Knowledge Production on Fourth Industrial Revolution in the ECOWAS Region in Africa: A Scientometric Analysis

Oluseye Oladayo Jegede[1],*, Olufikayo Opemipo Abodunde[2]

[1]ICT and MIS Academic Planning Unit, Federal Polytechnic, Ado-Ekiti, Ekiti State, NIGERIA.
[2]DHET-NRF South African Research Chair in Entrepreneurship Education, College of Business and Economics, University of Johannesburg, SOUTH AFRICA.

ABSTRACT
The study measured the trend of research output relating to the fourth industrial revolution (4IR) in the ECOWAS region in Africa. It examined the year wise growth, the breadth of collaboration and impact of collaboration on the productivity of research compared to the world's average. The study reports the findings of a scientometric study of 4IR knowledge production culled from the broad field of specialization in computer science research in all ECOWAS states. This data was extracted from the Scopus Database using "SciVal" an online analytic tool that allows visualization of research, benchmarking for comparison and analysis of strategic partnerships (collaborations) among actors in a research system. The analysis from the study provided information on volume and growth of knowledge supply on 4IR. It also provided information on the breadth of collaboration by ECOWAS member states on 4IR and the impact of the collaboration on research productivity of the ECOWAS region.

Keywords: ECOWAS region, Fourth Industrial Revolution, Knowledge supply, Collaborative research, Research productivity

INTRODUCTION

The reality of day-to-day living and working experience is increasingly characterized by adoption of disruptive technologies (National Research Council, 2010).[1] Examples include but not limited to Internet of Things (IoT), 5G Mobile Technology, Virtual Reality, Block Chain Technology, Artificial Intelligence (AI), Virtual Reality (VR), Robotics and so on (PwC Global, 2017).[2] These technologies are pointers to the advent of the fourth industrial revolution (4IR), an era in which we currently find ourselves.

The business environment has recorded a paradigm shift in the way it operates. Entrepreneurs and newer firms entering older industries are causing significant disruptions in the market – creating new markets while destroying the existing markets in some cases. The older firms must successfully adjust to these changes or would soon die. Indeed, competition is getting fiercer by the day and all businesses must learn to innovate or perish. The business world today has now moved into the digital age where humans and machines interact to bring about greater productivity. Indeed, conventional

ways of doing work involving large amounts of labour is phasing out gradually and increasingly being replaced by machines, robots, software, amongst others. The changes in the way businesses now operate has been referred to in recent literature as the Fourth Industrial Revolution or Industry 4.0. The fourth industrial revolution involves the use of digital technologies such as artificial intelligence, sensor technologies and automation in production (manufacturing) and business operation.[3]

From history (Atkeson and Kehoe 2001;[4] Crafts, 2004;[5] Sadeghi, Wachsmann and Waidner, 2015),[6] it was recorded that the first industrial revolution started off in the early1900s with mechanical production powered by water and steam. While the second industrial revolution started in the early 20th century which resulted in mass production powered by electricity. The third industrial revolution was known to have taken place in the 1970s. The third industrial revolution resulted in electronics and automated production. Looking critically at the nature of these industrial revolutions, it can be noted that the first and second industrial revolutions were characterized with physical systems i.e., involving machinery and equipment. While the third industrial revolution was characterized by cyber systems i.e., is premised on virtual systems (less physical). The fourth industrial revolution which just started off, is characterized by the combination or interaction of both physical and cyber systems – which makes it peculiar. The pillars of the fourth industrial revolution

include: Artificial Intelligence, Robotics and Autonomous Systems, Modelling and Simulation, Additive Manufacturing, Augmented and Virtual Reality, Data Analytics, amongst others (Ong, 2008; Posada, *et al.*, 2015; Li *et al.* 2017).[7-9]

The fourth industrial revolution allows humans and machines to work together in such as way a creative way that the outcome will surpass the output of humans working alone or machines working alone as it has been in the previous industrial revolutions (World Economic forum, 2016).[10] However, on the other hand, this paradigm shifts in the way the industry will now operate comes with a lot of advantages as well as disadvantages. While digitization will create new job opportunities for high technology industries, it will lead to massive job losses for low and medium-low technology jobs, which may then increase the unemployment rate (Pavon and Brown, 2010; Manyika, Chui, Madgavkar, and Lund, 2017).[11,12]

