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A Case Study of the Daedeok Innopolis Innovation Cluster and Its Implications for Nigeria

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Abstract

Innovation clusters are essential in the economic development of many developed countries across the world. While they present ways for under-developed and developing countries to grow their economies, fully operational innovation clusters are yet to be established in Nigeria. Many experts argue that learning from experience is an effective way of galvanizing economic development. Therefore, in this study, an empirical analysis involving a multi-variable quantitative analysis was used to examine the factors that influence the performance of the Daedeok Innopolis Innovation Cluster (South Korea). The results obtained show that the investment in education, Research and Development (R&D), labor capacity of key players within the innovation cluster, and the transfer of technology (within the cluster) were essential factors that influence the performance of the Daedeok Innopolis Innovation Cluster.

Keywords

Innovation clusters; Sustainable development; Human capital; Innovative capacity; Technical capacity

1. INTRODUCTION

The development and implementation of science parks and innovation clusters have been growing globally. Debresson (1989) posits that establishing innovation clusters are ways under-developed and developing countries can catch-up and bridge the technological gap between them and their developed counterparts. Innovation clusters are seen as ways to organize National Innovation Systems (NISs) to drive innovation and knowledge sharing for economic growth. In-line with this, various studies have shown that innovation clusters enhance innovative capacities within economies across the world. For instance, Baptista and Swann (1998) argue that companies within an innovation cluster, innovate more compared to firms that are not located in a network that a cluster provides. The concept of Science Parks (SPs) evolved from the notion of industrial parks which started in Britain during the industrial revolution. An example was the Trafford Park Industrial Estate in Manchester, which was strategically connected to the sea (Vila et al., 2008). However, the concept of industrial parks quickly evolved into the development of SPs in the United States (US) - where the pioneer science park was developed in 1950. This park was originally called the Stanford university science park. The second and third science parks to be developed were the Sophia Antipolis in France and the Tsukuba science city in Japan, respectively in the 1970s. Currently, there are over 400 SPs globally, and the concept of developing Innovation Clusters (ICs), as tools for economic development, keeps growing across all the regions of

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the world (United Nations Educational, Scientific and Cultural Organization, 2017). It is important to note that the 21st century has recorded a change in paradigm from the concept of the use of SPs to stimulate growth to the use of ICs.

However, Science Parks (SP) and Innovation Clusters (IC) have their similarities and differences. In-line with their similarities, Link and Scott (2003) concludes that science parks have three basic components; these include, a developed real estate, technology transfer in an ordered form, and a coordinated partnership between the university, government and firms. Similarly, innovation clusters are interrelated independent organizations that work together to drive national innovation in an economic sector or specific industry (Preissl, 2003; Cooke, 2001; Tan, 2006). Typical activities that take place within an innovation cluster include, researching, networking, cluster expansion, developing innovation and technology, training and educating, cooperation (commercial), and policy acting (Rialland, 2009).

On the other hand, there are fundamental differences that exist between the SPs and ICs. According to Hardman and Lange (2011), three key differences exist between them.

Firstly, while the SPs concentrates on developing innovation and sharing ideas within a geographical space, the ICs focus on developing a digital community without boundary limitations. Secondly, while SPs focus on local innovation, ICs concentrates on open innovation (borderless innovation). Finally, while SPs are technology driven spaces, ICs are technology-enabled spaces. In this study, emphasis will be placed on ICs because, there has been a change in paradigm from SPs to ICs in the 21st century.

The structures of ICs and SPs have evolved over time, while some researchers are in favor of the triple helix model, others are in support of the quadruple model. Triple helix models are made up of the academia, industry and government, interacting in such a way that seeks to improve knowledge flow amongst them while, the quadruple helix models consist of academia, industry, government and media-based & culture-based public, working together in a network to stimulate innovation (Leydesdorf and Etzkowitz, 1998; Carayannis and Campbell 2014; Park, 2013). While the structure of ICs is not within the scope of this study, their role in building national innovation capacity for economic growth and national technical capacity will be examined. National innovation capacity is the competence of a nation to manufacture and sell a steady flow of innovative technology over an extended period of time (Furman et al., 2002; Steenkamp et al., 1999; Mueller and Thomas, 2001). On the other hand, a technology or product cannot be an innovation without commercial value therefore, the relationship between ICs and economic growth will be explored, herein. The aim of this study is not to compare models, but to learn from the performance of the Daedeok science park in-order to derive essential lessons to improve ICs in Nigeria

