Available online at www.koozakar.com/journal/ajspim

African Journal of Science Policy and Innovation Management
OPEN ACCESS | PEER REVIEWED

The Nigerian Solar Energy Innovation System

Adeyemi O. Adepoju[1*], Joshua B. Akarakiri[2] and John-Felix K. Akinbami[2]
[1]Federal University of Technology, Akure, Nigeria
[2]Obafemi Awolowo University, Ile-Ife, Nigeria

*Corresponding author
Email: aoadepoju@futa.edu.ng

Article information

https://doi.org/10.69798/38425742

2756 – 4118
Copyright ©: 2024 The Author(s).
This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International (CC-BY-4.0) License, which permits the user to copy, distribute, and transmit the work provided that the original authors and source are credited.
Published by Koozakar LLC. Norcross GA 30071, United States

A Journal of the African Institute for Science Policy and Innovation, AISPI, Obafemi Awolowo University, Ile-Ife. Reproduced with permission. A prior edition of the African Journal of Science Policy and Innovation Management Volume 3 Issue 1, was published by Obafemi Awolowo University Press, Ile-Ife, Nigeria.

ABSTRACT

This study examined the breadth and depth of interactions undertaken by the knowledge driven elements in the Nigerian solar energy innovation ecosystem, and the constraints of interactions existing in the system. The study covered 5 geopolitical zones in Nigeria, namely, North Central, North-West, South-East, South-South and South-West. Data collected were predominantly from questionnaire administration on respondents in solar energy firms, universities and government agencies and institutes. The results showed that the level of interactions in the government agencies and research institutes with other stakeholders is very low. Similar result was found for the interactions of the universities in Nigeria with other stakeholders in the solar energy industry, while the firms' interactions belonged to the static or traditional typology. Policy mechanisms were suggested in this regard.

Keywords:
Interaction, technological capability, solar energy, innovation system, Nigeria.

1.0. Background

Interactions or openness are requisite for building technological capability within a nation's innovation system. The national innovation system (NIS) is a concept used to describe institutions and individuals who solely and jointly contribute to the development and diffusion of new technologies in a country (Nelson, 1993). The system, through its activities and interactions, initiate, import, modify and diffuse new technologies (Edquist, 1997). Education and Research, industrial production, finance, and public policy and regulation have been identified as the four key elements within the NIS (Freeman, 1987; Lundvall, 1993; Malerba, 2002). This study considers some of the important elements for the development of the solar energy sector in Nigeria. In the systems approach to innovation, if each part of a system does not interact with other parts, the system as a whole may not perform well. The explanation for this observation follows that the sum of the functioning of the elements in the system is quite often not equal to the functioning of the whole. It is evident that existing literature focuses attention on the firms as their unit of analysis (Oyelaran-Oyeyinka, 2003; Laursen and Salter, 2004; Laursen and Salter, 2006; Egbetokun *et al*., 2008; Iammarino *et al*., 2008; Iammarino *et al*., 2012; Egbetokun and Savin, 2014; Egbetokun, 2015a; Egbetokun, 2015b; Olomu *et al.*, 2016). Technological capability remains very important for long term economic growth (Lee, 2013). In the work of Iammarino *et al*. (2008) technological capabilities at the micro-level is defined as the knowledge and skills that the firm needs to acquire, use, adapt, improve, and create technology (knowledge, product or service). The evolutionary theory considers technological change in the industrial latecomer environment as an output of the firm via the development of their technological capabilities (Dutrenit, 2004). Multinational companies were viewed to be the vanguards of transferring technology from one country to another. Thus, the developing countries lacked the indigenous technological capabilities to generate new technologies and became beneficiaries of international technology transfer. Majority of the developing nations, in particular Nigeria, lack most ingredients required for capability building (Egbetokun, 2015b). In this paper, we use the definition of technological capability found in Iammarino *et al*. (2008) as 'the outcome of complex interactions among individuals, firms, and other organizations within specific institutional frameworks and geographical locations. According to Egbetokun (2015b), building technological capabilities requires firms to engage in a process of technological learning where imported technologies and interaction with knowledge-bearing institutions play a crucial role. Interactions are important within a nation's Innovation System (NIS). There are several reasons why firms and other elements in the NIS framework engage in interaction or openness, collaboration, and/or form alliances. Basically, firms interact with other parts of their innovation system to gain insight into useful technological information (Egbetokun, 2015a). Inter-firm alliances are becoming more pronounced nowadays due to rapid technological progress and changes in the business environment. Short-lived technological knowledge and rising costs of research and development (R&D) make it virtually impossible for any firm to be isolated and maintain in-house capabilities and knowledge required for production all alone. More often than not, firms require knowledge that lies outside their core competences. Hence, the formation of alliances with other organisations has proven to be an effective way to access external knowledge to complement endogenous capabilities (Powell and Grodal, 2005).

