Triple Helix of university-industry-government relationships in West Africa

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ABSTRACT

The West African countries' scientific publications data are downloaded from Web of Science. Analyses focus on university-industry-government collaboration. We compute data on each sector's production and collaboration among them. Particularly, the industrial production is extracted; the network, it induces is built and its structure analyzed with social network analysis methods and techniques, using Pajek. Results show that the university is the biggest information producer, followed by government; the number of industrial publications is meaningless; even some countries have no industrial output. Consequently, collaboration between the university and government is more visible. Collaboration between the three Triple Helix spheres occurred only in Nigeria. The mutual information between university, industry, and government is weak, illustrating the low level of knowledge flow between innovation actors in the region. These results could explain the negligible share of the developing countries in general and African and West African countries particularly to the World economy, and also the low level of development the region.

Keywords: Innovation, innovation system, research policy, scientific production, Triple Helix, West Africa

INTRODUCTION

Traditionally, university teaches and researches; industry commercializes the results as products, while government sets up the regulatory framework, collects taxes and brings financial support. Knowledge-based economies need to sustain a high level of innovation due to the growing and strengthening of relations between the university and firms, the effects of information and communication technologies and the emergence of networks and the need to reduce bureaucratic layers.[1] The importance of Triple Helix between university, industry, and the government was stressed during the last decades. It ensures the

knowledge flow among the three sectors and contributes to economic growth and hence to social and economic development. Through innovation and the renewal of the political economy and social structure, the Triple Helix is the key to knowledge-based economic development;[1] furthermore, knowledge creation, flows, and capitalization also stimulates economic development and contributes to regional growth.[2]

The African continent counts five regions based on cultural, historical, geographical, and economic criteria:[1] the Northern (6 countries),[2] the Western (15 countries), the Central (9 countries), the Eastern (13 countries), and the Southern (10 countries). The West African Member States (in alphabetical order: Benin, Burkina

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1   Resolution CM/Res. 464 (XXVI) adopted by the African Unity Organization (now African Union) Council of Ministers meeting in its 26th ordinary session in Addis-Ababa (Ethiopia) from 23rd February to 1st March 1976. The countries list was updated in 2004.

2   Even though Morocco is an African country and belongs to the North from a geographical point of view, it is not member of the African Union due to political reasons. Therefore, it is not considered in the African Union's classification. However, in this study, we included it into the Northern region.

Faso, Cape Verde, Cote d'Ivoire, the Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo) together constitute the Economic Community of the West Africa States (ECOWAS), a regional economic integration organization. Three international language communities speaking French, Portuguese, and English can be distinguished in the region.

Both African Union, African regional economic communities and individual countries have recognized the role of science and technology for poverty alleviation and development.[3] Regional and financial institutions, UNESCO, and other international institutions support the formulation and implementation of science, technology, and innovation policy. Thus, article 27 of the ECOWAS Revised Treaty[4] clearly spells out that research should serve other sectors to develop and thus contribute to economic growth and social welfare.

Few studies have used bibliometric data to explore the relationship between different sectors mentioned above.[5] This paper aims to study the collaboration network between university, industry, and government in West Africa regarding scientific publishing and its effects on progress toward welfare. Specifically, we will provide answers to the following research questions: (i) What are the shares of university, industry, and government in the West African scientific output? (ii) To which extent do the three sectors collaborate in West African papers? (iii) How strong are the sectorial relations in each of the West African Member State? (iv) Which are the main actors of each sphere of the Triple Helix in the West Africa?

Political and Sectorial Governance within the ECOWAS

From their independence early 1960s to the end of the Cold War (end of 1980s), African States including ECOWAS Members States were ruled by single-party authoritarian regimes with central control and a state monopoly in all sectors of the economy. The fall of the Berlin Wall in 1989 had changed the deal at international level and most of the developing countries were forced to switch over to democracy with a liberalized political and economic system. West Africa integration institutions and Member States have recognized democracy as a system that sustains peace, stability, economic growth, social, and economic development and a prerequisite to regional integration[6] and committed to "deepen and strengthen the democratic

institutions using appropriate international standards" with an "ECOWAS of people" as target.

