructure. The findings of these assessments for BRICS countries are extracted in Table 3. Here is breaking down the main model into different sub- categories to examining the impact of dynamics of absorptive capacity variables on economic development when assessed separately.

$$(1) \quad \gamma = \beta_0 + \beta_1 x_4 + \beta_2 x_5 + \beta_3 x_6 + \varepsilon_1 (\text{Model } 1)$$
$$(2) \quad x_4 = \beta_0 + \beta_1 \gamma + \beta_2 x_5 + \beta_3 x_6 + \varepsilon_1 (\text{Model } 2)$$
$$(3) \quad x_5 = \beta_0 + \beta_1 \gamma + \beta_2 x_4 + \beta_3 x_6 + \varepsilon_1 (\text{Model } 3)$$
$$(4) \quad x_6 = \beta_0 + \beta_1 \gamma + \beta_2 x_4 + \beta_3 x_5 + \varepsilon_1 (\text{Model } 4)$$

The results of model 1 in table 3 reveals thatR^2value of the economic development and infrastructure of BRICS countries significant effect on each other for Brazil (99%), Russia, (94%), India (96%), China (99%, and South Africa (93%) with F-value of Brazil (436.58), Russia, (66.60), India (111.70), China (1293.27), and South Africa (54.83)**.** The higher and significant superior F-value (above 1.0) for both model 1 and model 4 imply a long term supporting association between Economic development and Infrastructure of all BRICS countries. Basically, the VIF's as well as tolerant statistics for each and every model is fitted in satisfactory limits. The R^2results in Table 5.4specify additional a positive as well as significant two directional trend between economic development and infrastructure via model 1 and model 4, where these values are Brazil (99% and 99%), Russia, (94% and 94%), India (96% and 95%), China (99% and 99%), and South Africa (93% and 91%), with F-value of corresponding to Brazil (436.58 and 390.26), Russia, (66.60 and 63.49), India (111.70 and 79.63), China (1293.27 and 1992.28) and South Africa (54.83 and 45.30) respectively. The results for Model 2 indicate that a significant positive relationship between international trade and economic development exist with R^2 value of 85% for India and South Africa 57%. In case of Russia the international trade shows negative relationship between all the independent variables. On the other hand, the results for China and Brazil also demonstrate the significant positive relationship between the human capital and international trade for China and Brazil with beta value of 3.261 and 0.678 respectively.

The results for Model 3 for Brazil, and India illustrate that the positive relationship between human capitals and economic development with R^2 value of 77% and55 % for Brazil and India. On the other side the human capital have positive impact on infrastructure for China (beta.1.523 and R^2 of 98%) and, all the predictor indicators and outcome variable have negative impact for South Africa. In case of

Russia, human capital and economic development (beta0.631) also exhibit positive and significant relationship. The results of further model for all BRICS countries demonstrate that the infrastructure and economic development share significant positive relationship for Brazil with beta, 1.036 and R^2 of 99%, Russia with beta, 0.814 and R^2 of 94 %, India with beta, 0.967 and R^2 of 96 %, China with beta 0.827 and R^2 of 99%, and South Africa with beta 1.000 and R^2 of 91%. Moreover, this model 4 shows that the infrastructure have negative effect on both international trade and human capital for BRICS countries. As a result, human capital persist a key element of the national innovation systems of BRICS countries.

Table 2

Dynamics of absorptive capability of BRICS

Model 1

Dependent Variables	Countries	Independent variables x_4	x_5	x_6	R^2	*F Ratio*
		beta/ t-statistic				
y	Brazil	-0.022 (-0.757)	0.077 (1.429)	0.927*** (17.189)	0.991	436.588***
	Russia	-0.212 (-1.250)	0.038 (0.542)	0.778*** (4.555)	0.943	66.601***
	India	0.286* (2.514)	0.043 (0.541)	0.699*** (5.005)	0.965	111.702***
	China	-0.007 (-0.256)	-0.085 (-0.773)	1.081*** (10.059)	0.997	1293.278***
	South Africa	0.184 (1.806)	0.016 (0.203)	0.838*** (7.871)	0.932	54.832***

Model 2

Dependent Variables	Countries	Independent variables y	x_5	x_6	R^2	*F Ratio*
		beta/ t-statistic				
x_4	Brazil	-2.079 (-0.75)	0.678*** (1.280)	1.378*** (0.524)	0.140	0.651
	Russia	-0.543 (-1.250)	-0.020 -(0.178)	-0.391 (-0.895)	0.855	23.568***
	India	1.206*** (2.514)	-0.240 (-1.602)	-0.156 (-0.31)	0.854	23.453***
	China	-0.827 (-0.256)	3.261*** (3.844)	-2.308 (-0.633)	0.611	6.273***
	South Africa	1.163*** (1.806)	0.062 (0.311)	-0.425 (-0.651)	0.570	5.300***