The knowledge network in this paper is the one referred to as the structure and interactions of knowledge actors within the NIS (Oyelaran-Oyeyinka, 2003). This network comprises of network agents possessing different technological capabilities, in which core and linkage capabilities determine the depth of firms' innovativeness. Laursen and Salter (2006) developed the concepts of breadth and depth as the two components of the interaction of individual firms' external search strategies. This concept for firms is adopted for the other actors in the NIS considered for this study, that is, universities and research institutes. Egbetokun (2015b) opined that this interaction was in two modes, formal and informal. While the formal interaction involves a collaboration agreement, informal interaction means that an external source acts as a source of information for innovation (Freitas *et al*., 2011). These approaches include other types of elements interacting under a specific socio-economic and institutional framework including firms, universities, research institutes, finance institutions, suppliers and other related firms. At this level, it is believed that other types of elements interact with one another under a

specific socio-economic and institutional framework (Iammarino *et al.*, 2008).

Ajayi *et al.* (2011) opined that the interdependence between energy availability, its supply, demand and utilization is one of the factors that control national development. Based on this, efforts are mostly geared toward seeking ways of producing sufficient energy for the populace. The Nigerian government has shown commitment to this cause through the recent revision of the Renewable Energy Master Plan (REMP) initially developed in 2005 under the sponsorship of the United Nations Development Programme (UNDP) (ECN, 2017). REMP was put in place to provide a road map for the effective implementation of the renewable energy (RE) component of the National Energy Policy (NEP). The obligations are on a long-term basis for renewable electricity to contribute about 20 percent of total electricity supply in the country. In addition, the available capacity of 4,500 MW, can only meet one-third of the estimated demand (Saifuddin *et al.*, 2016). As laudable as RE potentials are to Nigeria's electricity generation, perceived high costs of investment and political-will have stunted its development. Since 2008, however, solar photovoltaic (PV) module prices have fallen and thereby have become affordable (IRENA, 2015). The Nigerian government has identified that a policy impetus (National Energy Master Plan) is necessary to aggressively pursue the integration of solar energy into the national energy mix, based on established national potentials and available technologies (ECN, 2014). The realisation of this laudable objective can be met in an environment where elements in the solar energy system of innovation adequately interact.

This study provides strategic intelligence on the range of interactions existing among the elements in the Nigerian solar energy system of innovation (NSESI). This entails (i) the portfolio or breadth of interactions; (ii) depth of interactions undertaken by each of the knowledge driven elements in the NSESI and (iii) the constraints of interactions existing in the universities and firms particular. This is critical to the deployment of solar energy in Nigeria. The successful deployment of solar energy can increase national potentials for jobs creation. Once the value chain is localised, RE can create linkages and spill-over effects in other related sectors and can be an important source of employment.

2.0. Methodology

The main instrument is a set of structured questionnaire designed to collect information from the firms, faculty members, and the research institutes belonging to the Nigerian Federal Ministry of Science and Technology.

2.1. Study area

The study area was selected from five of the six geo-political zones in Nigeria, namely; the North Central Zone; consisting of the Federal Capital Territory (FCT), and Niger and Kwara States; North West Zone capturing Sokoto State; the South East Zone, comprising of Enugu State; the South-South Zone; with Rivers State; and the South West Zone consisting of Lagos, Osun, Ondo and Ogun States. The FCT, Rivers and Lagos States were selected due to predominance of solar energy firms in the States. The choice of the remaining states was as a result of the presence of universities offering science and engineering courses required to build competence and capability to support the solar energy industry.