The importance of knowledge literacy in achieving 4IR cannot be overemphasized. Thus, the present study principally examines the role of the research community in knowledge supply relating to 4IR literacy within the fifteen (15) West African States otherwise referred to as the Economic Community of West African States (ECOWAS) region. The study specifically focuses on the ECOWAS member states because the ECOWAS region has been known for the important developmental role it has played in promoting trade among the members states (Jones, 2002; Zannou, 2010),[13,14] in the integration and economic growth of economies in Africa (Musila, 2005; Diop, Dufrénot, and Sanon, 2010)[15,16] and beyond Africa (Busse, Borrmann, Großmann, and Hamburg, 2004; Lang, 2006).[17,18] The EWOWAS region (West Africa) accounts for about 17% of Africa's total land surface area. The population of the region is a little more 300 million inhabitants, making it the most populated of the Regional Economic Communities in Africa, or nearly 27% of the total population of Africa. West Africa accounts for 45% of the GDP of Sub-Saharan Africa and 1% of global GDP (WorldBank 2015). Nigeria's production makes it by far the biggest economy in the region (Omo-Ogbebor, 2017).[19] According to World Bank (2015)[20] report, Nigeria alone accounts for nearly 78% of the region's GDP, followed by Ghana (4.8%), Côte d'Ivoire (4.6%) and Senegal (2.1%). The four economies alone account for 89.5% of the wealth produced in West Africa. Gambia and Guinea Bissau are the two smallest economies (with 0.1% each). The ECOWAS region has also contributed significantly to Africa's growth in terms of research outputs (Abodunde and Jegede, 2020; Abodunde, Jegede and Oyebisi, 2020),[21,22] technology (Bankole, Osei-Bryson and Brown, 2015),[23] Foreign Direct Investment (Eregha, 2012)[24] as well as in value of Gross Domestic Product (Abubakar, Kassim and Yusoff, 2015).[25] This study thus focuses on knowledge

production/supply within this region as previous studies have narrowly focused mainly on trade, regional integration and economic development of the member states in the region. It takes a critical look at collaborative research in the ECOWAS region, from the perspective that modern research focused on proffering solutions to multifaceted problems have a high propensity to be transdisciplinary, trans-institutional and funded by multiple sources.

The present study draws insight from the recent work by Chen, Zhang and Fu (2019).[26] It is thus premised on the ideology that collaboration will yield improved quality of research. It therefore critically assesses the nature of interactions or linkages between these countries and by extension institutions to present an objective assessment of the opportunities, potentials, strengths and weaknesses in 4IR research within the ECOWAS region. It explored the dynamics of the quantity of knowledge produced in the ECOWAS region in 4IR. It assesses the relevance of knowledge supply from the ECOWAS region to the global discuss on 4IR. It went further to examine the extent of collaboration intra and inter collaboration for knowledge generation among the ECOWAS member's states. Finally, the study attempts to determine the influence of the global North on the knowledge generated in the ECOWAS on 4IR. It then concluded by making policy recommendations can bolster identified low performance or intensify identified high performance.

The study's research questions are as follows:

What is the predominant publication type of 4IR literature in the ECOWAS region?

What is the volume and growth rate of 4IR literature in the ECOWAS region?

What is the nature and extent of collaboration at the internal, regional and international levels for research on 4IR?

What is the citation (based on number of co-authored publications collaboration) within the ECOWAS region compared to the world average?

METHODOLOGY

This study reports finding of a scientometric study of 4IR knowledge production culled from the broad field of specialization in computer science through collaborative research in all ECOWAS states. 4IR is driven by fusion of new developments in the application of computing technologies across the science, technology, engineering and mathematical (STEM) disciplines and even non-STEM disciplines, however critical to building a database of publications mostly relevant to 4IR research the study considers the computer science field of specialization most congruent with 4IR literature.

In order to assess the extent and impact of knowledge co-production among ECOWAS states, an analysis of the contributions of each of the countries publications output and citation impact was conducted. This data was extracted from the Scopus Database using SciVal. SciVal is an online analytic tool that allows visualization of research, benchmarking for comparison and analysis of strategic partnerships (collaborations) among actors (Countries, Institutions, researcher level) in a research system. The search query: Data Set – Publications in ECOWAS States (ALL 15); Year Range: 2010 – 2019; Subject Classification - All Science Journal Classification (ASJC) Used in Scopus; Filtered by – Computer Science; Type of Publications included – All Publications; Self-citations – Not Allowed; Data Source - Scopus; Date Scopus Last Updated – 25 March 2020; Date Exported – 02 April 2020. The search was limited to articles published between 2010 and 2019. This was to allow measurement of metrics over a longitudinal period to observe possible changes in trends or specialization focus especially as regards collaboration. This made for a balanced analysis of research among the countries on a regional, continental and international basis. Additional data is collected on collaboration information within the ECOWAS community. The queries for the data collected were as follows: Data Set – Countries/Regions collaborating with each ECOWAS State (ALL 15); Entity – ECOWAS State (ALL); Year Range: 2014 – 2019; Subject Classification - All Science Journal Classification (ASJC) Used in Scopus; Filtered by – Computer Science; Type of Publications included – All Publications; Self-citations – Included; Data Source - Scopus; Date Scopus Last Updated – 25 March 2020; Date Exported – 03 April 2020. The study critically notes that the year range in the collaboration module of SciVal is pre-classified and as such, it could not be altered to reflect the whole study period; hence, the study adopted the nearest pre-classified period, which coincided with improved research activity in the ECOWAS community.