Model 3

Dependent Variables	Countries	Independent variables			R^2	*F Ratio*
		γ	x_4	x_6		
		beta/ t-statistic				
x_5	Brazil	1.896*** (1.429)	0.177 (1.280)	-1.021 (-0.770)	0.775	13.816***
	Russia	0.631*** (0.542)	-0.131 (-0.178)	-0.876 (-0.780)	0.057	0.241
	India	0.553** (0.541)	-0.733 (-1.602)	0.761*** (0.894)	0.556	5.002***
	China	-0.558 (-0.773)	0.169 (3.844)	1.523*** (2.110)	0.980	193.976***
	South Africa	0.211* (0.203)	0.128 (0.311)	-0.600 (-0.641)	0.117	0.529

Model 4

Dependent Variables	Countries	Independent variables			R^2	*F Ratio*
		γ	x_4	x_5		
		beta/ t-statistic				
x_6	Brazil	1.036*** (17.189)	0.016 (0.524)	-0.046 (-0.770)	0.990	390.260***
	Russia	0.814*** (4.555)	-0.160 (-0.895)	-0.055 (-0.780)	0.941	63.490***
	India	0.967*** (5.005)	-0.051 (-0.310)	0.082 (0.894)	0.952	79.635***
	China	0.827*** (10.059)	-0.014 (-0.633)	0.178 (2.110)	0.998	1692.287***
	South Africa	1.000*** (7.871)	-0.080 (-0.651)	-0.055 (-0.641)	0.919	45.307***

Note: Number in parentheses are t-statistic, beta *,**,***, denotes significant at 1%. 5% and 10% level respectively
Source: The Authors.

4.5 Relationship between Innovation Capability and Absorptive Capability of BRICS

In this section we evaluate the degree to which absorptive capacity and innovation capacity of BRICS countries interrelate with each other. According to the results (table 4) for Brazil, bidirectional relationship has been demonstrated between international trade and innovation inputs as revealed in model 1 and model 4 with beta andR^2 value of 0.654 and of 59% and 0.575 and 82% respectively. Infrastructure also inserts positively significant effect on innovation inputs in model 1 for Brazil with R^2 of 59%. Human capital and innovation inputs of India are also bidirectional with beta value of 0.290 and 1.314, and R^2 value of 90% and 56 % respectively for model 1 and model 5. Here is breaking down the main model into different sub- categories to examining the relationship of dynamics of innovation and absorptive capacity variables when assessed separately.

(1) $x_1 = \beta_0 + \beta_1 x_4 + \beta_2 x_5 + \beta_3 x_6 + \varepsilon_1$ (Model 1)

(2) $x_2 = \beta_0 + \beta_1 x_4 + \beta_2 x_5 + \beta_3 x_6 + \varepsilon_1$ (Model 2)

(3) $x_3 = \beta_0 + \beta_1 x_4 + \beta_2 x_5 + \beta_3 x_6 + \varepsilon_1$ (Model 3)

$$(4)\quad x_4 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 (\text{Model } 4)$$
$$(5)\quad x_5 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 (\text{Model } 5)$$
$$(6)\quad x_6 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 (\text{Model } 6)$$

Table 4

Relationship between Innovation Capability and Absorptive Capability of BRICS

Model 1

Dependent Variables	Countries	Independent Variables			R^2	*F Ratio*
		x_4	x_5	x_6		
		beta/ t-statistics				
x_1	Brazil	0.654*** (2.277)	-0.584 (-1.167)	0.270* (0.482)	0.598	3.960***
	Russia	0.017 (0.068)	-0.034 (-0.316)	-0.929 (-3.817)	0.906	32.256***
	India	-1.027 (-5.409)	0.290* (2.424)	0.098 (0.475)	0.906	28.932***
	China	-0.140 (-0.605)	-0.743 (-0.969)	-0.148 (-0.217)	0.920	38.417***
	South Africa	0.660*** (2.505)	- -	-00.999 (-3.792)	0.709	7.318***

Model 2

Dependent Variables	Countries	Independent Variables			R^2	*F Ratio*
		x_4	x_5	x_6		
		beta/ t-statistics				
x_2	Brazil	.195 (.771)	-0.579 -1.239	0.973*** 2.070	.311	1.806***
	Russia	-1.038 (-2.488)	-.441 (-2.566)	-.439 (-1.044)	.658	7.680***
	India	-.180 -.391	0.279** .868	0.573** 1.015	.435	3.084***
	China	.481** (2.052)	-2.874 (-2.856)	3.528*** (3.591)	.742	11.523***
	South Africa	-.068 (-1.99)	.233 (.864)	.541** (1.507)	.227	1.175***

Model 3

Dependent Variables	Countries	Independent Variables			R^2	*F Ratio*
		x_4	x_5	x_6		
		beta/ t-statistics				
x_3	Brazil	.165 (2.637)	.003 (.027)	.981*** (8.419)	.958	90.351***
	Russia	.184 (.309)	-.499 (-2.036)	-.118 (-.198)	.303	1.739***
	India	.725*** (3.210)	-.170 (-1.076)	.311* 1.123	.864	25.372***
	China	.935*** (2.645)	-2.830 (-1.863)	2.972*** (2.003)	.412	2.807***
	South Africa	-.072 (-.310)	-.332 (-1.829)	.681*** (2.820)	.650	7.431***