But why was the Daedeok Innopolis innovation cluster (DIIC) chosen in this research (considering there are many ICs around the world)? Firstly, the DIIC was considered because of the close partnership that exist between the management of the DIIC and the Nigerian government in the construction of the Abuja Technology Village (ATV) Innovation Cluster. Consultants from the DIIC were involved in the development of the blue-print for the ATV, the development of its Information Communication and Technology (ICT) infrastructural plan, and the Korean government has trained key members of the Nigerian team involved in the development of the ATV in Nigeria. Secondly, the DIIC is one of the major strategies that the Korean government deployed to help it make the economic growth from a developing country (ravaged by poverty), to a developed country (within a short time). According to Yoo (1997), the Netherland, Demark, Belgium, France, Ireland, US, Germany, Canada, Norway, Sweden, Japan, Venezuela, Spain, Finland, Portugal, Taiwan, Malaysia, and Korea, made the transition from a developing country to a developed country in 98, 114, 75, 104, 114 ,54, 68, 41, 68, 45, 39, 32, 33, 25, 36, 20, 26 and 19 years, respectively. This shows that amongst all the countries examined, Korea had the fastest and shortest development trajectory. This presents an important reason why the DIIC was studied in this research. Furthermore, the contribution of the DIIC to the economic development of Korea has been studied over the years and results show that it has contributed immensely. Some of its contributions include; the creation of profitable spin-off and high-technology (with profitable commercial value), the growth of venture capital investment, network building, and start-up incubation (Oh, 2012). The DIIC produces over 7,000 patents per year, which generate funds from technology licensing during transfer of technologies to third parties (Seo, 2013).

2. BACKGROUND OF STUDY

Before describing the entrepreneurial ecosystems in Cyberjaya, it is important to explain the background of the Multimedia Super Corridor (MSC) Cluster—the MSC project was developed as a cluster of firms in the information and communication technology (ICT) sector. In August 1995, Dr. Mahathir Mohammed, the then prime minister of Malaysia, announced that the “Multimedia Super Corridor” (MSC) would be the centerpiece of the national ICT

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Table 1. Cluster types and description

	Type of Cluster	Description
1.	Truncated	This consists of various technologically independent entities, sometimes in different locations, their activities are technologically restricted as they use contemporary technologies rather than advanced technologies. New technologies usually emerge from ready made products
2.	Sectorial	This represents a set of companies producing standard goods and services by working in a synergy. New technology use is restricted to quality control and personnel management
3.	Innovation sectorial	These comprise of a set of businesses producing goods and services in a synergy. They are always evolving and upgrading their production process and product. They have a permanent and stable connection with research centers and educational institutions
4.	Pro-innovation	These are companies operating in a cluster where innovation is based on rapid assimilation of knowledge and technologies to improve competitiveness
5.	Innovation	This is made up of a cluster of companies that affect the performance of a region's industry, investment and social structure. They create a unique group of companies that use advanced knowledge and technologies, generates venture capital, lead the research of universities and other educational established, and have international networks
6.	R&D focused innovation cluster	This type of innovation cluster focuses on contributing to national economic growth through intellectual property creation and technology commercialization. This is a virtuous circle innovation cluster in which key activities that take place within it include; R&D, technology commercialization, technology transfer and re-investment. This type of innovation cluster operates a triple helix framework made up of the University, Government, and Private sector interacting with each other to drive knowledge and innovation

Source: Updated version of Rud et al. (2014)

strategy under the Seventh Malaysia Plan (1996-2000). The MSC project is a government-led program formulated with the support of various cluster oriented infrastructure and policies.

2.1 Innovation Clusters

The essence of science and technology ICs is to encourage and enhance development, as well as to create new improved technology firms which will meet the technology needs of the market and society. Also, the aim of establishing an IC is to stimulate economic development (regionally), promote the development of new technology based firms, and to support the transfer of knowledge amongst key players in the network (Hu, 2007; Naughton-Treves et al., 2011; Vila et al., 2008). According to Liyanage (1995) an important factor that influence the development of ICs, within national boundaries, are collaborative efforts amongst research institutes. Also, Lee et al. (2010) - in his research on factors that affects the development of ICs in Korea - identifies the role of government policies as an essential factor in the development of ICs. On the other hand, Rud et al. (2014) argues that there are various types of clusters and each has a different characteristic (See Table 1, for more details).

The DIIC was developed from the conscious effort of the government to drive innovation in the Korean economy; through its policies in its economic development plans, over the years and falls into the sixth category in Table 1. The Korean government's economic development plan was essential to the performance of its NIS (Shenkoya and Kim, 2018; Blakely et al., 2002; Park, 1990). Based on earlier studies, some of the factors that influence the productivity of ICs include the effect of government activities such as funding the education sector and Research and Development (R&D) activities. For instance, Varsakelis (2006) after studying 29 countries and examining the inter-country variations, in terms of innovative activities, concluded that there was a positive correlation between public funding of education and the innovativeness of the countries studied. Furthermore, the relationship between patent count and public funding in education show that there is a positive correlation between them (Varsakelis 2006; Diego and Paula, 2013). Likewise, government funding of R&D shows a positive relationship with patent count and public funding of education (Trajtenberg, 1990; Jaffe, 1986; Crosby, 2007). Meanwhile, Dietz and Bozeman (2005) studied the relationship between human capital and productivity by studying careers within the key