2.2. Population and sample size

a. Population

A population is the set of all objects under study (Wooldridge, 2013). Therefore, the target population included:

i. Solar energy companies
ii. Universities offering Science and Engineering courses namely, Chemical Engineering, Mechanical Engineering, Materials Engineering and Metallurgy, Electrical Engineering, and Civil Engineering, Physics and Engineering Physics as well as Energy Management/Economics.
iii. Relevant Government agencies such as the National Centre for Energy Research and Development (NCERD), Nsukka; Sokoto Energy Research Centre (SERC), Sokoto; Energy Commission of Nigeria (ECN); National Agency for Science and Engineering Infrastructure (NASENI) and; Sheda Science and Technology Complex (SHESTCO) were selected.

b. Sample and sampling technique

A sample is a subset or representative of a population. Multi-stage sampling which includes cluster, random and purposive sampling techniques was used in the selection of the samples. Multistage

sampling technique requires at least two stages. In the first stage, large groups or clusters were identified and selected. Afterwards, the second stage involves selecting the sample either through random or purposive sampling. The selection of the universities is based on the following criteria:

i. National University Commission ranking of the universities;
ii. Frequency of published papers relating to renewable energy (importantly solar energy);
iii. Proximity of university to research institute established for the purpose of renewable energy development; and
iv. Proximity of university to a commissioned project on solar energy.

The selection of the firms in the solar energy sector were based on a simplified formula (equation i) for proportions at 95 percent confidence level (Yamane, 1967; Israel, 2012).

$$n = N/(1 + Ne^2) \quad \text{(i)}$$

The sample size is denoted as 'n', population size as 'N' and 'e' as the level of precision. A sample size of 60 firms was obtained from a population size of 73 firms found in the business directory belonging to solar energy firms based on Israel's formula. A total of five government agencies and research institutes directly linked to solar energy research and development were surveyed. A simple random sampling method without replacement was adopted in the selection of respondents for the study. A total of 335 respondents were surveyed out of which only 296 sets of questionnaire were returned.

2.3. Pair-wise ranking method

Pair wise ranking is used to rank a list of concerns. Ranking helps the researcher to make decisions on the most important variables (Kitula, 2006). The step-by-step process is as follows;

i. In the cell where the first and the second issues intersect, the more important issue is noted. The first issue is then compared to the third issue and then the fourth and so on. The more important issue in the intersecting cell is once again noted. This procedure is undertaken for all the remaining issues keeping in mind the more important issue for each pair in the intersecting cell.
ii. In the second stage, the same procedure in 1 above is repeated for all the other issues by comparing it to all other issues. Fewer comparisons will begin to appear the more issues are compared.
iii. The number of times the first issue was determined to be the higher priority is then counted across the rows.
iv. The process in 3 is then repeated for all the issues and the issue that was named the highest priority the most often is the group's top issue.

3.0. Results and Discussion

3.1 Interactions between the government agencies and research institutes (RIs)

The research institutes are special organs of the ministries. One of their responsibilities is to provide new knowledge and support innovative activities. Table 1 lists the various collaborators that RIs can interact with for the purpose of developing science and technology capabilities. Other collaborators with the exception of banks were found to have low interactions with the RIs. It was not surprising that the banks were not interacting with RIs as they (the research institutes) are being funded by the Federal Government.

Table 1: Breadth of Interaction in the Research Institutes (RIs)

Collaborator	Not at All (%)	Low (%)	Medium (%)	High (%)	Index
Other RIs	3 (14.3)	9 (42.9)	7 (33.)	2 (9.5)	L
Universities	3 (14.3)	3 (14.3)	11 (52.4)	4 (19.0)	M
Polytechnics	6 (28.6)	11 (52.4)	4 (19.0)	-	L
Suppliers	5 (23.8)	9 (42.9)	6 (28.6)	-	L
Banks	13 (61.9)	5 (23.8)	3 (14.3)	-	NA
Solar firms	4 (19.0)	11 (52.4)	5 (23.8)	1 (4.8)	L
Average	5	8	6	1	L

NA = Not at All; L = Low; M = Medium; H = High

In Table 2, the study ranked the extent of RIs interaction with the collaborators. The results show that interaction with the universities is ranked first. This is followed by interactions with other RIs, solar firms and suppliers in that order. The other collaborators such as the polytechnics and the banks came fifth and sixth respectively. On the average, the level of interaction in the RIs was found to be very low.

Table 2: Pair-wise Ranking of Breadth of Interaction in the RIs

Breadth	A	B	C	D	E	F	Rank
Other RIs							2nd
Universities	2						1st
Polytechnics	1	2					5th
Suppliers	1	2	4				4th
Banks	1	2	3	4			6th
Solar firms	1	2	6	6	6		3rd
Frequency	4	5	1	2	0	3	

Table 3 shows that from fourteen sets of possible forms of interaction, affiliation to a university was ranked first. It can also be seen from Table 3 that training programs, workshop and conferences were also an important form of interaction engaged in by the RIs, as they were ranked second. It is also interesting to note that consultants on solar energy technology came third, and employees on the rank of supervisor in Ministries came fourth. There was a tie for the fifth position between useful information obtained from suppliers to aid research and member of a team on government policy.