The ECOWAS adopted several sectorial policies including the ECOWAS Policy on Science and Technology (ECOPOST) in 2012 and the West African Common Industrial Policy (WACIP) in 2010. Especially, ECOPOST should help ECOWAS Member States to master all science fields to compete, to exchange with and to challenge the best research teams worldwide. Some of the problems the West African science is facing are:[7] (i) Lack of coordination between research programs and research activities, (ii) lack of human and financial resources and equipment, and (iii) insufficiencies or inadequacies of funding and equipment. The WACIP envisions to "maintain a solid industrial structure which is globally competitive, environment-friendly, and capable of significantly improving the living standards of the people by 2030".[8] The region's economic performance remains too inadequate (low GDP growth rate, extremely high inflation, etc.) to hope to have a positive impact on the socio-economic conditions of populations. The natural resources, especially agriculture products, are not valorized and the manufacturing industry contributes only 7% to GDP. The high-tech subsectors are not valorized. Even though West Africa has a vast wealth of untapped mineral resource,[8] these products locally undergo elementary processing. They are exploited by multinationals (often from the Western countries) that export for transformation into finished products. Major industries are in a limited number and are local branches of multinational companies. The ECOWAS industrial sector is still embryonic and therefore, not sufficiently diversified to produce a wide variety of intermediary and finished products. Over half of the industrial units operate at <50% of their capacities.[8] Industrial output is insignificant; it represents 1% of the World total output.[8] Currently, no ECOWAS country has a robust and solid productive secondary sector to transform the national economy and join the global competition.

Even though, there exit some political instabilities due to coup d'Etats and armed conflicts, democracy, recognized as a condition for economic and social development, has spread within the region recently.

In comparison with the Cold War period, this has installed a relative peaceful environment that favors investment and development of the private sector.

Previous Studies

The triple helix of university-industry-government relationships

The relationships between university, industry, and government have gained attention in recent decades. They resulted from the transformation of actors' role in the new economy. The Triple Helix concept that represents the necessary dynamics among the three sectors was elaborated on this basis.[9] If research activities exploit existing knowledge and produce new ones, knowledge circulation between innovation actors ensures its transformation into innovations. Innovation takes an important place in industrial development, economic growth, and wealth production. There is a positive correlation between the levels of research and development activities, the level of absorption capacity and the pool of knowledge that can be exploited.[2] Hence, the knowledge flow between actors can indicate the level of development and the self-organization of society or region.

Measuring the triple helix

Due to their importance in the economy, the Triple Helix relationships are object of indicators to allow for measurement of performances. Indicators have become a key aspect of works on university-industry-government relations and one-third of publications on Triple Helix indexed in Social Science Index dealt with indicators; some papers proposed the use of indicators of science-technology interaction; others are concerned with measuring information flows especially through entropy measures; a third category developed and applied indicators that go beyond patent counts and capture a lot of other relevant third mission activities of universities.[10]

The Triple Helix configuration can be depicted statically using social network analysis.[11] Indeed, citation or patent analysis borrowed indicators to social network analysis because citations establish links or relations between citing and cited items. Social network analysis techniques are used to analyze research collaboration between university, industry and government. Indicators like density, average degree, number of component, size of the largest component, percentage of main components, degree centralization, betweenness centralization, mean closeness score, maximum distance, diameter, and clustering coefficient were used.[5] Mutual information was developed as a measurement of the intensity of the relations among the Triple Helix.[11] Considering the relations between university, industry, and government as variables, the author argued that the interacting fluxes generate probabilistic entropy and might be measured as an indicator of entropy. The resulting value can be negative, null, or positive. A negative value means an absence of central control and hence a self-organization of the system. Therefore, more negative a transmission, more non-coordinated and self-organized is the system. Mutual information was extended to the forth involving internationally co-authored papers;[12] besides, mutual redundancy was proposed as the positional counterpart of the relational communication of information.[13] Mueller[2] proposed a model based on annual growth rate of economic output and growth rate of total factor productivity, research, and development activities in private enterprises and the generation of knowledge in universities, entrepreneurship activity, and university-industry relations.