Table 2. Previous empirical studies on Innovation cluster

Year	Author	Journal	Research	Key findings	Unanswered research questions
2002	Löfsten and Lindelöf	Research Policy	The impact of science parks on the growth of technology spin-offs	Universities play a key role in the technology transfer and development within a science park	What is the impact of education on the performance of an innovation cluster? What are the factors that improve human capital for innovation cluster management? In-addition to these factors what are other empirical factors that are responsible for the performance of an innovation cluster? What are the factors that enhance innovation within an innovation cluster? What are other factors besides innovation that are responsible for the performance of innovation clusters?
2004	Zhang Yuehua	International Journal of Entrepreneurship and Innovation Management	Determining important factors in science park management	The administration of a park is more important than the location in which it is established	
2005	Lai et al.	Technovation	A comparison of innovation capabilities of science parks	Park research infrastructure, local demand of products within the park and closeness to other clusters are key elements in improving innovation	
2005	Löfsten and Lindelöf	Technovation	The impact of R&D and product innovation in technology (academic and non-academic) development within science parks	Universities are the primary research entities within science parks	
2006	Tan Justin	Journal of Business Venturing	This study focus on factors that influence the growth of the Beijing Zhongguancun Science Park	The high volume of technology transfer and the ability of the park to enhance innovation are key factors that affect its growth	
2010	Tsai and Tsai	The International Journal of Organizational Innovation	This research studied the impact of science parks on its occupants	Science parks are important to improving the value chain of businesses and their general performance	
2010	Zeng et al.	Technological and Economic Development of Economy	Determining the innovation capability of the Qingdao Science Park	A model for the evaluation of the innovativeness of a park was developed in the course of this study	
2013	Motohashi	Asia Pacific Business Review	Understanding the role of science parks in improving innovation performance	The management of the science park and its network is important to enhancing innovation	
2016	Díez-Vial et al.	Technovation	Understanding the role of universities in driving innovation	There is a positive relationship between universities and innovation improvement	
2016	Tsai and Chang	Kybernetes	Evaluating the factors that influence regional innovation	The role of government and R&D funding are important factors for regional innovation	

Source: Author's compilation

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players of the NIS (University, Government and Firms (U-G-F)). They concluded that while the factors that affect the relationship between human capital and productivity were different for engineers and scientist, there was a positive correlation between human capital and productivity. This result was obtained from their examination of the role of human capital in economic development, from aggregate cross-country data. Other research results prove that the total factor of productivity of a country is dependent on its human capital productivity (Benhabib and Spiegal 1994; Rauch, 1993; Engelbrecht, 1997).

On the other hand, Ernst and Spengel (2011), studied the effect of government incentives in terms of tax reduction for R&D inputs, and the effect of cooperate income tax on R&D business and its impact on productivity (patent application). They argued that tax incentives had a positive effect on R&D inputs but cooperate tax had a negative impact. Finally, Bergek and Bruzelius (2010) considered factors that affect innovativeness on an international scale by considering the relationship between patent and international collaboration between different countries. They and other researchers concluded that there was a positive relationship between these variables (Bergek and Bruzelius, 2010; Lee and Bozman, 2005; Noni et al., 2017).

Previous studies on the catch-up strategy of the Korean economy by Shenkoya and Kim (2018) developed a theoretical model (known as the "Multiple Skipping Development Trajectory-MSDT") that represents the factors that influenced the speedy development of the Korean economy. While two factors (public funding of education and R&D) were identified in the MSDT, other researches have shown that other factors (the productivity of labor, tax subsidies on R&D and international collaboration) also contribute to the development of ICs (See Table 2, for more details). This study seeks to synergize previous studies by revising the 'Multiple Skipping Development Trajectory' theory while seeking to apply the revised theory to a real life study (with empirical evidence). This revised theory will be used to develop an analytical framework that will be used in the examination of the factors that affects the performance of the DIIC. Also from the lessons learned herein, recommendations will be made to the Nigerian government on how the ATV can be enhanced to achieve, at-least, the same development pace recorded in Korea. Furthermore, while previous studies relating to the study of the performance of the DIIC have largely been theoretical, and sometimes involve univariate quantitative analysis, this study seeks to use a different approach that involves a quantitative multi-variable analysis that will synergize earlier studies to present a holistic and thorough examination of the subject matter. Table 2, contains a summary of previous research relating to the subject matter. Based on the unanswered questions in earlier researches (in Table 2 - column 6), this study seeks to provide answers to the following research questions:

RQ1: What is the importance of public funding of education to an innovation cluster?

RQ2: How important is labor capacity to the performance of an innovation cluster?

RQ3: Are there any benefits to government tax subsidies on R&D?

RQ4: What is the benefit of higher education on the performance of employees within an innovation cluster?

In-order to provide answers to the research questions raised herein, all the independent variables unilaterally analyzed by previous researchers will be combined to examine their effects on the innovativeness of the DIIC. This study presents itself as one of the earliest study relating to ICs in Nigeria and Sub-Saharan Africa. While there is a paucity of research on the subject matter, this study seeks to bridge this gap by studying the DIIC and drawing lessons for Nigeria.