There was also a tie in the sixth position between external examiner in a university and use of other universities' lab facilities. Bank collaboration to aid research came last in twelfth position. This may be associated with the poor technological competence and lack of adequate facilities in the RIs.

Table 3: Pair-wise Ranking of Depth of Interactions in RIs

Depth	1A	2B	3C	4D	5E	6F	7G	8H	9I	10J	11K	12L	13M	14N	Rank
University Affiliation															1st
University Examiner	1														6th
Supervisor to Agency Staff	1	3													4th
Supervisor to firm Owner	1	2	3												11th
Secondment to University	1	2	3	5											8th
Secondment to RIs	1	2	3	6	5										9th
Training, Workshop etc.	1	7	7	7	7	7									2nd
RIs Lab Facilities	1	2	3	8	8	8	7								7th
University Lab. Facilities	1	0	3	9	9	9	7	9							6th
Consultant	1	10	10	10	10	10	7	10	0						3rd
Information from Suppliers	1	11	0	11	11	11	7	11	0	10					5th
Bank aid for Research	1	2	3	4	5	6	7	8	9	10	11				12th
Government Policy Team	1	13	3	13	13	13	7	13	0	10	0	13			5th
Commercialisation with Firm	1	2	3	14	5	6	7	8	9	10	11	14	13		10th
Frequency	13	6	9	1	4	3	12	5	6	10	7	0	7	2	

3.2. Interactions in the universities

Technological development and institutional environments co-evolve and thereby bring about relevant albeit gradual changes in knowledge structure. Therefore, institutional behaviour and cooperation patterns between universities and other counterparts in the national innovation system (NIS) are decided to a large extent by social factors that are institutionalized over time. On this note, the study examined some collaborators within the NIS as breadth or portfolio of interactions, and also their form of interaction as the depth. Table 4 shows the level of portfolio of interactions found among the Nigerian universities. It would be observed that generally all the interactions with the collaborators are very weak and low.

In Table 5, the results show that among the collaborators that the universities engaged with the most are the departments within the same organization; this was followed by the collaborations with the RIs. The interactions with other universities occupied the third position, followed by the suppliers and then interaction with solar firms. The last position was also occupied by the banks similar to the results found with the RIs.

Table 4: Breadth of Interaction in the Universities

Collaborator	Not at All (%)	Low (%)	Medium (%)	High (%)	Index
within Department(s)	57(25.4)	77(34.4)	68(30.4)	21(9.4)	L
Other Universities	66(29.5)	81(36.2)	65(29.0)	11(4.9)	L
Research Institutes	61(27.2)	75(33.5)	70(31.3)	11(4.9)	L
Suppliers	73 (32.6)	84(37.5)	52(23.2)	10(4.5)	L
Banks	140(62.5)	45(20.1)	30(13.4)	4 (1.8)	NA
Solar firms	83 (37.1)	87(38.8)	41(18.3)	9 (4.0)	L
Average	80	75	54	11	L

Table 5: Pair-wise Ranking of Breadth of Interactions in the Universities

Collaborator	A	B	C	D	E	F	Rank
Other Department(s)							1st
Other Universities	1						3rd
RIs	1	3					2nd
Suppliers	1	2	3				4th
Banks	1	2	3	4			6th
Firms	1	2	3	4	7		5th
Frequency	5	3	4	2	0	1	

The pair-wise ranking of form of interactions shown in Table 6 revealed that training programs, workshops and participation in conferences had the most depth of interactions engaged in by the university's faculty members. The second and third on the list are use of other universities laboratory facilities, and use of other facilities within a university, respectively. This is an indication that research laboratory facilities are not adequately equipped in a particular university which may be attributed to government distribution of important equipment based on regional allocation or quota. Equally, some state or private universities which cannot afford such expensive facilities may have to seek for such in the federal university located within close proximity. It was also surprising to find out that interaction among faculty members within the university was weak. This confirmed the result of earlier study conducted by Oyelaran-Oyeyinka and Adebowale (2012) who reported that interactions between the various university departments itself is weak as a result of lack of information and absence of incentives amongst researchers to indulge in joint research.

