Contributions of Research Collaboration to Innovation across Disciplines: Assessing the Entrepreneurial Role of Two Ghanaian Universities

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Abstract
On the basis of debates in literature on the usefulness of research from different disciplines to innovation, this study sought to assess the extent to which research collaboration between university researchers and the carriers of innovation yield outputs that contribute to innovation. The paper analysed data from stratified sample of academics from the Sciences, Technology, Engineering and Mathematics, the Social Sciences, and the Arts, in two Ghanaian universities with the mandate to contribute to research and innovation in Ghana. Out of 266 respondents, a minimum of 40 and a maximum of 108 multiple responses were recorded on the perceived use of collaborative research findings in various types of innovation and for problem solving. Except for service innovation, Kruskal-Wallis tests of differences across disciplines did not reveal statistically significant differences, in the extent to which the academics perceived their collaborative research findings to have contributed to innovation. Thus, all academic disciplines can be relevant to innovation and should be given the necessary policy support.

Keywords: *Collaboration, discipline, entrepreneurial, innovation, research, university.*

Introduction

Research collaboration refers to interactions among persons and or entities of diverse interests to embark upon research and to use the research findings for pre-determined purposes such as advancing knowledge in a scientific field and for innovation (Baba, Shichijo & Sedita, 2009). It constitutes an entrepreneurial role of universities in the form of knowledge production and usage for innovation, for example product innovation, service innovation and technological innovation (Hughes, Kitson, Probert, Bullock & Milner, 2011; Robin & Schubert, 2013). As established by Schumpeter (1934/1983) in the theory of economic development, innovation is a major driver of economic development while by Acs, Braunerhjelm, Audretsch and Carlsson's (2009) postulate in the knowledge spillover theory of entrepreneurship, research and the flow of research findings from universities to knowledge users are fundamental to innovation.

Research collaboration acts as an essential medium for the flow of knowledge between universities and knowledge users for innovation in the private, public and third sectors of an economy (Hughes et al., 2011). In recognition of this fact, the global innovation index makes provision for the ranking of nations on indicators such as the level of university-industry research collaboration and government funding in the form of Gross Expenditure on Research and Development (GERD) (Dutta, Lanvin & Wunsch-Vincent, 2018). Government support assumes several forms including budgetary allocation to national Research and Innovation/Development (R&D), enactment of intellectual property laws and the creation of science and industrial parks.

Globally, government policies and funding have largely focused on the Sciences, Technology, Engineering and Mathematics (STEM) upon the premise that they are relatively more important to innovation (Bakhshi, Schneider & Walker, 2008; Hughes et al., 2011). This has been criticised by scholars such as Bakhshi, Schneider and Walker (2008) and Hughes et al. (2011) who argue that all academic disciplines are relevant to innovation, hence research and innovation policies should not leave some academic disciplines at the periphery of policy interventions.

Ghana, like other sub-Saharan African countries, recognise the importance of research, innovation and research collaboration to national development and as a result, makes budgetary allocations for these activities which constitute the mandate of the Council for Scientific and Industrial Research (CSIR), public universities and industry players (Mouton, Gaillard & van Lill, 2015). The country's budgetary allocations, in the 2018 Global Innovation Index, show that Ghana's GERD was 0.4 percent and university-industry research collaboration had a score of 41.2 as compared with that of top performers such as Switzerland with a score of 79.5 (Dutta et al., 2018). As a low performer on innovation, Ghana ranked 96 out of 141 countries in 2014 and 107 out of 126 countries in 2018 (Bartels, Koria & Vitali, 2016; Dutta et al., 2018).

Consistent with global trends, Ghana's R&D policies favour R&D by the STEM in spite of appeals to nations to give due attention to all academic disciplines (Bakhshi, Schneider & Walker, 2008; Hughes et al., 2011). The situation has been criticised by Oduro-Marfo (2015) who notes that the 2010 Ghana National Science, Technology, and Innovation Policy considers innovation as the prerogative of only Science and Technology. Moreover, few studies exist on the usefulness of research, from various academic disciplines, to innovation and particularly the usefulness the disciplines to the different types of innovation. This study was, therefore, conducted to offer some preliminary insights into the extent to which research collaboration between university researchers, from different academic disciplines, and knowledge users yield outputs that contribute to innovation.