Model 4

Dependent Variables	Countries	Independent Variables			R^2	*F Ratio*
		x_1	x_2	x_3		
		beta/ t-statistics				
x_4	Brazil	.650** (1.760)	.230 (.253)	-.194 (-.192)	.465	2.322***
	Russia	.575** (2.120)	-.182 (-.704)	.267** (1.693)	.823	15.494***
	India	-.279 (-2.022)	-.444 (-.795)	1.165*** (1.971)	.952	59.985***
	China	-1.461 (-3.559)	-.878 (-2.902)	-.318 (-1.040)	.628	5.628***
	South Africa	.491** (1.754)	.456** (1.049)	1.229*** (2.685)	.679	3.521***

Model 5

Dependent Variables	Countries	Independent variables			R^2	*F Ratio*
		x_1	x_2	x_3		
		beta/ t-statistics				
x_5	Brazil	-.009 (-.069)	-.111 (-.366)	1.069*** (3.174)	.941	42.295***
	Russia	-.326 (-.519)	-.126 (-.211)	.010 (.026)	-.236	.174
	India	1.314*** (3.148)	.083*** (.049)	1.290*** (1.290)	.566	3.908***
	China	-.763 (-5.51)	.306** (3.004)	-.051 (-.495)	.958	75.476***

Model 6

Dependent Variables	Countries	Independent Variables			R^2	*F Ratio*
		x_1	x_2	x_3		
		beta/ t-statistics				
x_6	Brazil	-.221 (-1.491)	.453** (1.238)	.401** (.988)	.914	28.224***
	Russia	-.983 (-5.096)	-.082 (-.446)	-.071 (-.634)	.910	33.845***
	India	.498** 3.708	1.053*** 1.939	.299* .521	.955	63.706***
	China	-.300 (-5.139)	.683*** (15.858)	.104 (2.398)	.992	438.840***
	South Africa	-.299 (-2.452)	.092 (.485)	.877*** (4.395)	.939	25.600***

Source: The Authors.

On the other hand, model 1 for Russia and China indicates negative relationship between innovation inputs, international trade and infrastructure. The results for Brazil (table 4), shows bidirectional relationship between technology output (beta 0.230 & R^2 of 46%) and international trade (beta 0.195 & R^2 of 31%) as calculated through the model 2 and model 4. The similar effect is apparent between infrastructure and technology output for India with R^2 values of 43%, and 95%, China (74%, 99%) and South Africa (22%, 93%). Infrastructure also affects positively and significantly on technology output in model 2 for Brazil with beta 0.973 and R^2 of 31%. International trade also influences significantly and positively on technology output in model 2 for China with beta 0.481 and R^2 74%. Furthermore, the relationship between human capital and technology output is also positive and significant for India (beta 0.279) and South Africa (beta 0.237).

The results for model 3 illustrate that scientific output effect is also positive and significant on international trade for Brazil (R^2 of 95%), India (R^2 of 86%), China (R^2 of 41%), and Russia (R^2 of 30%). While in the case of South Africa Model 3 shows that infrastructure affects positively on scientific outputs with R^2 value of 65%. On the other hand, there is also two way relationship between scientific outputs and international trade in model 3 and model 4 for Russia and India with (R^2 of 30%, and R^2 of 82%) and (R^2 of 86%, and R^2 of 95%) respectively. The Results for Brazil and India obtained from Model 5 specify that scientific output acquires positively significant effects on human capital with R^2 of 94% and R^2 of 56% correspondingly. On the other hand, technology output also poses a positive impact on human capital for China, where beta is 0.306 and R^2 is 95%. The results of Table 4 illustrate that scientific output contains significantly positively effect on infrastructure of Brazil (beta 0.401 and R^2 of 91%), India (beta 0.299 and R^2 of 95%), China (beta 0.104 and R^2 of 99%), and South Africa (beta 0.877 and R^2 of 93%), as shown in model 6.

4.6 Tests for robustness of absorptive capacity of brics countries (Additional indicators)

This section presents the findings and results of some additional variables for international trade, human Capital and infrastructure, to assess the robustness of the empirical model to investigate their effect on the preliminary results for the same models for all BRICS countries. In this manner, by varying the new indicators for international trade, human capital and infrastructure, the original model is modified as shown below and the acquired outcomes are outlined in table 5. The variables foreign direct investment for international trade, secondary enrollment ratio for human capital and number of mobile users for infrastructure were utilized to change trade, tertiary enrollment ratio and number of kilowatt of electricity consumed per capita. The results for these variables are outlined in table 5, 6 and 7 for all BRICS countries. Additionally, the VIF's lie far below 10 as well as the tolerant insights is well above 0.2 for these models too. The correlation matrix for these set of additional variables is shown in the appendix. These variables are introduced to check the sensitivity of models that is "to examine to what extent the results would change upon change in these variables".