Table 6: Pair-wise Ranking of Depth of Interactions in the University

Depth	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Rank
Internal Examiner																7th
External Examiner	1															8th
Supervisor Ministry Staff	1	2														9th
Supervisor Firm Owner	1	2	3													11th
Secondment University	1	2	3	5												10th
Secondment RIs	1	2	3	4	5											12th
Training, Workshops, Conferences	7	7	7	7	7	7										1st
RIs Laboratories	8	8	8	8	8	8	7									4th
Other Universities Labs	9	9	9	9	9	9	7	9								2nd
Facilities in another Department	10	10	10	10	10	10	7	10	9							3rd
Consultant	11	11	11	11	11	11	7	8	9	10						6th
Suppliers	12	12	12	12	12	12	7	8	9	10	12					5th
Bank	1	2	3	4	5	6	7	8	9	10	11	12				15th
Government Policy Team	1	2	3	4	5	6	7	8	9	10	11	12	14			13th
Collaboration of Products	1	2	3	4	5	6	7	8	9	10	11	12	15	14		14th
Frequency	8	7	6	4	5	3	14	11	13	12	9	10	0	2	1	

In Table 7, the results present the constraints responsible for the weak interactions noticed in the universities. The table shows that the first constraint preventing faculty members from interaction with other stakeholders in the NIS is inadequate research facilities to conduct industrially oriented research. This result is consistent with the earlier work of Akinwale (2016). On the second position is the low commercialization potential of university research outputs, followed by inadequate mechanisms for interaction and the time constraint due to teaching and other academic work occupying the fourth position. Others are interest rate charged by the banks, lack of motivation and entrepreneurial spirit, lack of interest of financial institutions in sponsoring research work in the universities were the fifth, sixth and seventh position respectively. It was interesting to note that in the tenth and last position were that the faculty members are not competent enough to undertake developmental research, and solar companies were not interested in interacting with the universities.

3.2. Interactions in the firms

Several reasons abound as to why firms look to create linkages with other actors within the NIS framework. First, firms seek external knowledge

Table 7: Pair-wise Ranking of Constraints of Interactions in the Universities

Constraint	A	B	C	D	E	F	G	H	I	J	K	Rank
Competency of Academic Scholar												10th
Time Constraint due to Heavy Teaching Work	2											4th
Inadequate Mechanism for Interaction	3	3										3rd
Inadequate Research Facilities	4	4	4									1st
Lack of Motivation	5	2	3	4								6th
Low Commercialisation Potential Research Outputs	6	6	6	4	6							2nd
No Collaboration Policy	7	2	3	4	5	6						9th
No Interest from Firm	1	2	3	4	5	6	7					11th
Lack of Interest from Financial Institution	9	2	3	4	5	6	9	9				7th
High Interest rate Charges by Banks	10	2	3	4	10	6	10	10	10			5th
No Separate Research Institute mainly for Solar Energy	11	2	3	4	5	6	11	11	9	10		8th
Frequency	1	7	8	10	5	9	2	0	4	6	3	

because of growing complexity involved in the optimal allocation of resources for profit maximization. Secondly, they do so because of the interactive nature of learning (Oyelaran-Oyeyinka and Adebowale (2012). Based on these two reasons, the study examined the level of interactions found in solar energy firms in Nigeria.

Table 8 shows the level of collaboration firms have with other actors in the innovation system. The table shows in all cases that the firms engage in networking most with the suppliers than any other collaborator. This gave credence to earlier studies (Oyelaran-Oyeyinka, 2003; NACETEM, 2013).

Table 8: Breadth of Interaction in the Firms

Interaction	Not at All (%)	Low (%)	Medium (%)	High (%)	Index
Universities	12(23.5)	10(19.6)	12(23.5)	16(31.4)	M
Research Institutes	8 (15.7)	7 (13.7)	19 (37.3)	16 (31.4)	M
Suppliers	1 (2.0)	6 (11.8)	18 (35.3)	25 (49.0)	H
Banks	4 (7.8)	12 (23.5)	20 (39.2)	14 (27.5)	M
Local firms	2 (3.9)	8 (15.7)	17 (33.3)	22 (43.1)	M
Foreign firms	7 (13.7)	18 (35.3)	15 (29.4)	10 (19.6)	L
Average	5	10	16	17	M

M = Medium; H = High

Table 9 revealed that firms' collaboration with the suppliers were ranked first followed by interaction with the local firms or competitors. Others such as RIs, banks and universities were ranked third, fourth and fifth respectively. It is not surprising that interaction with the foreign firms was ranked the least. This is an indication that most interactions of the firms are with their suppliers. While the solar energy sector has been in existence for a few years in the country, production capability is still lacking, hence the observed trend in the results. The study also agrees with the results of Sobanke *et al*. (2014) on the determinants of technological capability of firms in a developing country. They found out that firms collaborate mostly with their suppliers in the developing context and rarely interact with the knowledge institutions such as researchers in the universities and government research institutes. Laursen and Salter (2004) also reported that the number of firms who draw from knowledge institutions for their innovative activities are far less than those who interact with "market-related" and "specialized" sources. In a nutshell, the level of collaborations or interactions revealed in this study could be categorised as static or traditional according to the typology in Oyelaran-Oyeyinka (2003).