2.2 Theoretical Foundation

2.2.1 The revised 'Multiple Skipping Development Trajectory' theory

In an earlier study of the Korean NIS, Shenkoya and Kim (2018) developed the 'Multiple Skipping Development Trajectory' theory. However, in this study the 'Multiple Skipping Development Trajectory' theory will be revised and used to model the analytical framework that will be used to analyze the factors that improves the performance of the DIIC. Within the context of the original theory, the role of the government in improving the education system and public funding of R&D was identified as key factors that are responsible for the performance of the NIS. While other researchers identified essential factors to the performance of the IC as the capacity of labor, government tax subsidies on R&D and technology transfer (amongst the key players of the IC), this study seeks to synergize earlier

Table 3. Theoretical formulation

Theory	Assumptions
The Multiple Skipping Development trajectory	Factors that determine the performance of innovation clusters include; government funding of the education sector, and public expenditure on R&D. In this theory, the role of the government is particularly emphasized compared to other members within the National Innovation System. Furthermore, this theory makes the assumption that the role of government within an NIS is the role of coordination, management and policy implementation (See Shenkoya and Kim (2018), for a detailed explanation)
The Revised Multiple Skipping Development trajectory	Factors that determine the performance of innovation clusters include; government funding of the education sector, R&D, labor capacity, education level of employees, technology transfer, and tax subsidies on R&D. The reason for the new addition of variables is because other researches - on the performance of innovation clusters - have shown that these variable are important. For instance, the positive relationship between the productivity of labor and the performance of innovation clusters has been established (Dietz and Bozeman, 2005; Benhabib and Spiegal 1994). On the other hand, researchers such as Ernst and Spengel (2011) and Bergek and Bruzelius (2010) showed in their respective research that government tax subsidies on R&D improved the performance of innovation clusters. Finally, technology transfer within an innovation cluster is relevant to innovativeness (Chyi et al., 2012; Cho and Shenkoya, 2019; Chandrashakar and Subrahmanya, 2019)

Source: Author's compilation

Table 4. Daedeok Innopolis Evolution Trajectory

Phase	Stage / Year	Description
1	Science Park Stage (1973-1989)	This was an initiative of the Korean government to develop a science city - outside the national capital - to enhance research capabilities by coordinating the activities of the key players of the NIS (Government, University and Industry).
2	Technopolis (1990-2004)	the science park. This led to the Technopolis phase. This period, specifically focused on the development of high technology. Based on this, it was designated as the first Special R&D Zone. Its main aim was to lead regional innovation and economic development with strong support from the central government.
3	Innovation cluster (2005- till date)	The aim of this stage is to make the DIIC a world-class innovation cluster and hub for global technology commercialization. This stage concentrates on national development through the development of appropriate networks.

Source: Oh and Kang (2011)

studies by combining all the prominent factors to formulate the 'Revised Multiple Skipping Development Trajectory' framework (See Table 1, for more details). By doing this, the multiple effects of all these variables will be examined while seeking to determine the relevant variables that are particularly important for effective performance and sustainable development. (See Table 3, for detailed explanation). The results that will be obtained will be more robust than earlier studies.

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Table 5. Details of the Daedeok Innopolis and Abuja Technology Village Innovation cluster

Description	Abuja Technology Village	Daedeok Innopolis
Land size	7.02 km2	Total area: 70.4 km2 Zone 1. Daedeok Science Town (DST; 1972~1999): 27.8km2 - for research and education, and includes a residential area Zone 2. Daedeok Techno-Valley (DTV; 2005): 4.3km2 - venture business area, pilot plants Zone 3. Daedeok Industrial Complex; 1988): 3.1km2 - local industrial park & manufacturing area Zone 4. Projected area (Green-Belt area): 30.2km2 – a green belt area and includes land set aside for incoming Zone 5. Agency for Defence Development: 5.0km2 - for military and defence-related industry
Specialty	Information, technology and communication (ICT), biotechnology, mineral technology and energy technology.	Nanofabrication, biotechnology, robotics, telecommunications, nuclear fusion, design, mechanical engineering, fuel cells, aeronautics, nuclear and hydro power, new materials, new drugs and environmental technologies
Status	Non-operational	Operational
Tenants	N/A	4,804 (in 2016)
Established	2007	1973
Location	Abuja, Nigeria.	Daejeon, South Korea.

Source: Author's compilation

2.3 Brief Overview of the Daedeok Innopolis (South Korea) and Abuja Technology Village Science Park (Nigeria)

In the 1980s and 1990s after the world war II and the civil war encountered by Korea, the government in a bid to drive economic development, adopted the idea of developing a science park. The DIIC is located in Daejeon city; a strategic position to secure its location and inhabitants from external aggression. Over the years, it has evolved based on the various targets and objectives the Korean government seeks to achieve (See Table 4, for more details). According to Kim (2010), the DIIC derives its innovative nature from the fact that it effectively coordinates ideas about business and technology amongst; policy makers, researchers, and business people in various industries.