(i) Innovation Inputs :-(x_1)- Agriculture Value added (% of GDP), Research & Development expenditure (% of GDP),

(ii) Technology output: -(x_2) - No. of patents applications,

(iii) Scientific Output: -(x_3) - number of scientific and technical journal,

(iv) International Trade:- (s_4) FDI, net inflow (% of GDP)

(v) Human Capital:- (s_5) Secondary School enrollment,(% gross),

(vi) Infrastructure :-(s_6) Electric power consumption (kWh per capital)

γ : -Economic development: - GDP per capita 2005

(1) $$\gamma = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_{3+} \beta_4 s_4 + \beta_5 s_{5+} \beta_6 s_6 + \varepsilon_1 \text{(Main Model)}$$

The table 5 indicates the outlines of the results for robustness of national innovation capacity of BRICS countries with additional indicators. The results for all BRICS countries in table 5 are related to the earlier findings in table 1 Innovation inputs seem to have insignificant effect on national innovation capacity for all the countries due to insignificant values of beta or weak coefficients (Table 5). Similar trend was observed for technology outputs among all the countries of this variable on national innovative capacity (Table 5). These results show that international trade turned out to be insignificant for India, China and South Africa, and similar trend is noticed in case of Russia as well.

Table 5

Results for robustness of absorptive capacity of BRICS countries (Additional indicators)

Country	Input Variables	Beta	t	R^2	F ratio
Brazil	Innovation Inputs	-.014	-.135	.978	37.110
	Technology Output	.038	.130		
	Scientific Output	.324	.887		
	International Trade (s_4)	.083	.848		
	Human Capital(s_5)	0.065	.353		
	Infrastructure(s_6)	.727	3.180		
China	Innovation Inputs	.033	.506	.998	754.076
	Technology Output	.059	.450		
	Scientific Output	.026	.729		
	International Trade (s_4)	-.041	-2.097		
	Human Capital (s_5)	-.035	-1.003		
	Infrastructure (s_6)	1.002	4.768		
India	Innovation Inputs	.042	.853	.999	986.906
	Technology Output	.355	2.251		
	Scientific Output	.214	.779		
	International Trade (s_4)	-.003	-.078		
	Human Capital (s_5)	.102	.824		
	Infrastructure (s_6)	.370	1.998		
Russia	Innovation Inputs	.135	.756	.994	181.434
	Technology Output	-.112	-1.422		
	Scientific Output	-.038	-.773		
	International Trade (s_4)	.006	.116		
	Human Capital (s_5)	-.034	-.618		
	Infrastructure (s_6)	1.207	5.268		
South Africa	Innovation Inputs	.086	.378	.979	15.207
	Technology Output	.128	.321		
	Scientific Output	.818	1.102		
	International Trade(s_4)	-.075	-.218		
	Human Capital(s_5)	.271	.414		
	Infrastructure (s_6)	.138	.622		

Dependent variable:- Economic development.

Source: The Authors.

The robustness of absorptive capability of BRICS countries were applied in this section to create the relationship between economic development and additional variables of absorptive capacity like international trade, human capital and infrastructure (table 6 using models 1 to model 4). The findings of these additional variables assessment for BRICS countries are tabulated in Table 6. According to the results of table 6, it has been observed that economic development and infrastructure of BRICS countries affect significantly each other in model 1 for Brazil (R^2, 98%), Russia, (R^2, 99%), India (R^2, 99%), China (R^2, 99%, and South Africa (R^2, 91%) with F-value of Brazil (126.250), Russia, (356.195), India (575.155), China (1305.447), and South Africa (33.567)**.** The model 1 and model 4 for Robustness of absorptive capability of BRICS countries also have significant positive two directional relationships between economic development and infrastructure. The high and significant F value (more than 1.0), for both model 1 and model 4 imply a long term supporting association between Economic development and Infrastructure of all BRICS countries.

$$(1) \quad \gamma = \beta_0 + \beta_1 s_4 + \beta_2 s_5 + \beta_3 s_6 + \varepsilon_1 (\text{Model 1})$$
$$(2) \quad s_4 = \beta_0 + \beta_1 \gamma + \beta_2 s_5 + \beta_3 s_6 + \varepsilon_1 (\text{Model 2})$$
$$(3) \quad s_5 = \beta_0 + \beta_1 \gamma + \beta_2 s_4 + \beta_3 s_6 + \varepsilon_1 (\text{Model 3})$$
$$(4) \quad s_6 = \beta_0 + \beta_1 \gamma + \beta_2 s_4 + \beta_3 s_5 + \varepsilon_1 (\text{Model 4})$$

The results for Model 2 point out that a significant positive relationship between international trade and economic development exist with R^2 value of 65% for Russia, 50% for India and 47% for South Africa. On the other hand, the outcomes for model 2 demonstrate the negative relationship between the economic development and international trade for China with beta value of -8.544. While Brazil have positive relation between infrastructure and international trade with be arranging to 0.892 respectively.