FINDINGS AND DISCUSSION

The findings of this study are presented and discussed under the following sub-headings:

1. Contributions of ECOWAS states to global research output

For the reference period 2010 to 2019, on publications relating to 4IR knowledge literacy, the study identified 4542 journal articles representing 48.25% of the materials used in the analysis and 3326 conference papers representing 45.31% (Table 1). There were also 241 book chapters and 130 reviews representing 3.28% and 1.77% of the total documents used in the analysis (Table 2). Other published documents used in the analysis were 9 articles in press, 7 books, 1 data paper, 64 editorials, 5 erratum, 1 letter, 12 notes and 2 short surveys

Table 1: Document wise distribution of publications in the ECOWAS region.

Document Type	Number of Publications	Percentage
Article	3542	48.25
Article in Press	9	0.12
Book	7	0.10
Chapter	241	3.28
Conference Paper	3326	45.31
Data Paper	1	0.01
Editorial	64	0.87
Erratum	5	0.07
Letter	1	0.01
Note	12	0.16
Retracted	1	0.01
Review	130	1.77
Short Survey	2	0.03

Togo	0.00	0.00	300.00	-100.00	-	-100.00	-	300.00	50.00	83.33

(Table 1). Table 3 shows that Nigeria had the highest volume of publication on 4IR within the reference period; 2558 articles and 2237 conference papers, followed by Ghana which had 450 journal articles and 408 conference paper. Other countries with notable publications were Senegal (157 journal articles and 437 conference papers) and Cote D'Ivorie (157 journal articles and 27 conferences). From Table 4, it is observed that the remaining 11 ECOWAS member states had much fewer publications relating to 4IR within the reference period.

Our research showed that there has been consistent slight increase in the volume of research output on the theme of fourth industrial revolution over the ten-year period (2010 to 2019) except for the little decline observed in 2013 (Table 5). This indicates that knowledge on 4IR from the ECOWAS region has continually been increasing; researchers have been doing extensive work while users of knowledge are having more information/data/knowledge to use. The last three years 2017 to 2019 had the highest volume, which also coincides with the advent of the use of 4IR technologies such as IoTs, Augmented Reality, Big Data analytics, Cloud Computing, Virtual Reality, 5G Mobile Technology, amongst others. From the study (Table 4), Nigeria is the largest producer of knowledge for 4IR as far as the ECOWAS region is concerned. Ghana and Senegal together with Nigeria make the top three while the bottom three were: Guinea-Bissau, the Gambia and Carpe Verde (Table 4).

General and specialized volume of research output in the ECOWAS region (Annual Growth Rate, Relative growth Rate and Doubling Time)

Table 2: Relative Growth Rate of Publications in the ECOWAS region.

Year	Number of Publications	Cumulative Sum	W1	W2	RGR (W2 - W1)	Dt
2010	416	416	-	6.03	-	-
2011	454	870	6.03	6.77	0.74	0.94
2012	464	1334	6.77	7.20	0.43	1.62
2013	417	1751	7.20	7.47	0.27	2.55
2014	499	2250	7.47	7.72	0.25	2.76
2015	551	2801	7.72	7.94	0.22	3.16
2016	684	3485	7.94	8.16	0.22	3.17
2017	895	4380	8.16	8.38	0.23	3.03
2018	1348	5728	8.38	8.65	0.27	2.58
2019	1613	7341	8.65	8.90	0.25	2.79

Table 3: ECOWAS Country distribution of publication types.

	Publication Type													
	Article	Article in Press	Book	Chapter	Conference Paper	Data Paper	Editorial	Erratum	Letter	Note	Retracted	Review	Short Survey
Benin	59			1	85							1	
Burkina Faso	64	1			59								
Cape Verde	7				6							1	
Côte d'Ivoire	157			3	27								
Gambia	5			1	5								
Ghana	450	1		32	408		6	2		1		18	
Guinea	1				1								
Guinea-Bissau	1												
Liberia	7				3		1						
Mali	28				27		1					1	
Niger	20				9								
Nigeria	2558	6	7	189	2237	1	49	2	1	10	1	106	2
Senegal	157	1		14	437		7	1		1		3	
Sierra Leone	13				6								
Togo	15			1	16								

Table 4: Country wise distribution by percentage share of number of publications in the ECOWAS region.

Country	Number of Publications	Percentage (%)
Benin	146	1.99
Burkina Faso	124	1.69
Cape Verde	14	0.19
Côte d'Ivoire	187	2.55
Gambia	11	0.15
Ghana	918	12.51
Guinea	2	0.03
Guinea-Bissau	1	0.01
Liberia	11	0.15
Mali	57	0.78
Niger	29	0.40
Nigeria	5169	70.41
Senegal	621	8.46
Sierra Leone	19	0.26
Togo	32	0.44

Table 5: Annual Growth Rate of Publication in the ECOWAS region.