On the other hand, the ATV is a science park that is in its developmental stage and is located in Abuja, Nigeria. Currently, the key road networks within the IC has been completed. Also, the blueprint of the IC and the framework for its ICT infrastructure, have been completed (in partnership with consultants from the DIIC). The next phase involves the construction of a parameter fence as required by law and the implementation of its development plan. When completed it seeks to be one of the largest science park in Africa. It occupies a land area of 702 hectares (7.02 km2) and is divided into four clusters. Of the total land size, 60 percent represents a green space and the remaining 40 percent will be developed. Since 2007, when the ATV was founded, an extensive, but a slow pace of infrastructural development is ongoing. The slow pace of development is caused mainly by inexperienced management. In Table 5, a summary of the

Table 6. Dataset of factors that influence the performance of Daedeok Innopolis Innovation Cluster

Year	Registered Patents (Unit: case)	Total R&D Investment (Unit: USD Millions)	Education Level of Employees (Number of Ph.Ds.)	Labor Capacity (Unit: Person)	No. of Technology Transfer (Unit: case)	Tax subsidy rates on R&D expenditures (%)
2005	28560	1813117	6236	23558	611	0.14
2006	30784	2727219	6495	46379	723	0.14
2007	31839	2822409	6800	55430	815	0.28
2008	32977	3939279	6783	83978	974	0.18
2009	35391	5152175	7661	98629	910	0.18
2010	40297	5871489	9055	101947	778	0.18
2011	62137	6015013	9317	118643	1587	0.18
2012	74947	6875157	10930	119463	2126	0.18
2013	91023	7210530	11413	133158	2759	0.18
2014	98353	7608297	11461	132741	2980	0.18
2015	110062	9805177	13129	159613	2980	0.18
2016	110935	9961415	15000	178270	3660	0.18

Source: Daedeok Innopolis (2019); OECD (2018); Kim and An (2012)

features of the ATV and DIIC is given. The superiority and advance nature of the DIIC makes it a suitable choice for learning for the Nigerian government hence, this was factored into its choice as a case study, in this research. Therefore, a study of the factors that influence the performance of the DIIC will be carried out to seek areas of learning for the Nigerian government.

3. METHODOLOGY

3.1 Data and Variables

The Data used in this study are presented in Table 6. They were collected from documents and reports relating to the DIIC (both online and offline) and other published materials. It is important to note that in cases where a range was given to cover a certain period, the data (estimates) for these periods were generated based on the range value using the R-program. However, this does not infer with the integrity of the data in anyway.

As this research involves a multivariable quantitative analysis, the statistical analysis method known as the multiple linear regression will be used to analyze the data collected. This method is especially important to study the relationship between the dependent and independent variables in this research. The multi-variable approach to studying the

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Table 7. Earlier studies and variables considered

Dependent Variable (y^1)	Registered Patents	
Independent variable (x^1)	Total R&D Investment	Trajtenberg (1990); Jaffe (1986); Crosby (2007)
Independent variable (x^2)	Education Level of Employees	Varsakelis (2006)
Independent variable (x^3)	Technology transfer	Dietz and Bozeman (2005), Benhabib and Spiegal (1994)
Independent variable (x^4)	Tax subsidy rates on R&D expenditures	Chyi et al. (2012); Cho and Shenkoya (2019); Chandrashakar and Subrahmanya (2019)
Independent variable (x^5)	Tax subsidy rates on R&D expenditures	Ernst and Spengel (2011), Bergek and Bruzelius (2010)

Source: Author's compilation

performance of ICs, used in this study, is a viable option for studying the relationship between the dependent and independent variables. In Table 7, a list of variables considered in earlier researchers, their reference, and a brief description is given.

3.2 Analytical Framework

In this research, the analytical framework used is shown in Figure 1. The analytical framework was derived based on the assumptions made in the 'Revised Multiple Skipping Development Trajectory' theory adopted in this study. Furthermore, the analytical framework is similar to those successfully used in earlier researches. This research seeks to add value to the body of knowledge by synthesizing the variables used in earlier studies (to check the collective effects of these variables) to develop a more comprehensive model to study the performance of ICs. Based on this, the following hypothesis will be tested:

H1: There is a positive relationship between the amount of registered patents within an innovation cluster and the total R&D Investment within the innovation cluster.

H2: The amount of registered patents within an innovation cluster is positively related to the education level of employees within the innovation cluster.

H3: The amount of registered patents within an innovation cluster is positively related to the capacity of labor within the cluster.

H4: There is a positive relationship between the number of technology transfer within the cluster and the number of registered patents it has.

H5: The amount of registered patents within an innovation cluster is positively related to the tax subsidy rates on R&D expenditures.