Table 6

Robustness of absorptive capability sub-model for BRICS

Model 1

Dependent Variables	Countries	Independent Variables s_4	s_5	s_6	R^2	*F Ratio*
		beta/ t-statistic				
γ	Brazil	-.035 (9-.645)	-.005 (-.051)	.970*** (9.831)	.974	126.250***
	Russia	.045 (.933)	-.005 (-.147)	.961*** (19.436)	.991	356.195***
	India	.043 (1.370)	.269* (1.725)	.707*** (4.731)	.994	575.155***
	China	-.052 (-3.091)	-.020 (-.489)	1.031*** (25.504)	.997	1305.447***
	South Africa	.241* (2.306)	.971*** (9.949)	.256* (2.490)	.910	33.567***

Model 2

Dependent Variables	Countries	Independent variables γ	s_5	s_6	R^2	*F Ratio*
		beta/ t-statistics				
s_4	Brazil	-1.143 (-.645)	.125 (.223)	.892*** (.489)	.157	.623
	Russia	1.764*** (.933)	-.092 (-.476)	-.966 (-.510)	.639	5.910***
	India	3.709*** (1.370)	.713*** (.435)	-3.857 (-1.758)	.498	3.309***
	China	-8.544 -3.091	-.167 -.323	8.984*** 3.149	.497	3.951***
	South Africa	1.440*** (2.306)	-1.533 (-2.472)	-.611 (-2.399)	.461	2.848***

Model 3

Dependent Variables	Countries	Independent Variables γ	s_4	s_6	R^2	*F Ratio*
		beta/ t-statistics				
s_5	Brazil	-.052 (-.051)	.040 (.223)	-.791 (-.785)	.733	9.167***
	Russia	-.466 (-.147)	-.240 (-.476)	.831*** (.270)	.063	.223
	India	.854*** (1.725)	.026 (.435)	.123 (.256)	.982	178.731***
	China	-.996 (-.489)	-.052 (-.323)	1.927*** (.932)	.845	21.772***
	South Africa	.936*** (9.949)	-.247 (-2.472)	-.251 (-2.494)	.913	34.959***

Model 4

Dependent Variables	Countries	Independent Variables			R^2	*F Ratio*
		γ	s_4	s_5		
		beta/ t-statistic				
s_6	Brazil	.934*** (9.831)	.026 (.489)	-.073 (-.785)	.975	131.274***
	Russia	1.014*** (19.436)	-.026 (-.510)	.009 (.270)	.990	337.284***
	India	.977*** (4.731)	-.061 (-1.758)	.053 (.256)	.992	415.197***
	China	.952*** (25.504)	.050 (3.149)	.035 (.932)	.997	1414.432***
	South Africa	1.496*** (2.490)	-.598 (-2.399)	-1.525 (-2.494)	.472	2.979***

Source: The Authors

In case of India and South Africa, the results for Model 3 demonstrate that human capital and economic development have positive relationship with beta and R^2 values as 0.854, 0.936 and 98% and 91% respectively. The human capital has positive impact on infrastructure for China with beta values of 1.927 and 0.831 for China and Russia respectively. The results of robustness of absorptive capability for our last model 4 for all BRICS countries demonstrate that the infrastructure and economic development have significant positive relationship for Brazil (beta, 0.934 and R^2 of 97%), Russia (beta 1.014 and R^2 of 99 %), India (beta, 0.977 and R^2 of 99 %), China (beta, 0.952 and R^2 of 99%) and South Africa (beta, 1.4996 and R^2 of 47%).

According to table 7, coherence exists between innovation capability and absorptive capability of BRICS countries. In this table, we estimate the degree to which absorptive capacity and innovation capacity of BRICS countries interrelate with each other, relative to the additional variables of absorptive capacity

$$(1) \quad x_1 = \beta_0 + \beta_1 s_4 + \beta_2 s_5 + \beta_3 s_6 + \varepsilon_1 (\text{Model 1})$$

$$(2) \quad x_2 = \beta_0 + \beta_1 s_4 + \beta_2 s_5 + \beta_3 s_6 + \varepsilon_1 (\text{Model 2})$$

$$(3) \quad x_3 = \beta_0 + \beta_1 s_4 + \beta_2 s_5 + \beta_3 s_6 + \varepsilon_1 (\text{Model 3})$$

$$(4) \quad s_4 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 (\text{Model 4})$$

$$(5) \quad s_5 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 (\text{Model 5})$$

$$(6) \quad s_6 = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon_1 (\text{Model 6})$$

According to the results in table 7, there is a significant relationship between human capital and innovation inputs as revealed in model 1 with R^2 of 51% and 85% for Brazil and China correspondingly. On the other hand, model 1 for India and South Africa indicates that the human capital and innovation inputs have negative relationship. The results in model 2 demonstrate significant positive relationship between technology output and infrastructure, with R^2 values of 44%, 61% and 57% for Brazil, India and China respectively.