Year	Number of Publications	AGR
2010	416	0
2011	454	9.13
2012	464	2.20
2013	417	-10.13
2014	499	19.66
2015	551	10.42
2016	684	24.14
2017	895	30.85
2018	1348	50.61
2019	1613	19.66

Figure 1: Graph Showing Annual Growth Rate of Publications in the ECOWAS region.

Table 5 and Figure 1 outlined the annual growth rate of the publications over the ten-year period. 2011 recorded a 9.13% growth rate over the 2010 research outputs while a 2.2% growth rate was recorded in 2013 over 2012 research output. However, in 2013, there was negative growth rate of 10.13% but the growth rate picked up again in the positive direction in 2014 recording a whopping 19.66% growth rate in 2014. The publications maintained a growth rate for the rest of the period with 10.42% in 2015, 24.14% in 2016, 30.85% in 2017, 50.61% for 2018 and 19.66% in 2019.

The robust growth rates show a growing knowledge literacy for 4IR in the ECOWAS region. This also connotes that the knowledge supply on 4IR has not reached a saturation point yet. Hence, a lot still can still be explored on 4IR. Table 5 digs deeper into this information by providing the annual growth rate of the knowledge literacy in each of the ECOWAS member states. Three patterns were noticed from Table 6 countries that consistently had negative growth rates in the knowledge of 4IR over the ten-year period. The second category are those that had a fluctuating growth rate between positive and negative. While the third category were those countries that had consistent positive annual growth within the ten-year period. Carpe Verde, Guinea, Guinea Bissau all had consistent negative annual grow rate while Nigeria and Ghana, on the other hand, had consistent annual growth rate apart from in 2013 were both countries recorded a decline in the outputs relative to 2012. Majority of the countries had a staggering output, fluctuating between positive annual growth rate and negative annual growth rate. The countries that fall into this category were Benin, Burkina Faso, Côte d'Ivoire, Liberia, Mali, Niger, Senegal, Sierra Leone, Togo.

Table 2 shows the relative growth rate as well as well as the doubling time for the research output for each year (from 2011 to 2019). The relative growth rate in 2011 and 2012 were the highest, 0.74 and 0.43 years respectively, consequently they had the lowest doubling time for the research outputs (Table 2). The reason for this is because the number of

research output from the ECOWAS member's states within the reference period (2010 to 2019) was relatively low. Hence, it will take lesser effort to double the volume of 2010 output in 2011 and that of 2011 in 2012. Between 2013 and 2019 the relative growth rate ranged between 0.22 and 0.27 therefore attracting doubling time that ranged between 2.55 and 3.03 years (Table 2). Because the volume of research output increased greatly as the years rolled by, relative growth rate significantly reduced while the time for the research outputs of a particular year to double the output of the previous year significantly increased (Table 2).

Comparison of internal, regional and international research output and collaboration

Table 7 shows that all the ECOWAS member states collaborated more with other countries outside of African than African countries for their research. For instance, Guinea collaborated entirely with other countries outside Africa (with Malaysia) on 4IR within between 2014 and 2019. Liberia for instance, out of the 32 countries it collaborated with about 4IR within the reference period, 26 out of the 32 countries were outside Africa. Liberia only collaborated with 3 African countries which are all in the ECOWAS region. Liberia collaborated the most with Malaysia, Central African Republic, United Kingdom and United States. Sierria Leone had 8 collaborating countries, of which 7 were outside Africa while it collaborated with only 1 African country which isn't a member state of ECOWAS. Sierra Leone collaborated the most with China, South Africa and United States. On the other hand, Nigeria collaborated with the most countries (106) mostly outside Africa (76) only a small fraction of the collaboration was from the ECOWAS region (7). Nigeria collaborated the most with Malaysia, South Africa, United Kingdom, United States and India on 4IR within the reference period. Ghana also recorded a high frequency of collaborations. It recorded collaborations with 78 countries within the reference period. 51 countries out of 78 were situated outside Africa; only 19 countries were from Africa and only 9 from the ECOWAS region. Ghana had most of the collaborations with China, United States and United Kingdom. Senegal, which collaborated with 65 countries within the reference period. 40 countries out of the 65 were located outside Africa; only 16 were from African countries and only 9 from the ECOWAS region. Senegal collaborated mostly with France, United States, Canada, Cameroon and China for their research outputs about 4IR within the reference period. It can be drawn from Table 2 that the breadth of collaboration of the member state of ECOWAS was quite strong.