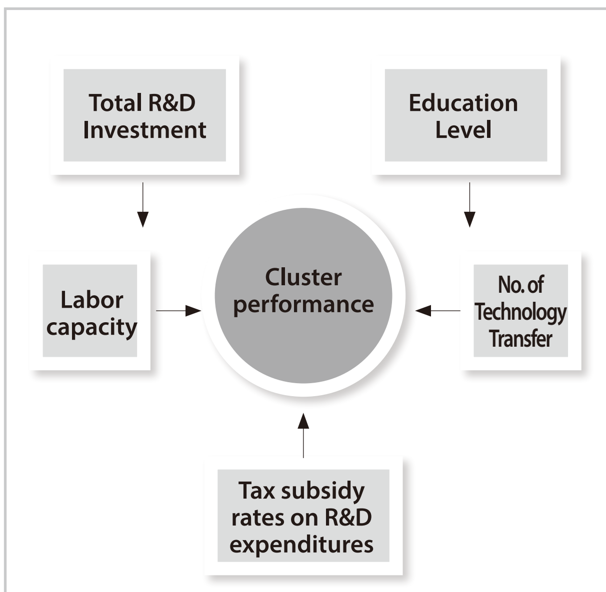

Fig. 1. Research Analytical Framework

Source:Author's

Table 8. Factors that influence the performance of Daedeok Innopolis innovation cluster

Independent Variable	Estimate	Standardized	t-value	Pr(>|t|)
Constant	1.573e+04	1.369e+04	1.149	0.294166
Total R&D Investment (Unit: US Dollars)	1.196e-02	4.482e-03	2.668	0.037113 *
Education Level (Number of Ph.Ds)	-2.717e+00	2.990e+00	-0.909	0.398533
Labor capacity (Unit: Person)	-4.348e-01	1.862e-01	-2.334	0.058285 .
No. of Technology Transfer (Unit: case)	2.639e+01	4.327e+00	6.098	0.000886 ***
Tax subsidy rates on R&D expenditures	1.233e+04	3.987e+04	-0.309	0.767674

a Multiple Regression Analysis: $\gamma 2 = 0.9907$, Adjusted $\gamma 2 = 0.9829$, $F (5, 6) = 127.5$, $\varrho <0.01$.
b Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4. ANALYTIC RESULTS

In-order to explore the relationship between the variables in this study, a coefficient analysis was carried out. The correlation matrix of the variables is presented in the Appendix section (Table A) of this paper. The results show that the patent count is positively correlated with R&D investment, education level, labor capacity and technology transfer, but a negative relationship was found between it and tax subsidies on R&D. Also, there was a positive relationship between R&D investment and education level, labor capacity, and technology transfer, but a negative relationship was observed between it and tax subsidies on R&D. In addition, education level was positively related to labor capacity and technology transfer, but not with tax subsidies on R&D. Surprisingly, labor capacity was positively correlated with technology transfer and tax subsidies on R&D, while technology transfer was not related to tax subsidies on R&D.

The results of the multiple regression analysis carried out in this study were presented in Table 8. From the results in Table 8, it can be seen that the model used in this study represents a strong relationship between the factors that influence the performance of the DIIC. The r-squared value of $\gamma 2 = 0.9907$ shows that all the independent variables considered were necessary for innovation within the Daedeok Innopolis Innovation Cluster.

The results of earlier studies show that the performance of an IC was correlated with the public funding of education, public funding of R&D, labor capacity, tax subsidy rates on R&D expenditures, and the transfer of technology (unilaterally). Also, in the multi-variable analysis carried out on the DIIC, the result shows that there is a strong relationship between the performance of an IC and the R&D funding, labor capacity, number of technology transfer but not education level of employees, and tax subsidies on R&D. This was based on the significant level assigned to the variables in Table 8. The results show that a key factor involved in the performance of the DIIC has been the Korean governments drive to champion and actively participate in coordinating the activities of the IC. The Korean government invested actively and developed policies in education and research to build human capital within and outside the science park. This is true because the Japanese and the Korean government have been leading other countries in terms of technology innovation governance; which focuses on greater public - private partnership (in the specialized technology industries), encouraging entrepreneurship, enhancing research - university incubators and

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prioritizing technological innovation capacity building projects (Sharif, 2012; Hobday 1995; Cho et al., 1998).

In this study, government drive was divided into two forms. The first was government funding of education and the second was government's spending in research endeavors. Hill (2008) in his study of public spending in the United States on various programs (bordering education and research) concluded that it has been effective in driving innovation in the economy. Also, the human development plan of institutions within the science park has been an important factor to the innovativeness of the clusters. The three main institutions within the Korean NIS (U-G-F) focus on improving labor productivity of their staffs to drive growth. The competitiveness of ICs in East Asian countries, including the DIIC, is as a result of these ICs focusing on building the technological capabilities of their staffs (Park 2011; Hobday, 1995; Yeung, 2009). On the other hand, it was discovered that the economic support from the government, such as tax subsidies on R&D had no effect on the impact on productivity within the Daedeok Innopolis cluster. Furthermore, technology transfer was an important factor in the performance of the IC. Based on the results obtained herein, the revised 'Multiple Skipping Development trajectory' theory has been successfully examined empirically. This means the extension made to the original model was viable.