Applying triple helix indicators

As mentioned before, there is sparse literature dealing with Triple Helix of university-industry-government relationships. For studies on bibliographic records, data sources are either Internet or multidisciplinary bibliographic national or international databases such as Web of Science. Mutual information approach[11] has mainly been used for three or four-dimensional systems (e.g., [11,12,14,15]). Social network analysis techniques were also used.[5] However, difficulties arise while attributing labels to records based on affiliations data[14] (p. 2454). For example, an institution's name only may not be sufficient to allow for categorization. As illustration, Chinese Academy of the Sciences (CAS) and the Chinese Academy of the Social Sciences (CASS) are considered either as public belonging to the government or university; consequently, two Chinese mutual information values were computed taking into account this dual categorization.[15] Whatever the case is, globally, university publishes more than government that, in turn, publishes more than industry. University's ranking is due to the continuous flow of PhD students[1] and publication mission of scholars. Because of these positions, university-government output is higher when bilateral relations among the sectors are considered, followed by university-industry and industry-government research output. The joint collaboration university-industry-government is the weakest due to the effect of the double Boolean operator AND.[11,12,14,16] Globally, relations between the three spheres depend on the political and economic conditions and also on the international environment.

Some studies dealt with the university-industry-government relationships in African countries: Nigeria,[17] South Africa[18] and the whole Africa;[19] in 2012, the Association of African Universities conducted a survey on university-industry linkages in Africa.[20] However, these studies did not use any indicator; they neither studied the whole West African region nor used bibliographic databases.

SUBJECTS AND METHODS

The elaboration of the Triple Helix of university-industry-government relationships approach lies in collaboration between the three sectors. Of course, collaboration may cover several aspects; furthermore, not all collaboration yield publications. In this paper, however, we focus on research collaboration understood as co-authorship because its entails the tacit transfer of information and knowledge.[5] It has become an indicator for scientific collaboration measuring and is widely used in Academia.[5,21-23]

We downloaded West African scientific publications data from Thomson Reuters' Web of Science over a 10-year period (2001-2010). The databases searched were Science Citation Index Expanded (SCI-EXPANDED), Conference Proceedings Citation Index-Science (CPCI-S), Conference Proceedings Citation Index-Social Science and Humanities (CPCI-SSH), and Index Chemicus (IC). The search expression was *(cu = dahomey or cu = benin) or (cu = ivory coast or cu = cote ivoire) or cu = niger or cu = senegal or (cu = caboverde or cu = cape verde) or cu = senegambia or cu = gambia or cu = ghana or cu = nigeria or cu = togo or cu = mali or cu = liberia or cu = sierra leone or cu = guinea or (cu = Burkina faso or cu = upper volta) or cu = guinea-bissau*. The 28,380 resulting records were downloaded into a bibliographic database managed with the CDS/ISIS[3] software application. Based on Leydesdorff's[11] method for address assignment, we established a list of words or abbreviations to attribute a label 'university', 'industry' or 'government' to each address. We applied some adaptations to the three international languages encountered in the region. Therefore, we coded a Pascal CDS/ISIS[4] program that assigned each address the corresponding label. A record may contain many addresses; therefore, one record may have two or more different

labels. The CDS/ISIS program was also instructed to read countries' name from addresses and automatically add the associated two characters ISO codes to the label. Non West African countries were given a unique identifier ZZ. Therefore, in the inverted file, a university in Benin appears under the label UNIV-BJ, an enterprise in a non-West African country appears under ZZ-INDU. Furthermore, a second CDS/ISIS program was used to generate the social network file for the joint collaboration for analysis with Pajek, a software application for large social network analysis.[27] The print service of CDS/ISIS was used to output some data into a text file for statistical analyses. Finally, we used the program proposed by Leydesdorff[5] to compute the mutual information between university, industry, and government.

We assigned labels to 84.37% of addresses, 96.20% of records and 88.4% of the West Africa-based addresses and 90% of the records if West Africa alone is taken into account [Table 1]. This identified a total of 13,162 institutions of which 5161 (38%) are based in West Africa.

RESULTS

It should be born in mind that numbers are very low for many sectors and that this analysis represents the emergence of research structure in a group of countries with historically low levels of R and D investment compared, for example, to Europe. This analysis therefore, provides both a case study of the present and a reference benchmark for the future.

Production Per Triple Helix Sphere

Over the period 2001-2010, there were university addresses on 19,145 (67.45%) papers, industry addresses on 145 (0.52%) papers, and government addresses on 8994 (31.09%) papers. Industry's 145 papers over a 10-year period is an average of 15 papers/year for all the 15 West African countries and 1 paper/year per Member State. University (U) and industry (I)'s shares are trending upwards whereas government's (G) one is trending downwards [Figure 1]. This does not mean a diminishing government output, but rather a growth less than that of the total production of the region [Table 2]. It is clear, however, that the private sector contributes to the knowledge exchange marginally in West Africa, regarding scientific publishing.