Collaboration was not limited to the ECOWAS region alone but went to the rest of the regions in Africa unto the

Table 6: Annual Growth Rate of Publications per ECOWAS country.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Benin	0.00	14.29	37.50	-9.09	-20.00	62.50	7.69	64.29	-34.78	146.67
Burkina Faso	0.00	0.00	183.33	-35.29	-54.55	180.00	-7.14	-15.38	118.18	-29.17
Cape Verde	0.00	-	-100.00	-	-	-33.33	-100.00	-	0.00	-33.33
Côte d'Ivoire	0.00	-36.96	-3.45	-85.71	25.00	120.00	-81.82	400.00	150.00	8.00
Gambia	0.00	-		-	200.00	0.00	-66.67	-100.00	-	-50.00
Ghana	0.00	35.29	45.65	-31.34	41.30	6.15	17.39	28.40	65.38	36.05
Guinea	0.00	-	-	-	-100.00	-	-	-	-100.00	-
Guinea-Bissau	0.00	-	-	-	-100.00	-	-	-	-	-
Liberia	0.00	-	100.00	-100.00	-	-	0.00	0.00	200.00	-33.33
Mali	0.00	-50.00	400.00	40.00	-42.86	50.00	-66.67	200.00	16.67	142.86
Niger	0.00	-50.00	0.00	0.00	200.00	66.67	40.00	-100.00	-	100.00
Nigeria	0.00	13.27	-15.92	3.93	20.62	4.56	39.78	28.65	43.94	18.95
Senegal	0.00	23.81	84.62	-8.33	6.82	25.53	-18.64	47.92	85.92	-5.30
Sierra Leone	0.00	-66.67	0.00	-100.00	-	0.00	0.00	0.00	500.00	-33.33

Table 7: Number of Collaborating Countries Worldwide, Africa ECOWAS region 2014 -2019.

Country	Number of Collaborating Countries	No. of Other Countries (excluding Africa)	% of Other Collaborating Countries (excluding Africa)	No. in other African Countries/ Region	% of Africa Collaborating Countries of the World	No Collaborating in ECOWAS region	% of ECOWAS region Collaboration of Africa	Top Collaborating Countries (Worldwide)
Benin	39	22	56.41	12	43.59	5	29.41	France| Belgium| Italy| United States|
Burkina Faso	37	21	56.76	12	43.24	4	25.00	France| Senegal| Luxembourg| United States| Germany
Cape Verde	13	8	61.54	4	38.46	1	20.00	Portugal| Brazil| Norway|
Côte d'Ivoire	50	35	70.00	10	30.00	5	33.33	France| United States| Cameroon| China| Italy
Gambia	10	7	70.00	2	30.00	1	33.33	United Kingdom|
Ghana	78	51	65.38	19	34.62	8	29.63	China| United States| United Kingdom| South Africa| France
Guinea	1	1	100.00	0	0.00	0	n/a	Malaysia|
Guinea Bissau	0	0	n/a	0	n/a	0	n/a	
Liberia	32	26	81.25	3	18.75	3	50.00	Malaysia| Central African Republic| United Kingdom| United States|
Mali	35	17	48.57	12	51.43	6	33.33	France| China| United States| Botswana| Kenya
Niger	25	18	72.00	3	28.00	4	57.14	Italy| United States| France|
Nigeria	106	76	71.70	23	28.30	7	23.33	Malaysia| South Africa| United Kingdom| United States| India
Senegal	65	40	61.54	16	38.46	9	36.00	France| United States| Canada| Cameroon| China
Sierra Leone	8	7	87.50	1	12.50	0	0.00	China| South Africa| United States|
Togo	25	16	64.00	5	36.00	4	44.44	France| Ghana| China| Senegal| United States

rest of the world. From literature, collaboration strengthens research. It also shows the leverage of resources that the researchers had while conducting the research. The strong breadth of collaboration is a positive sign for the research that is being done about 4IR; it connotes wide dissemination and acceptability of the research outputs coming from member's state of ECOWAS on knowledge of 4IR within the reference period (2014 to 2019).

Table 8 shows the number of publications co-authored (collaboration) among ECOWAS member countries within the reference period. For instance, a researcher/institution in Benin had collaboration on one research output with a researcher/institution in Burkina Faso, one collaboration with a researcher/institution in Cote d'Ivoire, two in Ghana, two in Nigeria and two in Senegal based on Table 8. From Table 8, it can be observed that most of the countries had between 1 to 2 collaborative outputs with other member's states in the ECOWAS region within the period 2014 to 2019 except for Nigeria and Ghana. For instance, Senegal, Ghana and Nigeria collaborated more with other countries in the ECOWAS region. More specifically, Ghana collaborated with Benin on two research outputs, with Burkina Faso on two research outputs, with Cote d'Ivoire on 1 research output. There was a paper in which Ghana had a collaboration with Niger, yet another publication with Liberia. According to Table 8, Ghana collaborated with Nigeria on 19 research outputs while Ghana has 3 collaborative research outputs with Senegal and 6 with Togo

Contributions of ECOWAS states each other's citation impact based on collaborated Publications

One of the critical measurements of scholarly impact is the number of citations a publication receives. Citation analysis measures the relative importance or impact of an author or a publication by counting the number of times that author or publication has been cited by other publications. For this study, citations are counted with a bias for publications that were collaborated on between ECOWAS countries. This was done to establish the impact of 4IR literature within the region. The study further includes the field weighted citation impact (FWCI), which indicates how the number of citations received by publications compares with the average number of citations received by all other similar publications indexed in the Scopus database (world comparison).