Table 9: Pair-wise Ranking of Breadth of Interaction in the Firms

Breadth	A	B	C	D	E	F	Rank
Universities							5th
RIs	2						3rd
Suppliers	3	3					1st
Banks	4	2	3				4th
Local firms	6	6	3	6			2nd
Foreign firms	1	2	3	4	6		6th
Frequency	1	3	5	2	4	0	

Firms in a static quadrant are characterised by lack of knowledge networking, poor learning, largely supplier networking, mainly agglomerative benefits and very weak linkage capabilities

The solution suggested by Mazzarol (2004) is for the firms to move away from their traditional circles (homophilous groupings), where relationships are usually strong but knowledge exchange is isomorphic (similar), into new circles (heterophilous groupings) where social relationships are not as strong, but new ideas and tacit knowledge can be exchanged via social interaction. Table 10 shows the depth of interactions firms have with other stakeholders in the innovation system. Among the top ten from the table is the interaction due to organized workshops,

Table 10: Pair-wise Ranking of Depth of Interactions in the Firms

Depth	1A	2B	3C	4D	5E	6F	7G	8H	9I	10J	11K
Interaction within the firm											
Workshops, trainings and conferences	1										
Interactions with co-contractors	1	3									
Employing competitor's staff	1	2	3								
Interaction with faculty member of a universities	1	2	3	4							
Interaction with foreign university	1	2	3	4	5						
Knowledge obtained from local suppliers	1	2	3	7	7	7					
Knowledge obtained from foreign suppliers	1	2	3	8	8	8	7				
Interactions with similar firm	1	2	3	9	9	9	7	8			
Cooperation/alliance with other firms to execute projects	1	2	3	10	10	10	7	10	10		
Consultant to Knowledge institutions	1	2	3	11	11	11	7	8	9	10	
Commercialisation of product from knowledge institutions	1	2	3	12	12	12	7	8	9	10	11
Team member with staff of university on a project	1	2	3	4	5	13	7	8	9	10	11
Team member with staff of RIs/ministries	1	2	3	14	14	14	7	8	9	10	14
Obtained certification/diploma from RIs	1	2	3	4	5	15	7	8	9	10	11
Team member to develop national policy	1	2	3	4	5	16	7	8	9	10	11
University student internship	1	2	3	17	17	17	7	8	9	10	17
Project financing credit from commercial banks	1	2	3	4	5	18	7	8	9	10	11
Bank guarantee from commercial banks	1	2	3	4	5	19	7	8	9	10	11
Overdraft facilities to meet daily activities from banks	1	2	3	4	5	6	7	8	9	10	11
Invoice discounting to get good/service from third parties	1	2	3	4	5	21	7	8	9	10	11
Foreign grant or aid through bank	1	2	3	4	5	6	7	8	9	10	11
Financial support from government	1	2	3	4	5	6	7	8	9	10	11
Frequency	22	20	21	11	10	3	19	17	16	18	13

Table 10: Pair-wise Ranking of Depth of Interactions in the Firms (Continued)

Depth	12L	13M	14N	15O	16P	17Q	18R	19S	20T	21U	22V	23W	Rank
Interaction within the firm													1st
Workshops, trainings and conferences													3rd
Interactions with co-contractors													2nd
Employing competitor's staff													12th
Interaction with faculty member of a universities													13th
Interaction with foreign university													19th
Knowledge obtained from local suppliers													4th
Knowledge obtained from foreign suppliers													6th
Interactions with similar firm													7th
Cooperation/alliance with other firms to execute projects													5th
Consultant to Knowledge institutions													10th
Commercialisation of product from knowledge institutions													11th
Team member with staff of university on a project	12												16th
Team member with staff of RIs/ministries	14	14											9th
Obtained certification/diploma from RIs	12	15	14										14th
Team member to develop national policy	12	16	14	15									15th
University student internship	17	17	17	17	17								8th
Project financing credit from commercial banks	12	13	14	15	16	17							18th
Bank guarantee from commercial banks	12	13	14	15	16	17	19						17th
Overdraft facilities to meet daily activities from banks	12	13	14	15	16	17	18	19					20th
Invoice discounting to get good/service from third parties	12	13	14	15	16	17	18	19	21				18th
Foreign grant or aid through bank	12	13	14	15	16	17	18	19	20	21			21st
Financial support from government	12	13	14	15	16	17	23	19	20	21	22		21st
Frequency	12	7	14	9	8	15	4	6	2	4	1	1	