Table 7

Relationship between innovation capability and absorptive capability of BRICS

Model 1

Dependent Variables	Countries	Independent Variables s_4	s_5	s_6	R^2	*F Ratio*
		beta/ t-statistic				
x_1	Brazil	-.320 (1.222)	.530* (1.061)	-.260 (-.521)	.519	2.872***
	Russia	.008 (.083)	.148 (2.470)	-1.005 (10.683)	.966	95.883***
	India	-.089 (-.527)	-2.667 (-4.104)	1.907*** (3.075)	.879	21.739***
	China	-.190 (1.405)	.146 (.580)	-.951 (-3.700)	.851	19.074***
	South Africa	.330** (.988)	-.679 (-2.005)	.188 (.531)	.598	2.482***

Model 2

Dependent Variables	Countries	Independent Variables s_4	s_5	s_6	R^2	*F Ratio*
		beta/ t-statistic				
x_2	Brazil	.165 (.722)	.297* (.886)	.809*** (2.471)	.447	3.239***
	Russia	.304* (1.142)	-.292 (-1.196)	-.625 (-2.382)	.340	2.061***
	India	.037 (.165)	.177 (.479)	.628*** (1.875)	.616	6.412***
	China	-.110 (-.556)	-.155 (-.326)	.923*** (1.928)	.572	5.346***
	South Africa	-.155 (1.101)	-.578 (-4.060)	-.792 (-5.520)	.767	13.188***

Model 6

Dependent Variables	Countries	Independent Variables x_1	x_2	x_3	R^2	*F Ratio*
		beta/ t-statistic				
s_6	Brazil	-.242 (-1.467)	.299* (.736)	.522** (1.155)	.893	22.314***
	Russia	-.852 (-6.221)	.170 (1.305)	.048 (.601)	.955	70.422***
	India	.194 (3.087)	.435** (1.713)	.719*** (2.676)	.990	301.657***
	China	-.296 (-4.929)	.655** (14.798)	.149 (3.336)	.992	415.157***
	South Africa	-.229 (-.536)	.615** (.925)	.650** (.928)	.248	.551

Source: The Authors.

The results for model 3 illustrate that scientific output influences positively and significantly on human capital for Russia (beta 0.412, R^2 of 95%), India (beta 1.175, R^2 of 90%), and South Africa (beta 0.872, R^2 of 75%), While negative relationship holds for Brazil and China. On the other hand, there is positive relationship between international trade and scientific outputs in model 4 for India with (R^2 of 83%), China (R^2 of 37%), and South Africa (R^2 of 51%) respectively. The Results for Model 5 indicate that human capital positively significant effects on scientific output for all countries, Russia R^2 of 25%, India R^2 of 98%, South Africa R^2 of 90% and China R^2 of 72%. The Table 7 illustrates that infrastructure have a positive significant effect on Technology output of Brazil (R^2 of 89%), India (R^2 of 99%), Russia (R^2 of 95%), China (R^2 of 99), through model 6.

5 Conclusion and limitation

To understand development and growth from an economic perspective the national innovation system has still attracted the attention of the scholars and research about the characterization of innovation system as theory, a concept or a framework. This issue originates from necessity of having strong basis to study evolutionary process. Innovation Systems are frequently condemned for their hypothetical consolidating and flaccid structure (Niosi, Saviotti, Bellon, & Crow, 1993) All things considered, such feedback does not consider that evolutionary theorizing ought to be founded on open structures, in which multifaceted nature and the data originating from non-static situations must be always fused in the analysis (Nelson & Winter, 1977, Nelson & Nelson, 2002).

The agility in innovation system is helpful to comprise unpredictability in the hypothetical analysis of economic development and could be a wellspring of adjustment and development of the speculations that it supplements: it presents an open window to continually return to the hypothetical foundations in which research and policy are being planned (Bengt-Åke Lundvall, 2007). The empirical analyses here incorporated have been considered from this perspective. The models have been propelled out yonder to-the-outskirts convention. Actually, they have been increased to incorporate the socio-institutional dimension, the innovative capacities, the globalization activities and the productive structure as determinants of the development at the national level.

In these days, dynamic empirical analysis may possibly acquire quicker to the requirements of hypothetical basics of innovation and economic development. In the earlier stages, data was most certainly not as challenging as it was before. Multiple imputation techniques permit the utilization of accessible data at nation level (Castellacci, F., Natera, 2011). The reason for multiple imputations is to produce conceivable values for missing values, accordingly making some "complete" sets of data. Explanatory processes that work with multiple imputation data sets, create output for each "complete" data set, in addition to mutual output that approximate, what the outcomes would have been if the original data set had no missing values. These mutual results are frequently more precise than those gave by single imputation techniques.

It doesn't constrain the evaluations to react to a specific model, it reflects the diversity of the process and the reciprocation's among indicators while evaluating data point and there are robustness techniques to survey the unwavering quality of the assessments. We recognize that there are a few hazards when we utilize nation level data information and that they enhance in significance when we evaluate the missing data. Multiple computation is neither an impeccable answer for all cases (Abayomi et al., 2008), nor an all-inclusive cure, yet it permits us to acquire critical information. It gives the chance of exploring the uncovered structure of innovation and development further considered as an open way to applying really dynamic econometric strategies, for example, co-integration. The co-integration procedure is one of the more appropriate econometric instruments to perform empirical analysis on innovation and development from a systemic viewpoint. As a matter of first importance, it deems how indicators co-evaluate and respond, when a change arises. It decides the dynamics of non-linear impacts among the distinctive relationship. In addition, co-integration has the upside of unraveling the long-run structure from the short term.