A FWCI =1.00 indicates that publications have been cited at the world average, if FWCI > 1.00 then publications have been cited more than the expected world average and if FWCI < 1.00 it means citation for publication is under–cited based on world average. Table 9 shows that for the stated period, the publications between Nigeria and Liberia received 267% higher rate of citations compared with the world average

in its field. Ghana and Burkina Faso received 211% higher rate of citations compared to the world average. Senegal and Ghana publications received 156% higher rate of citations compared to the world average. Other collaborations worthy of mentioning are Togo and Ghana, Niger and Burkina Faso, Liberia and Ghana, Liberia and Côte d'Ivoire and Ghana and Côte d'Ivoire with 61%, 54%, 14%, 14% and 14% higher rates of citations that world average. Senegal and Burkina Faso publications were cited at exactly the world publication average. Incidentally, Benin and Senegal publications, which received the highest citations per publication (CPP) of 6.7 received 2% lower rate of citations compared to the world average. Côte d'Ivoire and Senegal with a comparatively high CPP of 6.3 equally received 10% lower rate of citations compared to the world average. Overall, Liberia's collaboration with other ECOWAS states (Nigeria, Côte d'Ivoire and Ghana) all had higher rates of citations compared to the world average. Ghana's collaboration with other state equally performed well with (Togo, Senegal, Burkina Faso, Côte d'Ivoire and Liberia) all having higher rates of citations compared to the world average with only Nigeria and Benin exhibiting lower rates of citations. Nigeria's collaborations did not fair too well based on the field weighted citation impact as all country collaborations except Liberia turned out lower citations rate than the expected world average. Finally, Senegal, which tops the chart for having the greatest number of ECOWAS state collaborations over the study period, equally exhibits lower citations rates compared to the world average except for Burkina Faso and Ghana.

CONCLUSION

Adopting the same search query as defined in the methodology of this study, the total world publications for 4IR literature was 3,618,609 publications. As a continent, Africa contributed 88,156 publications (2.44% of World) by further analysis it infers that the ECOWAS region contributed only 0.20% of the world's publications over the 10-year period. In relative comparison to Africa, the ECOWAS region contributed 8.33% of the publications while the closely related Southern African Development Community (SADC) contributed 20.04% to African literature in the field. It was observed from the study that the ECOWAS region can intensify efforts to increase participation in research focused on the theme of the fourth industrial revolution despite the observed continuous increase in the amount of knowledge supplied in the stated study period. The volume of knowledge supplied within the region had increased in recent years and based on the linear regression trend line (Figure 1) it is projected that growth of 4IR literature could increase as much as 40% over 2019 publications in 2020 ceteris paribus. The knowledge supply is expected to continue to increase from the ECOWAS region.

Table 8: Number of Co-authored publications in the ECOWAS region 2014- 2019.

	Country	Benin	Burkina Faso	Cape Verde	Côte d'Ivoire	Gambia	Ghana	Guinea	Guinea Bissau	Liberia	Mali	Niger	Nigeria	Senegal	Sierra Leone	Togo	Total Principal
	Country B (Contributing) ECOWAS Country																
Country A (Principal) ECOWAS Country	Benin		1		1		2						2	3			9
	Burkina Faso	1			1		2				1						5
	Cape Verde													1			1
	Côte d'Ivoire	1	1				1						3	3			9
	Gambia													1			1
	Ghana	2	2		1					1		1	19	3		6	35
	Guinea																0
	Guinea Bissau																0
	Liberia				1		1						1				3
	Mali	1	1				2						2	2		1	9
	Niger		2				2						2			1	7
	Nigeria	2			3		19			1	2	2		3			32
	Senegal	3	8	1	3	1	3				2		3			3	27
	Sierra Leone																0
	Togo						6				1	1		3			11
	Total Contribution	10	15	1	10	1	38	0	0	2	6	4	32	19	0	11s	

Table 9: Number of Citations, Citations per Publication a- Citation Impact of Co-authored Publications.