trainings and conferences which is third on the list, knowledge from local and foreign suppliers are fourth and sixth respectively on the table. This further reinforces the importance of suppliers to the solar energy firms in Nigeria. Also very important to the firms is the cooperation with competitors to execute a project and to solve problems that may arise during project execution. It is also noteworthy that firms have more interactions with the research institutes than with universities. From Table 10, the

bottom half of the ranking shows that firms dealing in solar energy also engage in aggressive acquisition of people from their competitors. This is an indication of recognition of the importance of tacit knowledge as compared with to codified knowledge.

Table 11 shows the constraints preventing firms from collaboration with other actors. The study found out that interest rate charges by banks is assumed too high. The situation is explicitly explained by Panda and Ramanathan (1996) on why technological capability assessment can offer several benefits to a firm. One of such is the view of the financing agencies which may charge a higher interest rate on the capital they lend to a firm having a low level of technological capability. This is followed by inadequate interaction mechanisms and lack of adequate research facilities. The study gave credence to the work of Oyelaran-Oyeyinka and Adebowale (2012) that reiterate the need to establish bridging institutions between the knowledge institutions and the firm.

Table 11: Pair-wise Ranking of Constraints of Interactions in the Firms

Constraint	1 A	2 B	3 C	4 D	5 E	6 F	7 G	8 H	9 I	10 J	11 K	12 L	13 M	Rank
Scholars lack of competence in developmental research														5th
Supplier not competence to produce replica	2													4th
No adequate mechanism for interaction	3	3												2nd
Universities lack adequate research facilities	1	2	3											6th
No interaction interest from the universities	1	2	3	4										10th
Low commercialisation potential outputs from knowledge institutions	1	2	3	4	6									8th
Don't know who to meet for collaboration in knowledge institutions	1	2	3	4	7	7								7th
Low capital base of Nigerian banks	1	2	3	4	5	6	7							11th
Banks perception of solar technologies as risky	1	2	3	4	9	6	7	9						9th
High interest rate by banks	10	10	10	10	10	10	10	10	10					1st
Lack of research facilities in RIs	11	11	3	11	11	11	11	11	11	10				3rd
No separate department for solar energy	1	2	3	12	12	6	7	12	9	10	11			9th
No separate research institute for solar energy development	1	2	3	4	5	13	13	13	13	10	11	13		7th
Frequency	8	9	11	6	2	4	5	0	3	12	10	3	5	

4.0. Conclusion

The study concluded that the rank of interaction in RIs was very low. It was also evident from the RIs that interaction with the financial institution was very poor. This might be because the RIs are not profit driven organisations. These noticeable results in RIs were also similar in nature to those observed in the universities. With respect to the firms the study concluded that the category of interactions obtained belonged to the static or traditional typology. It should be recalled that the highest ranked constraint of interaction in the firms was the interest rate on loan obtained from the bank, which is a clear indication towards low technological capability.

References

Ajayi, O. O., Fagbenle, R. O., Katende, J. and Okeniyi, J. O. (2011). Availability of Wind Energy Resource Potential for Power Generation at Jos, Nigeria. *Frontiers of Energy*, 5(4): 376–385.

Akinwale, Y. O. (2016). Indigenous Technology and Innovation Capability Building in Nigerian Upstream Oil and Gas Subsector: The Academia Perspective. *Advances in Management and Applied Economics*, 6(2): 49-70.

Dutrénit, G. (2004). Building Technological Capabilities in Latecomer Firms: A Review Essay. *Science Technology Society*, 9(2): 209–241.

Energy Commission of Nigeria- ECN (2012).Renewable Energy Master Plan-updated. Abuja, Nigeria.

Edquist, C., ed. (1997). Systems of Innovation Technologies, Institutions and Organizations. London and Washington: W.W. Norton. Egbetokun, A. A. (2015a). The More the Merrier? Network Portfolio Size and Innovation Performance in Nigerian Firms. *Technovation*, 43-44, 17-28.

Egbetokun, A. A. (2015b). Interactive Learning and Firm-Level Capabilities in Latecomer Settings: The Nigerian Manufacturing Industry. *Technological Forecasting and Social Change*, 99(1): 231-241.