5. DISCUSSION AND CONCLUSION

While Nigeria is still struggling with high levels of poverty, experts and policy makers are seeking effective methods to help resolve this ongoing dilemma. The current economic condition in Nigeria is severe and is a source of concern to the government, its citizenry, economic experts, and financial experts. These professionals are actively seeking solutions to the problem of poor economic performance in Nigeria (Oyedele and Aluko, 2018; Igbedioh, 1993; Folorunso, 2007). Even though the Nigerian government has identified and recognized the importance of ICs in driving economic growth, the federal government is yet to complete its pilot IC (the ATV). Nigeria is widely regarded as the giant of Africa; this is mainly because it has the largest economy in Africa. However, just like every other country in Africa, it is still a developing country with poverty on the rise and an ailing economy. Similarly, after the Korean War in 1950, the Korean economy was in a similar situation like Sub-Saharan Africa country today. However, the Korean government was able to build its economy through the enhancement of its NIS, of which the DIIC played an important role. Based on this, this research set out to study the factors that were involved in helping the DIIC achieve this feat. Over the years, factors responsible for the performance of several ICs across the world have been studied. But, most of these studies have been unilateral in nature and sometimes qualitative research. However, in this research a quantitative multiple variable approach was used.

Shenkoya and Kim (2018) - in their research on the Korean NIS - concluded that the Korean NIS (including the DIIC) was important in the fast development of Korea from a developing country to a developed country. Therefore, in this study, the DIIC was studied to determine the factors that influenced its contribution to the economic growth in Korea, while seeking to discover useful lessons for the enhancement and development of the ATV in Nigeria. But how was the DIIC used as a tool for development? According to Oh and Kang (2011), the initial plan of developing the DIIC was to improve the national techno-economic competitiveness of the Korean economy through research for economic growth. However, the DIIC has evolved into a powerhouse that drives the sustainable regional development in Korea. In this study, the 'Multiple Skipping Development Trajectory' theory was revised by infusing more factors (established by earlier research) that affect the performance of ICs. This theory was used to develop the analytical model used herein. Even though previous studies showed that factors that spur innovation within the NIS include public spending in education, government spending on research, labor capacity, the number of technology transfer, and tax subsidies. When all these factors were considered together, the result shows that there is a strong relationship between the performance of an IC and the R&D funding, labor capacity, and the number of technology transfer but not education level of employees, and tax subsidies on R&D.

Therefore, based on the result obtained in this study, it is recommended that the Nigerian government seeks ways of completing the ATV and make it a fully operational IC, in the shortest possible time. Furthermore, it is important that the Nigerian government invest in the quality of education in the country. This will help improve the capabilities of the prospective workforce in the IC. Also, the government needs to set aside funds for R&D and the development of clusters of innovation within the country as a stand-alone in its yearly budget. The Nigerian government should enact and implement poli

Table 9. Evolution of the Korean Government's S&T policies

Period	Main goal of the S&T policy
2003-2007	improve the S&T innovation system in Korea (government led initiative) develop the regional innovation capability in Korea focus on prospective S&T opportunities for the future develop a knowledge based economy to create jobs
2007-2012	improve the S&T innovation system in Korea (change from government led to private sector) improve national R&D efficiency seek for new opportunities in the S&T field
2012-date	develop regional innovation systems with focus on local competence increase local government participation and contribution to R&D create regional opportunities for S&T improvement improve national and international collaboration improve human capital development and manpower

Source: Author's compilation

cies that improve the investment activity of the government in education, investment in R&D, and labor capacity and the transfer of technology. However, it is very important that these funds should be used for what they are assigned to. Also it is suggested that the Nigerian National Budget should make adequate provisions for education and research as standalone to achieve this goal. Furthermore, the ATV (the first government IC) should be completed and given high priority in the development plans of the government. In-addition, the government can develop programs that will be implemented all across the country to improve R&D and education funding.

This will be beneficial to enhancing the NIS. The changes required within the Nigerian NIS can be effectively realized with the use of appropriate policies. As such the policy implication for the Nigerian government and policy makers will be discussed.

5.1 Policy Implications

However, what specific lessons can be learnt from the management of the DIIC? One of the key success factors in the development of the DIIC was the effective development and implementation of appropriate policies. The Korean government actively engaged in the development of policies to strengthen its NIS to be able to foster the growth and development of its economy. According to Shenkoya and Kim (2018), the economic development plan of the Korean government was essential to the development of its NIS. In Table 9, a summary of the goals of the Korean Government's S&T targets is detailed.