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3 CDS-ISIS is text database management software developed and distributed by UNESCO.[24]

4 CDS/ISIS provides a programming language "designed to develop CDS/ISIS applications requiring functions which are not readily available in the standard package".[25] This programming language enables users to extend functions of the standard package, to make it more robust and in order to meet users' specific needs.[26]

5 The program is available at http://www.leydesdorff.net/th2/index.htm.

Table 1: Repartition of records and addresses per Triple Helix sphere (West Africa)

| Affiliation category	All institutions				West African institutions			
	Record		Address		Record		Address	
	No.	%	No.	%	No.	%	No.	%
University	23,503	82.82	44,873	56.53	19,143	67.45	27,277	61.32
Industry	304	1.07	321	0.40	145	0.52	147	0.33
Government	11,661	41.09	21,778	27.43	8,994	31.69	11,963	26.89
Sub-total	27,302	96.20	66,972	84.37	25,518	89.92	39,387	88.54
Not classified	1,078	3.80	12,409	15.63	2,862	10,08	5,099	11.46
Total	28,380	100	79,381	100	28,380	100	44,486	100
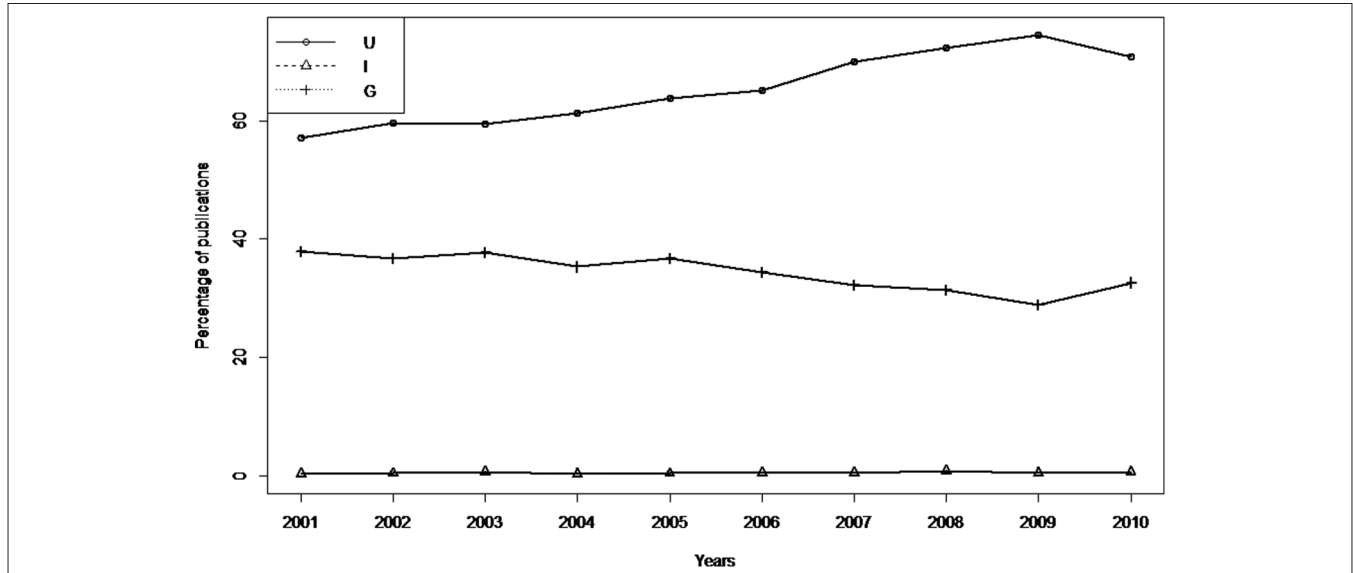
Figure 1: Percentage shares of university, industry, and government in the West African scientific publishing (2001–2010)

Analysis at individual countries' level shows disparities regarding each sphere's contribution to the research output. Industry was absent completely in the scientific output of six countries (Benin, The Gambia, Guinea Bissau, Liberia, Mali, and Niger). In Nigeria and Ghana, it produced 101 papers and 30 papers respectively, ranking these two countries first and second respectively. However, the highest percentage share of industrial output is registered in Cape Verde (21.4%) due to the country's lower total output (52 papers). University is the biggest science producer in Ghana (56.85%), Nigeria (87.80%), and Togo (51.96%) and government is the prime producer elsewhere. This result may have been influenced by the categorization we did, because hospitals were classified as belonging to the government.