More specifically, using the case of the Kwame Nkrumah University of Science and Technology (KNUST), with a relatively higher focus on the STEM, and the University of Cape Coast (UCC), which is much inclined towards the Social Sciences and the Arts, this paper explored the perceptions of academics on the extent to which their collaborative research findings have contributed to innovation by knowledge users. Both universities were set up under the leadership of the first president of Ghana, Osagyefo Dr. Kwame Nkrumah. KNUST was established in 1951, as the Kumasi College of Technology, to promote science and technology in Ghana while UCC was established in 1962 as a University College with the core mandate to promote science education in Ghana (KNUST, 2005; UCC, 2012). Although the two universities have maintained their core mandates over the years, they have grown in size and in focus. Their teaching, research and extension activities are carried out in academic disciplines in the Arts, the Social Sciences and the STEM.

In pursuit of the objectives of the study, literature review was conducted on related theoretical and empirical studies. The outcome of the literature review is presented in the following section. Subsequent sections of the paper consist of methodology and results. These are followed by discussions, conclusions and policy implications, and limitations for future research.

Literature Review

Theoretical and Conceptual Framework of the Contributions of Research Collaboration to Innovation

Research collaboration is defined as interactions among persons and/or entities of diverse interests to embark upon research and to use the research findings for pre-determined purposes such as advancing knowledge in a scientific field and or innovation (Baba et al., 2009). It is regarded as an entrepreneurial role of research-oriented universities and underpins other entrepreneurial roles that universities are expected to play in society. Generally, the entrepreneurial roles of universities may encompass one or a combination of feeding the labour market with entrepreneurial and enterprising graduates through teaching, conducting and disseminating innovation-driven research and contributing to regional and national development through extension (Audretsch, 2014; Sharma, 2015).

Research collaboration between the university and knowledge users is described as an entrepreneurial role of universities due to the fact that it is a means of generating knowledge that could serve as sources of entrepreneurial opportunities (Braunerhjelm, Audretsch & Carlsson, 2010). It is also an indispensable means of converting the opportunities, in the form of tacit knowledge, into innovation (Abdulai, Thomas & Murphy, 2015; Cunningham & Link, 2015). This fact is upheld both in theory and in practice. For instance, the theory of economic development by Schumpeter (1934/1983) established innovation as a primary driver of economic growth and development and, as a means of tracing the source of entrepreneurial opportunities for innovation, Schumpeterian growth models brought to light, research as major source of knowledge for innovation (Braunerhjelm et al., 2010).

The knowledge spillover theory of entrepreneurship by Acs et al. (2009) affirmed the revelation by the Schumpeterian growth models. The theory illustrates that the more efficiently knowledge flows over from entities such as universities and research institutions to other entities for exploitation, the bigger the effect of new knowledge on entrepreneurship for innovation, competitiveness, growth and development (Acs et al., 2009; Acs et al., 2013). In practice, university research and research collaboration, in particular, have been valuable sources of knowledge and/or entrepreneurial opportunities for regional and national innovation.

Costa and Teixeira (2005) in a survey of 425 technology-intensive firms located in Portugal established, through estimations of ordered logit models, that universities are an important source of information and knowledge for innovative activities. Another study by Mueller (2006) also showed that research, entrepreneurship and university-industry relations, as well as physical capital, labour and regional knowledge stock, significantly influenced regional economic growth in West German regions. On the premise that the Arts and Humanities/Social Sciences were often ignored in studies on interactions between academia and external entities, Hughes et al. (2011) explored collaboration between academics in higher education institutions and businesses in the United Kingdom (UK). They found out that the Arts and Humanities collaborated with businesses for several reasons and that they could consist of disciplines that are applied in nature and could make valuable contributions to collaborative innovation in the private, public, and third sectors of the UK economy, if given the needed policy support.

A comparative analysis of France and Germany by Robin and Schubert (2013) revealed that collaboration with public research institutions had a significant positive influence on product and process innovation intensity although the impact was twice as high in Germany as the impact in France due to the more diffusion-oriented German science policy. A related study in Ghana by Abdulai et al. (2015) revealed mediating effects of co-operate collaborations and knowledge-based networking on the link between industry-university interactions and organisational innovation.