Egbetokun, A. A., *et al.* (2008). Innovation in Nigerian SMES: Types and Impact. Paper presented in the IV GLOBELICS Conference at Mexico City, September 22-24, 2008.

Egbetokun, A. and Savin, I. (2014). Absorptive capacity and innovation: when is it better to cooperate? *J. Evol. Econ.*DOI 10.1007/s00191-014-0344-x.

Freeman, C. (1987), Technology Policy and Economic Performance: Lessons from Japan. London: Frances Printer.

Freitas, I.M.B., Clausen, T., Fontana, R., Verspagen, B., (2011). Formal and informal external linkages and firms' innovative strategies.A cross-country comparison. *J. Evol. Econ*. 21, 91–119.

Iammarino, S., Padilla, R. and von Tunzelmann, N. (2008). Technological Capabilities and Global–Local Interactions: The Electronics Industry in Two Mexican Regions. *World Development*, 36 (10): 1980–2003.

Iammarino, S., Piva, M., Vivarelli, M. and von Tunzelmann, N. (2012). Technological Capabilities and Pattern of Innovative Cooperation of Firms in the UK Regions. *Regional Studies*, 46(10): 1283-1301.

IRENA, (2015). Renewable Energy Prospects: United Arab Emirates, Re-Map 2030 Analysis IRENA. Abu Dhabi. www.irena.org/remap.

Kitula, A. G. N. (2006). The Environmental and Socio-Economic Impacts of Mining on Local Livelihoods in Tanzania: A Case Study of Geita District. *Journal of Cleaner Production* 14: 405-414.

Laursen, K. and Salter, A. (2004). Searching High and Low: What Types of Firms use Universities as a Source of Innovation? *Research Policy*, 33(1): 1201-1215.

Laursen, K. and Salter, A. (2006). Open for Innovation: The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms. *Strategic Management Journal*, 27: 131–150.

Lee, K. (2013). Schumpeterian Analysis of Economic Catch-up: Knowledge, Path-Creation, and the Middle-Income Trap. Published in the United States of America by Cambridge University Press, New York.

Lundvall, B.A., (19 93). National Systems of Innovation. Frances Pinter, London.

Lundvall, B. A. (2015). The Origins of the National Innovation System Concept and its Usefulness in the Era of the Globalizing Economy.Paper at the 13th Globelics Conference, Havana in 23-26 September.

Malerba, F. (2002). Sectoral Systems of Innovation and Production. *Research Policy*, 31: 247-264.

Mazzarol, T. (2004).Small Firms, their Customers and the Value of Strategic Alliances and Networks to Innovation. Paper Presented at Australia and New Zealand Academy of Management Conference, Dunedin, New Zealand, 8-11.

Misra, K. B. (2008).Engineering Design: A System Approach.In the 'Handbook of Performability Engineering' Edited by Misra, K. B. ISBN: 978-1-84800-130-5, Springer.

National Centre for Technology Management (NACETEM) (2013), Assessment of Technology Innovations in Manufacturing Industries in Small Scale Industrial Estate in Lagos, Monograph Series Number 11, Lagos, Nigeria.

Nelson, R., 1993. National Innovation Systems: A Comparative Study. Oxford University Press, Oxford.

Olomu, M. O., Akinwale, Y. O. and Adepoju, A. O. (2016).Harnessing Technological and Non-Technological Innovations for SMEs Profitability in the Nigerian Manufacturing Sector. *American Journal of Business, Economics and Management*, 4(4): 75-88.

Oyelaran-Oyeyinka, B. (2003). Knowledge Networks and Technological Capabilities in the African Manufacturing Cluster. *Science Technology Society*, 8(1): 1-23.

Oyelaran-Oyeyinka, B. and Adebowale, B. A. (2012).University-Industry Collaboration as a Determinant of Innovation in Nigeria.*Institutions and Economies*, 4(1): 21-46.

Panda, H. and Ramanathan, R. (1996). Technological Capability Assessment of a Firm in the Electricity Sector. *Technovation*, 16(10): 561-588.

Powell, W. W. and Grodal, S. (2005). Networks of innovators. In: Fagerberg J, Mowery DC, Nelson RR (eds) Oxford handbook of innovation, vol 3. Oxford University Press, Oxford, pp 56–85.

Sobanke, V., Adegbite, S., Ilori, M. and Egbetokun, A. (2014).Determinants of Technological Capability of Firms in a Developing Country. *Procedia Engineering*, 69(1): 991-1000.

Yamane, T. (1967). Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row.