The panel case (Castellacci & Natera, 2013), demonstrated that there is proof of co-evolving between innovation capacities, absorptive capacities and economic development. This is a focal point that does not reflect on the multidimensional nature of growth. Those reductionist methodologies are liable to neglect to give applicable suggestions. In any part of the framework will drive numerous shift in alternate elements; thus, predicted outcome in a particular measurement will likewise rely upon the impacts, it acquires from whatever remains of the system (Arthur et al., 1999). The purpose of this study is to evaluating the innovation and absorptive capacities of the national innovation systems of BRICS countries, with a specific end goal to discover confirmation of ways and execution to their economic development. In view of the conceptual framework derived from the research literature, this study has utilized the indicators related to innovation capacity, absorptive capacity and economic development to measuring the capabilities, utilizing annually time series data of 16 years in the period 1999 to 2014 for BRICS nations and evaluated the effect of innovation capacity, and absorptive capacity on economic development for BRICS nations. The research study additionally investigated the degree to which these variables keep up the growth of each other so as to acquire further information on the relations in all systems and system discrepancy. The statistical analysis used is a series of multi-regression analysis. The statistically significant indicators fascinated the concentration of the scholars plus researcher in respect of the role of variables in national innovation system as well as the degree to which they comprehend the difference between the nations.

The comprehensive significance from results demonstrates that innovation capacity and absorptive capacity indicators are quite connected by a set of long run structural interaction over the period 1999-2014. In all the BRICS countries the policy priorities and institutional structures are similar to each other. Our study is empirical, where we have argued on the BRICS countries national innovation system. We draw attention to the most common conclusion. In particular, the national innovation systems are determined by the co-evolution of two sets of components, from one perspective the elements of innovation capacity, for instance, innovation input, scientific output and technology output, whereas on the other perspective, the elements of absorptive capacity like international trade, human capital and infrastructure. The mutual relationship between the innovation capacity variables and absorptive capacity variables are additional empowered and maintained by the GDP per capita growth. Human capital which belongs to the factor of absorptive capacity ordinarily is expressed by gap in technology and imitation based growth model, does likewise coevolves regarding the system. In any case, the particular part of this variable relies upon the element that it is utilized to quantify it. At the point when secondary education is utilized, human capital has a two-directional relationship to innovation activities on the other hand the tertiary education variable have indirect impact by sustaining the GDP per capita but it does not having an direct impact on the elements of innovation activities. Thus the NIS is the multifaceted set of two way relationship.

A few limitations have been confronted amid the development of this study. For example, catching the mind boggling measurements that are understood in the catching up process is still a major dispute. Accessible indicators/variables are not free of inadequacies. Regarding the methodological perspective, changes in external sources as well as, changes in data collection methods and techniques, may influence the estimation of the indicators/variables and the data that could be extricated from it (Hall et al., 2010). When using the annual time series data are utilized, it is important to remember that changes from one year to the next may be brought about by methodological overhauls and not as a matter of transforms in the process that we might want to measure. In applied or conceptual methodology, the choice of indicators/variables as a proxy is a difficult task, and is still an issue. Additionally, measuring absorptive capacity with number of indicators/ variables is also difficult, challenging and is not free of obstacles. We have to consider its versatile nature and this is just conceivable when diverse dimensions are fused in the examination. Different constraints are identified with the portrayal of the time structure. As a matter of first importance, in the panel analysis, the structural breaks formation has not been completely developed (Banerjee, 2006, Banerjee, Marcellino, & Osbat, 2004), when investigating group of nations collectively, it is difficult to control fully the changes in the behavior of variables. Moreover, the structures exposed by this study could change after some time, in case of time series data in which structure breaks can be depicted. It is essential to consistently return to the model by including new data that could enhance and change the outcomes. . The interdependence of national innovation system grows with internationalization of technology transfer with the international flow of scientific and technical persons. National policies and institutions relevant to innovation systems are national within the perspective of funding, education, and intellectual property rights regulation.

The evolution of the current structure of BRICS countries' national innovation system, discussed in this research, reveals the important role that the country has played in laying the foundations and outlining the goal trend under the ruling political leadership for many years. A Country's mediation via technology and innovation policies has been a determining factor in building a NIS furthermore establishing national innovation capacities. Additionally, the findings showed the degree to which components of the NIS for all BRICS nations rely on one another. So in this way, any change in one indicator in the NIS affects the other indicators in system. This demonstrates collaborations and connections within the BRICS national innovation system are distinctive, furthermore every system might have extraordinary. This affirms the results and findings of Jan Fagerberg et al., (2007), and Castellacci & Natera, (2013), on the distinctions in the NIS of middle income as well as catching up economies

These results have significant connotation for policy makers. China ought to keep on extending the reform in science and technology system, as well as develop an institutional framework of the national innovation system. In the reforming science and technology system, two objects are crucial to the development of the NIS. One is to develop the reform of scientific research institutions, and second is to modify the role of the country. Government policies are the central point as well as a desire to promote the development of the NIS model of Russian would guarantee effective utilization of the nation's R&D and innovation prospective, which will accelerate economic growth as well as improved personal satisfaction. On the other hand, Russian encounter once in a while gives samples when government activities transform into serious hindrance. In the future, a comprehensive study of national innovation system of BRICS countries ought to be done separately taking into account a study to gather more illustrative information on innovation, science and technology activities of BRICS countries.