Country A	Country B	Citations	Citations per Publications	FWCI	Country A	Country B	Citations	Citations per Publications	FWCI
Benin	Senegal	20	6.7	0.98	Mali	Ghana	2	1	0.43
	Ghana	1	0.5	0.43		Nigeria	1	0.5	0.43
	Nigeria	1	0.5	0.43		Senegal	1	0.5	0.43
	Burkina Faso	0	0	0		Benin	1	1	0.86
	Côte d'Ivoire	0	0	0		Burkina Faso	0	0	0
Burkina Faso	Ghana	7	3.5	3.11		Togo	0	0	0
	Benin	0	0	0	Niger	Burkina Faso	9	4.5	1.54
	Côte d'Ivoire	0	0	0		Nigeria	4	2	0.83
	Mali	0	0	0		Ghana	0	0	0
Cape Verde	Senegal	0	0	0		Togo	0	0	0
Côte d'Ivoire	Senegal	19	6.3	0.9	Nigeria	Ghana	46	2.4	0.76
	Ghana	1	1	1.14		Liberia	16	16	3.67
	Nigeria	0	0	0		Niger	4	2	0.83
	Benin	0	0	0		Senegal	1	0.3	0.29
	Burkina Faso	0	0	0		Benin	1	0.5	0.43
Gambia	Senegal	1	1	0.89		Mali	1	0.5	0.43
Ghana	Nigeria	46	2.4	0.76		Côte d'Ivoire	0	0	0
	Togo	11	1.8	1.61	Senegal	Benin	20	6.7	0.98
	Senegal	9	3	2.56		Côte d'Ivoire	19	6.3	0.9
	Burkina Faso	7	3.5	3.11		Burkina Faso	9	1.1	1
	Benin	1	0.5	0.43		Ghana	9	3	2.56
	Côte d'Ivoire	1	1	1.14		Togo	4	1.3	0.84
	Liberia	1	1	1.14		Nigeria	1	0.3	0.29
	Niger	0	0	0		Mali	1	0.5	0.43
Liberia	Nigeria	16	16	3.67		Gambia	1	1	0.89
	Côte d'Ivoire	1	1	1.14		Cape Verde	0	0	0
	Ghana	1	1	1.14	Togo	Ghana	11	1.8	1.61
						Senegal	4	1.3	0.84
						Mali	0	0	0
						Niger	0	0	0

Though only a few of ECOWAS members states Nigeria, Ghana and Senegal are the chief drivers of knowledge supply in the regions, there is a need to encourage these countries to not plateau in terms of churning out scholarly content. There are strong indications as observed from the trend in annual growth of literature that other member states such as Guinea, Guinea–Bissau, Liberia, Sierra-Leone, Cape Verde, Gambia, Togo, Niger are under-performing and hence need to critically strategize to intensify efforts in increasing scholarly contribution in 4IR research. Other Member states like Benin, Burkina Faso, Côte d'Ivoire, Mali fall into the middle-class performance group and need to consolidate efforts to produce more 4IR research that is more scholarly. Overall, given the general percentage share of contribution, the ECOWAS region needs to consider implementation of programs to spur more activity within the region's research system.

The breadth of collaboration within the ECOWAS region although can be said to be interactive could still benefit from improved activity between members states in terms of the number of scholarly publications co-authored. The study discovered that of the 7,341 publications identified for the study only 149 (2.01%) publications were co-authored among ECOWAS members (Table 8) implying 98% of collaboration of member states are carried out, outside of the region i.e. Africa and the rest of the world. Senegal records the highest interaction with member states 9, Ghana and Nigeria round up the top ECOWAS collaborators with 8 and 7 countries respectively. However, this interaction is not reflective in the number of publications co-authored among the states. It is worthy to note that the ECOWAS region is comprised of both Anglophone and Francophone countries and this could present a potential barrier for collaboration. This could also explain why countries like Benin, Burkina Faso, Côte d'Ivoire, Togo, Niger and Senegal all have France as one of their top collaborating partners. Cape Verde, the Portuguese speaking ECOWAS country, has Portugal as her top collaborator. This potentially raises the argument that colonization could be playing a large role in influencing collaboration among ECOWAS states as the study observes that most ECOWAS states have their colonial masters as one of the top collaborators. Incidentally, spurring research activity within the region can be driven by policy. The region has a functional multilateral organization (ECOWAS) charged with the responsibility of promoting regional integration to accelerate sustainable development. Effecting policy backed with incentives can engender activity in research like 4IR that directly affects day-to-day human living. Conversely, it could also swing for strength that ECOWAS member states predominantly collaborated with countries considered as developed economies of the world such as the United States of America and United Kingdom as well as emerging economies like China, Malaysia and India indicating a cross

fertilization of ideas – this is essential to research. This furthers the globalization agenda sacrosant with the advent of the fourth industrial revolution.

Finally, the study found out that a handful of publications co-authored among the member states had received citations considered to be of high impact in comparison to the world based on the Scopus field weighted citation impact (FWCI). Liberia and Ghana collaborations dominated this metric while Nigeria and Senegal despite being part of the top three largest suppliers of publications underperformed on this metric. This metric compares the citations received by a publication to similar publications in the same research field calculating the world average. It infers the extent of acceptability and degree of importance of those research outputs. Hence, it can be said that the knowledge supplied from those key countries in the ECOWAS region are very important to the world's discussion on 4IR.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