Contextual support is paramount to the ability of research collaboration to facilitate knowledge production and the uptake of the knowledge for innovation. The studies by Hughes et al. (2011) and Robin and Schubert (2013) confirmed the importance of an enabling environment to research collaboration, especially government support in the form of policy and funding. However, except Hughes et al.'s (2011) study which gave an insight into the relevance of research from academic disciplines outside the STEM to innovation, the other studies focused on the broader concept of the usefulness of research collaboration to innovation.

Acknowledging the fact that research collaboration embraces all academic disciplines and the outcomes of the collaboration could be relevant to innovation, the contributions of research collaboration to innovation is conceptualised to consist of the extent to which research findings, from collaboration between university researchers and knowledge users from the private, public and third sectors of the economy are used in innovation (Figure 1). It is also recognised in the framework that government support helps in creating an enabling environment and may come in various forms such as lesser administrative and regulatory burdens, budgetary allocations and establishment of research and innovation policies and funding (Acs et al., 2009; Braunerhjelm et al., 2010). Mindful of the usefulness of all types of research – pure basic research, pure applied research and use-inspired basic research – to innovation (Archibugi & Filippetti, 2018), no distinction is made among the three types of research.

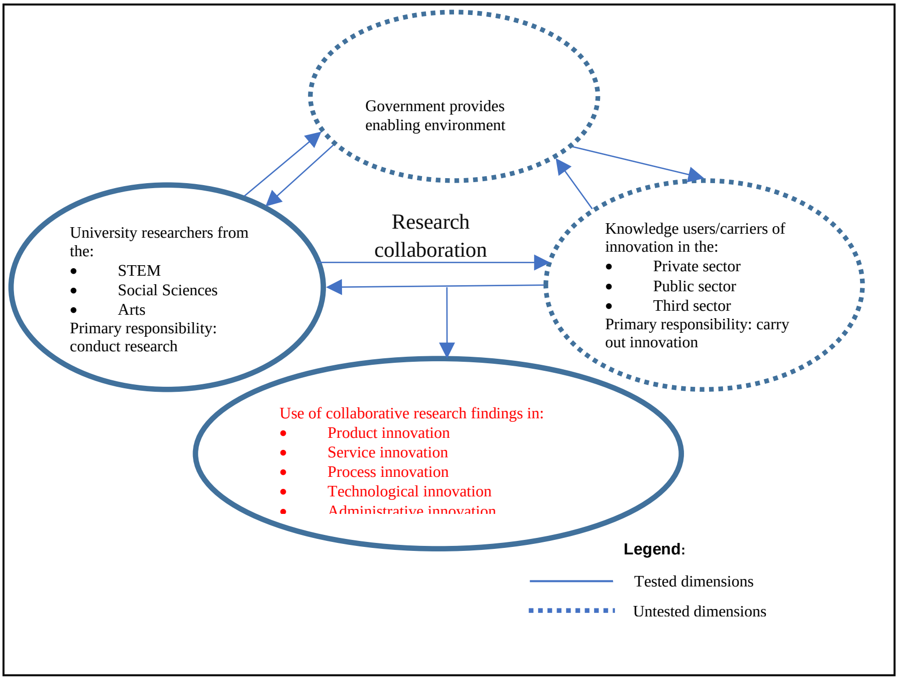

Figure 1: Conceptual framework of the contributions of research collaboration to innovation
Source: Author's construct (2015)

However, a differentiation is made on the basis of academic discipline (Figure 1) as a result of the apparent debate on the capability of research from academic disciplines outside the STEM to make significant contributions to innovation by knowledge users in various sectors of the economy (Bakhshi et al., 2008; Hughes et al., 2011). Generally, government policy has favoured the STEM due to the conviction that the Arts and the Social Sciences are less relevant to innovation. Nevertheless, emerging studies, for example, by Hughes et al. (2011) and Moore, Hughes and Ulrichsen (2010) indicate that research by all academic disciplines, including the Arts and the Social Sciences or the Humanities, can make substantial contributions to innovation.