Authors' contributions

Contribution	KHALID USMAN	LIU ZHIYING	SHEN HUAYAN	JIE XIN	JIN YUJIA
Contextualization	√	√	----	----	----
Methodology	√	√	----	----	----
Software	√	----	√	√	√
Validation	√	----	√	----	----
Formal analysis	√	√	----	----	----
Investigation	√	√	√	----	----
Resources	√	------	----	------	------
Data Curation	√	------	----	------	------
Original	√	√	-------	-------	-------
Revision and editing	√	-------	√	√	√
Viewing	√	√	-------	-------	-------
Supervision	-------	√	----	-------	-------
Project management	√	√	-------	-------	-------
Obtaining funding	-------	-------	-------	-------	-------

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Appendix 1

Table 4.1

Descriptive statistics for BRICS

	Variables	Brazil	Russia	India	China	South Africa
		Mean/Std. Deviation	*Mean/Std. Deviation*	*Mean/Std. Deviation*	*Mean/Std. Deviation*	*Mean/Std. Deviation*
Innovation Inputs	Agriculture Value added (% of GDP	5.60	5.41	19.45	11.50	2.91
		(0.62)	(1.45)	(2.24)	(2.19)	(0.44)
	R&D Expenditure (% of GDP)	1.05	1.1	0.82	1.31	0.94
		(0.08)	0.08	0.12	0.36	0.11
Technology Output	Number of Patents applications	6697.3	26977.74	8257.93	188871.9	3684.18
		(10735.5)	5884.727	10673.02	203655.3	11525.649
Scientific Output	Scientific and technology journals	11369.78	15428.18	15871.91	40797.04	5420.05
		3932.48	1615.68	3986.78	25267.8	6137.98
International Trade	Trade % of GDP	25.45	55.65	41.45	48.99	57.88
		2.45	6.57	11.16	9.72	6.60
	FDI, net inflow(% of GDP)	3.05	2.46	1.50	3.84	1.74
		1.02	1.16	0.81	0.66	1.45
Human Capital	School enrollment tertiary (% of gross)	26.08	61.94	17.03	19.07	30.16
		(6.16)	17.07	7.50	7.51	2.79
	Secondary school enrollment(% gross)	91.18	85.90	59.21	74.62	92.0
		(12.57	5.76	11.62	13.25	7.41
Infrastructure	Mobile cellular users(per100people)	66.70	91.48	29.82	43.07	76.75
		(46.23	64.63	30.54	29.49	45.7
	Electric power consumption (kwh per capital)	2201.89	5508.03	840.89	2224.41	4419.74
		(398.56	1090.02	865.52	1001.12	554.48
Economic Development	GDP per capita (constant 2005 US $)	5119.90	5.41	850.89	2222.63	2.951
		(618.71	1.457	234.0353	940.4112	0.44

Source: The Authors.

Appendix 2

Table 1

Results for national innovation capacity of BRICS countries

Country	Input Variables	Beta	t	R^2	F ratio
Brazil	Innovation Inputs	-0.026	-0.416	0.993	126.953
	Technology Output	-0.257	-1.492		
	Scientific Output	0.422	1.402		
	International Trade	0.065	0.772		
	Human Capital	-0.191	-1.001		
	Infrastructure	1.012	4.140		
China	Innovation Inputs	-0.043	-0.776	0.999	1105.875
	Technology Output	-0.206	-1.441		
	Scientific Output	-0.024	-0.657		
	International Trade	0.088	2.360		
	Human Capital	-0.592	-3.660		
	Infrastructure	1.715	5.804		
India	Innovation Inputs	0.038	0.792	0.999	1235.182
	Technology Output	0.356	3.301		
	Scientific Output	0.456	3.853		
	International Trade	0.030	0.542		
	Human Capital	-0.023	-1.236		
	Infrastructure	0.210	3.669		
Russia	Innovation Inputs	-.331	-1.638	0.982	64.052
	Technology Output	0.146	1.339		
	Scientific Output	0.050	0.710		
	International Trade	-.073	-0.443		
	Human Capital	0.139	2.324		
	Infrastructure	0.467	2.176		
South Africa	Innovation Inputs	0.101	0.692	0.985	40.210
	Technology Output	0.023	0.175		
	Scientific Output	0.091	0.315		
	International Trade	0.116	0.890		
	Human Capital	0.909	3.053		
	Infrastructure				

Dependent variable: - Economic development.
Source: The Authors.