1. National Research Council. Persistent forecasting of disruptive Technologies - Report 2. National Academies Press; 2010.
2. PwC Global The essential eight: Your guide to the emerging technologies revolutionizing business now, PwC; 2017 [cited Apr 07 2020]. Available from: https://www.pwc.com/gx/en/issues/technology/essential-eight-technologies.html.
3. Shwab K. The fourth Industrial Revolution: what it means, how to respond. Cologny, Switzerland: World Economic Forum; 2016.
4. Atkeson A, Kehoe PJ. The transition to a new economy after the second Industrial Revolution. National Bureau of Economic Research; 2001;20.
5. Crafts N. Steam as a general purpose technology: A growth accounting perspective. The Economic Journal. 2004;114(495):338-51. doi: 10.1111/j.1468-0297.2003.00200.x.
6. Sadeghi AR, Wachsmann C, Waidner M. Security and privacy challenges in industrial internet of things. In2015 52nd ACM/EDAC/IEEE Design Automation Conference (DAC). IEEE Publications; 2015:1-6.
7. Ong SK, Yuan ML, Nee AYC. Augmented reality applications in manufacturing: A survey. International Journal of Production Research. 2008;46(10):2707-42. doi: 10.1080/00207540601064773.
8. Posada J, Toro C, Barandiaran I, Oyarzun D, Stricker D, De Amicis R, et al. Visual computing as a key enabling technology for industrie 4.0 and industrial internet. IEEE computer graphics and applications. 2015;35(2):26-40. doi: 10.1109/MCG.2015.45, PMID 25807506.
9. Li BH, Hou BC, Yu WT, Lu XB, Yang CW. Applications of artificial intelligence in intelligent manufacturing: A review. Frontiers of Information Technology and Electronic Engineering. 2017;18(1):86-96. doi: 10.1631/FITEE.1601885.
10. World Economic Forum. The future of jobs: Employment, skills and workforce strategy for the fourth Industrial Revolution. Global challenge insight report. Geneva: World Economic Forum; 2016.
11. Pavon F, Brown I. Factors influencing the adoption of the World Wide Web for job-seeking in South Africa. South African Journal of Information Management. 2010;12(1):1-9. doi: 10.4102/sajim.v12i1.443.
12. Manyika J, Chui M, Madgavkar A, Lund S. Technology, jobs, and the future of work. McKinsey Global Institute; 2017 [cited 20/10/2020]. Available from: https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Employment%20and%20Growth/Technology%20jobs%20and%20the%20future%20of%20work/MGI-Future-of-Work-Briefing-note-May-2017.pdf.
13. Jones B. Economic integration and convergence of per capita income in West Africa. African Development Review. 2002;14(1):18-47. doi: 10.1111/1467-8268.00044.
14. Zannou A. Determinants of intra-ECOWAS trade flows. African Journal of Business Management. 2010;4(5):678-86.
15. Musila JW. The intensity of trade creation and trade diversion in COMESA, ECCAS and ECOWAS: A comparative analysis Journal of African Economies.

2005;14(1):117-41. doi: 10.1093/jae/ejh039.

16. Diop A, Dufrénot G, Sanon G. Is per capita growth in Africa hampered by poor governance and weak institutions? An empirical study on the ECOWAS countries. African Development Review. 2010;22(2):265-75. doi: 10.1111/j.1467-8268.2010.00236.x.

17. Busse M, Borrmann A, Großmann H, Hamburg J. The impact of ACP/EU Economic Partnership Agreements on ECOWAS countries: An empirical analysis of the trade and budget effects. Friedrich-Ebert-Stiftung; 2004.

18. Lang R. A partial equilibrium analysis of the impact of the ECOWAS-EU Economic Partnership Agreement; 2006. Available from: https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2008 accessed 20/20/1010 [cited 16/11/2021].

19. Omo-Ogbebor DO. Nigerian foreign policy approach towards ECOWAS. Journal of Human Sciences. 2017;14(4):4015-22. doi: 10.14687/jhs.v14i4.4656.

20. World Bank. Sub-Saharan Africa. Global Economic Prospects. 2015:157-74. doi: 10.1596/978-1-4648-0483-0_ch2_SSA.

21. Abodunde O, Jegede O. R&D productivity for science, technology and innovation policy development in Nigeria: A scientometric analysis of academic literature. African Journal of Science, Technology, Innovation and Development.

22. Abodunde O, Jegede OO, Oyebisi T. A longitudinal assessment of Nigeria's research output for evidence based science policy development. International Journal of Big Data Management. 2020;1(2). doi: 10.1504/IJBDM.2020.112407.

23. Bankole FO, Osei-Bryson KM, Brown I. The impact of information and communications technology infrastructure and complementary factors on Intra-African Trade. Information Technology for Development. 2015;21(1):12-28. doi: 10.1080/02681102.2013.832128.

24. Eregha PB. The dynamic linkages between foreign direct investment and domestic investment in ECOWAS countries: A panel cointegration analysis. African Development Review. 2012;24(3):208-20. doi: 10.1111/j.1467-8268.2012.00317.x.

25. Abubakar A, Kassim SH, Yusoff MB. Financial development, human capital accumulation and economic growth: empirical evidence from the Economic Community of West African States (ECOWAS). Procedia-Social and Behavioral Sciences. 2015;172:96-103. doi: 10.1016/j.sbspro.2015.01.341.

26. Chen K, Zhang Y, Fu X. International research collaboration: An emerging domain of innovation studies? Research Policy. 2019;48(1):149-68. doi: 10.1016/j.respol.2018.08.005.