Table 3 computes the specialization indexes of the Triple Helix spheres in West Africa using Frascati Manual categories[28] with the whole West Africa region as reference. While government specializes in *Health and medical sciences* (certainly a consequence of the classification of hospitals into G), university dominates the *Social sciences* and industry *Engineering and technology*. The pattern is therefore very much as should be expected.

Bilateral Collaboration between Triple Helix's Spheres

Because the total output of the industry is negligible, its breakdown per year yields weak trends. Because of this, collaboration between industry and government, industry and university, and joint collaboration between the three spheres is difficult to index. However, industry collaborates more with university (UI) than government (IG); the university-government (UG) relations output the highest number of bilateral publications. All the three curves show an increasing trend and the collaboration indexes are also trending upwards [Figure 2].

At individual countries level, all the 15 Member States have data on university and government collaboration; but only two countries have on industry and university collaboration: Ghana (7 papers -0.23% of the Ghanaian total output

Table 2: University, industry, and government production and relations in West Africa

Sphere	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
U	884	1013	1084	1164	1665	1751	2421	2772	3196	3195	19,145
I	5	7	12	6	10	12	16	31	20	28	147
G	587	625	689	671	958	924	1117	1203	1236	1471	8994
UI	1	0	3	2	3	6	7	16	12	14	64
UG	107	133	171	162	262	246	343	413	443	511	2791
IG	1	1	1	0	1	2	2	7	2	4	21
UIG	0	0	0	0	0	2	1	3	1	2	9

U=University, I=Industry, G=Government, UI=University-industry, UG=University-government, IG=Industry-government, UIG=University-industry-government

Table 3: Specialization indexes of the Triple Helix spheres in West Africa

Field of science	Number of papers					
	U		I		G	
	No.	Index	No.	Index	No.	Index
Natural sciences	6504	1.04	67	1.44	2313	0.79
Engineering and technology	3268	1.27	38	1.97	508	0.42
Health and medical sciences	8344	0.89	8	0.11	5650	1.28
Agricultural sciences	2260	0.90	20	1.07	1287	1.09
Social sciences	573	1.46	4	1.37	122	0.66
Humanities	56	0.85	1	2.03	22	0.71
Total	19,143		143		8994	

U=University, I=Industry, G=Government

and 33.33% of the country's industrial production; and Nigeria (53 papers -0.34% of the Nigeria total and 51.43% of the Nigerian industrial output). Only these countries also had publication collaboration between industry and government. The percentage share of university-government relations got its maximal value in case of Guinea Bissau (81.22% of the country's total output) perhaps due to the lower level of the latter or to the weaknesses in the Bissau-Guinean universities research system.

Joint collaboration between university, industry, and government is marginal; 9 publications spread thinly across environment and health categories. Seven of them have Nigerian-based co-authors; the remaining two records have co-authors based in different West African countries. We used the mutual information indicator proposed by Leydesdorff[11] to evaluate the level of self-organization or central control in an economy. We calculated the related value for the West African region over the period 2001-2010. The values are all negatives, ranging from −13 to −32 millibits, with an average of −19 millibits[6] showing the weaknesses of information exchange between university, industry, and government in West Africa from

6 The 'maximum value' of the mutual information, in this case is −2.807 millibits.

the perspective of research publishing as an indicator of collaboration.

The Industrial Research Network

The production of the industry is very small; its co-publication with the other sectors is weaker due to the Boolean operator effect. The 145 industrial records contained 107 institutions. The visualization of the network reveals 23 components of which 20 have very few members. We deleted these and focused on the remaining three with 33, 15, and 9 actors. Each institution name was prefixed with its country's ISO two characters code. The first two components group together Nigeria-based institutions and the third Ghana-based ones. The numbers are extremely low and connectedness is therefore, weak. As a result, indicators of centrality are probably not yet informative. Shell Nigeria, University of Ibadan, University of Lagos, and Rivers State University dominate the larger Nigerian component [Figure 3] while in the smaller, the leaders are University of Calabar, Mobil, University of Maiduguri, Innovation Biotech Ltd., University of Jos, etc., On the Ghana-based component, University of Ghana is central.