Primary knowledge users, that is the carriers of innovation, have been identified to include all individuals and entities in the private, public and third sectors of an economy (Hughes et al., 2011; Hughes & Kitson, 2012). Following definitions by Hughes et al. (2011) and Hughes and Kitson (2012), the private sector comprises individuals and entities, such as entrepreneurs and businesses that pursue privately-owned economic activities whereas the public sector consists of state-owned institutions as well as public sector organisations and employees. Charities, voluntary organisations and social enterprises including the local community and Non-Governmental Organisations (NGOs) constitute the third sector.

On the premise that university research can be beneficial to innovation as a process and outcome of the process (Quintane, Casselman, Reiche & Nylund, 2011; Robin & Schubert, 2013), the conceptual framework (Figure 1) embraces the two realities of innovation and categorises innovation into six types. These are product innovation, service innovation, process innovation, technological innovation, administrative innovation and opportunity-related innovation. This position contradicts the process view of innovation which includes hard or technological innovations (e.g. generation of patents or the introduction of new product, process) and soft or non-technological innovations (e.g. organisational innovation, market innovation) (Tavassoli & Karlsson, 2015). Bloch (2007) in a review of the 2005 Oslo Manual indicates a shift of emphasis from the word "technological" to characteristics or intended uses in order to make the definitions more applicable to innovation in services.

Therefore, product innovation is defined as the process or outcome of the process of developing or offering a new or improved good. This definition is consistent with that of Schumpeter (1934/1983) which is the introduction of a new good or a new quality of a good. On the other hand, service innovation consists of the process or outcome of the process of developing or offering a new or upgraded service while process innovation is conceptualised as involving the procedure or outcome of the procedure of developing or introducing a new or improved production or service delivery method. Boachie-Mensah and Acquah (2015) adopted a similar definition of process innovation in their study of innovation and firm performance in Ghana. They defined process innovation as the process of re-engineering and improving the internal operations of organisational processes.

Contrary to the process-based conceptualisation of technological innovation as a set of activities through which a firm conceives, designs, manufactures and introduces a new product, service or process (De Massis, Frattini, Pizzurno & Cassia, 2015), technological innovation is captured in the framework (Figure 1) as the process and outcome of the process of developing or offering new or improved tools, equipment or component parts. Administrative innovation is conceptualised in line with Schumpeter's definition (1934/1983) which is the carrying out of new or improved organisation of any industry. Damanpour, Szabat and Evan (1989) argue that administrative innovation affects the social system of an organisation which includes rules, roles, procedures, and structures. It is close in meaning to organisational innovation which is the implementation of a new organisational method through strategic management decisions, as highlighted by Camisón and Villar-López (2014).

The definition of opportunity-related innovation (Figure 1) also follows Schumpeter's opening of a new market and or the conquest of a new source of supply of raw materials. Opportunity-related innovation is, therefore, close in meaning to market innovation defined by Johne (1999) as improving the mix of target markets and how the chosen markets are best served. Nevertheless, the definition of opportunity-related innovation, in the conceptual framework (Figure 1), also embraces introduction of alternative sources of livelihood to reflect the relevance of social entrepreneurship and consequent innovation outcomes for the marginalised in society. This view is buttressed by Bartels et al.'s (2016) argument that current policy debates on research, technology and innovation are tilting towards societal challenges rather than solely towards economic growth objectives.

In sum, research collaboration embraces all academic disciplines. Nevertheless, it is not very clear in literature whether research findings from disciplines outside the STEM could be beneficial to specific types of innovation. In recognition of the different types of innovation, the following two composite hypotheses guided the study of the contributions of research collaboration to innovation, across disciplines:

H_0: There are no significant differences among academic researchers in the Sciences, Technology, Engineering and Mathematics (STEM), the Social Sciences, and the Arts, in the extent to which their collaborative research findings contribute to product innovation, service innovation, technological innovation, process innovation, administrative innovation and opportunity-related innovation.

H_1: There are significant differences among academic researchers in the Sciences, Technology, Engineering and Mathematics (STEM), the Social Sciences, and the Arts, in the extent to which their collaborative research findings contribute to product innovation, service innovation, technological innovation, process innovation, administrative innovation and opportunity-related innovation.