Regarding public spending in the education sector, the Korean educational system is ranked amongst the best in the world. Three factors are responsible for the growth of this sector; these include, social-cultural tradition, economic development and the educational model used (Shin, 2011). But most especially, the long term policy framework of the Korean government is responsible for the quality of education in the country (Lee, 2010; Lee et al., 2010; Byun and Kim, 2010). Furthermore, the Korean government also enacted various policies to enhance the public investment in the field of R&D. While studying the Biotechnology Small Medium Enterprises (SMEs), it was discovered that the support of the government; through the funding of R&D, is essential to firm innovation (Kang and Park, 2012). Also, the Korean government has been actively investing in R&D over the years, funding projects and giving grants to universities, as well as research institutions. On the other hand, the government use policies to enrich the labor productivity in Korea through the maximization of labor and by increasing the availability of skilled labor. Westphal (1990), in

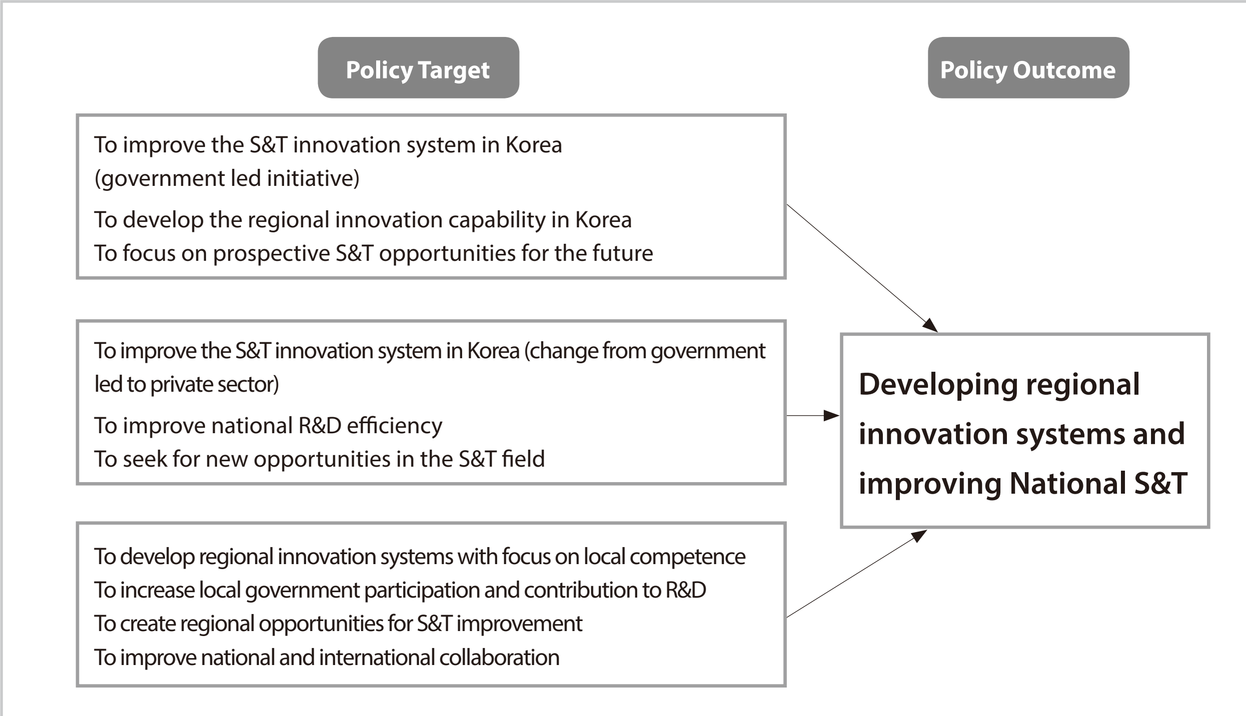

Fig. 2. Proposed S&T policy development framework for improving S&T in Nigeria

Source: Author's compilation

his study of the Korean government's policy, posits that the industrial policies of the Korean government have been essential to the rapid development of the country and its increasing international competitiveness. These policies encourage credit rationing, licensing and public enterprise creation. Studies on the evolution of the DIIC, show that one of the factors responsible for the success recorded by this IC, can be attributed to the government's leading role and the top-bottom leaders structure which has an umbrella policy (Hwang et al., 2018; Sharif, 2012; Jung and Mah, 2014).

From the above lessons learnt, from the Korean government, the Nigerian government can tailor the policy approaches successfully used by the Korean government in its NIS and the development of the ATV Innovation Cluster. These policies can be modelled as shown in Figure 2.

However, like every other research, this study has its limitations. First, the activities of the DIIC were not divided into sectors. Second, there are other factors such as political, cultural and social factors that may affect the performance of ICs that were not covered in this study. Therefore, future research to resolve these limitations are required.

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APPENDIX

• **Table A1**: Correlation Matrix of study variable

Variables	1	2	3	4	5	6
1	Registered Patents	1.0000000				
2	Total R&D Investment	0.93415036	1.0000000	–		
3	Education Level of Employees	0.96509882	0.97022117	1.0000000		
4	Labor Capacity	0.90171061	0.98491526	0.9434013	1.0000000	
5	No. of Technology Transfer	0.98682984	0.90869951	0.9560291	0.89066076	1.0000000
6	Tax subsidy rates on R&D expenditures	-0.03455128	-0.01550934	-0.0180101	0.03761687	-0.01598394