DISCUSSION

University is the biggest information producer, but industry so far contributes little to the West African scientific production. Globally, university produced more than government that, in turn, produced more than industry. This conclusion conforms the results of Khan and Park[14] as regarding web pages and also that of Leydesdorff and Sun[12] and Leydesdorff[11] The joint collaboration between the three spheres is negligible because of weakness of the industrial sector's scientific output and the effect of the double Boolean operator AND. In West African, as in other developing countries, the economy is characterized by an important informal sector -60% of the global added value[8] - that weakens the formal sector. Even though
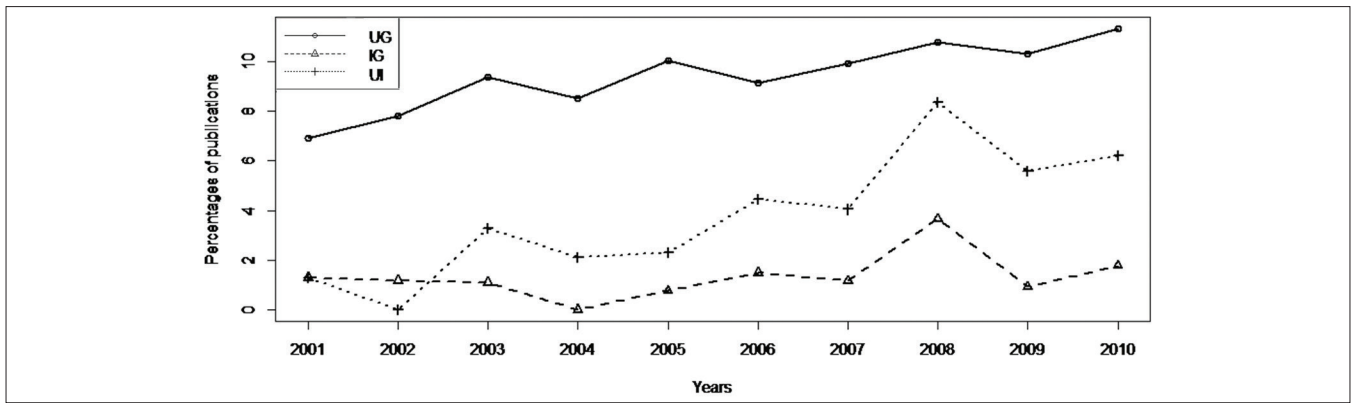
Figure 2: Bilateral collaboration indexed between university, industry, and government in West Africa (2001-2010)
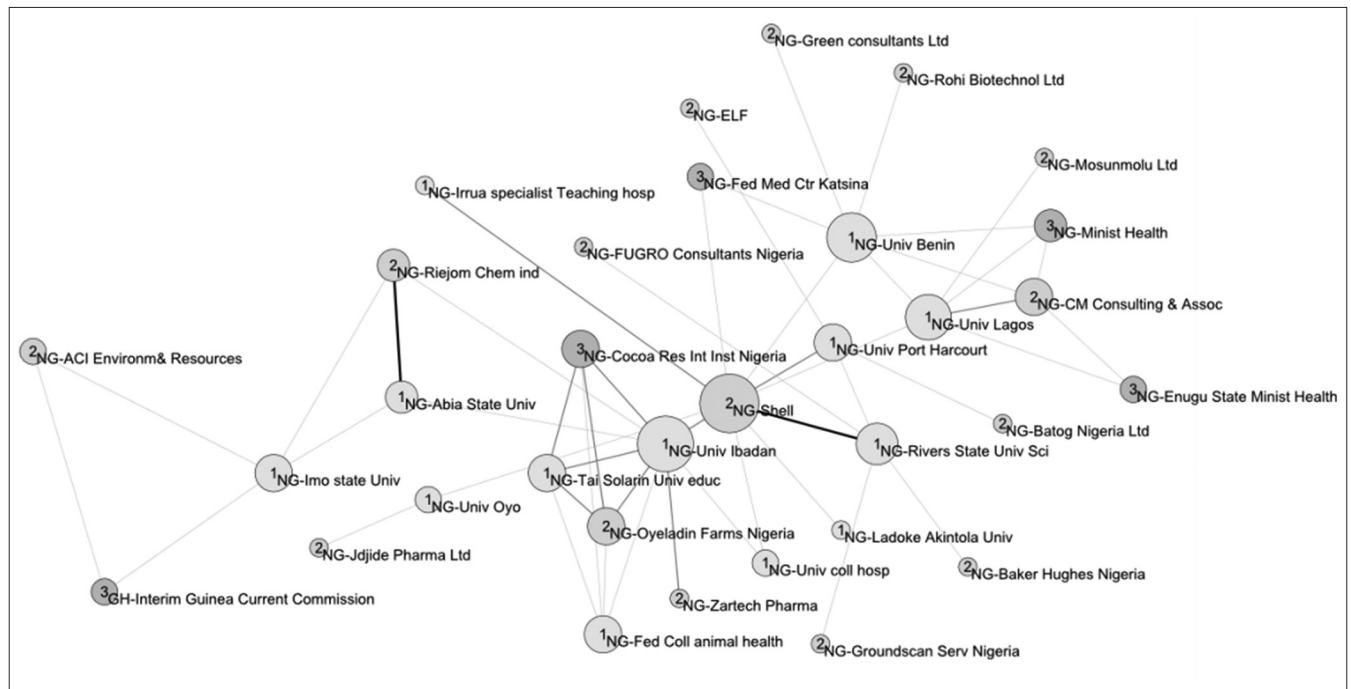

Figure 3: The larger Nigeria-based industrial relations network. Note: 1 = University; 2 = Industry; 3 = Government

the industrial sector contributes 30.3% to the regional GDP, this is still weak, in comparison with the emerging countries[8] and is focused on low-technology areas to sustain a developing economy.

The negativity of the mutual information between university, industry and government is a positive point, although its absolute size is low. It indicates that the innovations system is changing from a state-controlled to a self-organized one due certainly to the advancement of liberal democracy within the region. We compared the percentage share of the industrial sector to the West African scientific output to that of the BRICS countries. Whereas it is only 0.5% in case of West Africa, its values are 2.4% in Brazil, 1.62% in Russia, 3.13% in India, and 11.07% in

China (data taken from Leydesdorff[11]); mutual information values are respectively -27.11, -58.16, -109.5, -19.45/-36.01, and -21.35 millibits (data taken from Ye *et al.*[15]) whereas it ranges from -13 to -32 millibits in case of West Africa with an average of -19 millibits.

The West African universities and governmental bodies also collaborated with non-West African industrial sector ('foreign industry' from a West African perspective); but the outcome is also marginal (16 records) even though two fold the number of records government and university shared with the local industry. Globally, the industrial sector contributed 304 papers to the West African output, of which 167 are authored by 'foreign industry'. It may be underlined that foreign industry did not share any publication with the

local industry. The weak output of industry in the region is explained by the factors that are hindering the industrial development and referred to previously. Particularly, the vast wealth of untapped mineral resource the region is endowed with locally undergo elementary processing; they are exported and transformed into finished products that are sold back to African. Consequently, the local industry role is reduced to resources extracting and exporting; it is no needs to explore the local market, to produce for local consumers. In other words, local industry has not the opportunity to do research and innovate.

SUMMARY AND CONCLUSIONS

Publications data of West Africa over the period 2001-2010 indexed in Thomson Reuters' Web of Science were analyzed. We focused on university, industry and government relationships both at regional and individual country levels. The results showed that university produced more than the government that produced, in turn, more than industry. The industrial sector's share to the region's output is marginal. University and government have relations in all the West African countries, but industry exhibits relations with government or university in Nigeria and Ghana only. The relations between the three sectors occurred only in Nigeria. The mutual information is weak illustrating the weakness in the information flow between the three actors in the region, when research output is concerned. Shell Nigeria, University of Ibadan, University of Lagos, and Rivers State University dominate the larger Nigerian component while in the smaller; the leaders are University of Calabar, Mobil, University of Maiduguri, Innovation Biotech Ltd., and University of Jos, etc., In the Ghana-based component, University of Ghana only is central. The Triple Helix thesis is that the university-industry-government relations lead to competitiveness and economic growth.[2,11] According to Mueller,[2] the level of research and development products absorption determines the level of development. The data we treated are too weak; moreover, research collaboration is not limited to publishing only; therefore, any conclusion could not be drawn about information flow within the Triple Helix system and the level of development in West Africa.

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