Methodology

Survey design, based on the mixed methods approach (Leedy & Ormrod, 2010), was used to analyse the perceived contributions of research collaboration to innovation. The population of the study comprised all academic senior members of UCC and KNUST with teaching, research and outreach responsibilities. The study was conducted at KNUST and UCC because the pool of academics from the two universities was comprehensive and versatile for the test of hypothesised differences by academic discipline towards the debate on the usefulness of disciplines outside the STEM to innovation. Based on each university's directory, in January 2015, the study population was 1531 with 41 percent from UCC and 59 percent from KNUST. The elements of the population belonged to academic disciplines which were similar in nature across the two universities thereby, subsequently, permitting stratification of the study population into three academic disciplines of STEM, Social Sciences and Arts. In all, the STEM had 896 academics, Social Sciences had 408 while the Arts had 227, resulting in the total population of 1,531.

With a working sample of 511, the sample sizes of the three strata – 297 for the STEM, 138 for the Social Sciences and 76 for the Arts – were determined through proportionate stratified sampling, firstly by institution and secondly by academic discipline (Schönbrodt & Perugini, 2013). Selection of respondents from each stratum was done by the computerised sample selection method. Eleven key informants were purposely selected for the qualitative aspect of the study. The informants comprised eight academics who had long standing experience in research collaboration. They were recommended by the leadership of the Directorate of Research, Innovation and Consultancy (DRIC) at UCC and the Office of Grants and Research (OGR) at KNUST. The remaining three informants were the Director of DRIC, the Head of the OGR and the Head of the Technology Consultancy Centre (TCC) at KNUST.

In reference to the conceptual framework of the study (Figure 1), innovation variables were assessed on a semantic differential scale, through questionnaire design (Zikmund, Babin, Carr & Griffin, 2013). The scale varied from 1, representing “least beneficial”, to 7, representing “very beneficial”. Data requirement constituted the extent to which collaborative research findings, within the past ten years, was beneficial to external collaborating parties in terms of improving upon or developing any of the six types of innovation which are illustrated in the conceptual framework. Academic discipline of respondents was measured using nominal scale. Two separate interview guides were developed for the two groups of informants to elicit their research collaboration experiences over the past ten years. A number of questions and prompts in the interview guides were derived from major issues that emerged from the quantitative study.

Ethical clearance for the study was given by the University of Cape Coast Institutional Review Board in September, 2014. The questionnaire was pilot tested from September, 2014 to October, 2014 at the KNUST. After refining the questionnaire, it was administered from November, 2014 to March, 2015 while interviews were conducted in May, 2015 and June, 2015.

Quantitative data were analysed with IBM Statistical Product and Service Solutions (SPSS) Version 19. Test of hypothesised differences across academic discipline was done with the Kruskall-Wallis test instead of ANOVA due to violation of one of the assumptions for the conduct of ANOVA, that is, the presence of conditions with less than 25 participants (Schmider, Ziegler, Danay, Beyer & Bühner, 2010). Qualitative data were transcribed and analysed on the basis of major themes.

Results and Discussion

Results

This section of the paper consists of presentation and analysis of the results of the study. The results encompass descriptive analysis of the demographic characteristics of respondents and the use of collaborative research findings in innovation. The descriptive analysis is followed by tests of hypothesised differences in the extent to which collaborative research findings from the STEM, the Social Sciences and the Arts are perceived to have contributed to the various types of innovation, presented in the conceptual framework of the study (Figure 1).

Descriptive Results

Assessment of four demographic characteristics of respondents – sex, rank, academic discipline and years of service – showed that most respondents were males. That is, out of a total of 266 responses on sex, 76 percent were from males while 24 percent were from females. In terms of rank of respondents, 265 responses were recorded with senior lecturers accounting for the most (48%) while professors were the least (2%). Assistant lecturers, lecturers and associate professors constituted 11 percent, 33 percent and six percent of the responses on rank. In relation to 256 responses on academic discipline, the majority (62%) came from the STEM while the minority was from the Arts (13%). The remaining 25 percent of responses on academic discipline were from the Social Sciences. A total of 261 responses were documented on years of service with a minimum score of one year and a maximum of 39 years, and a mean score of 10 years.

In accordance with the conceptual framework of the study which proposes that research collaboration can be useful to developing or improving upon various types of innovation, data were analysed on the extent to which collaborative research findings are perceived to have contributed to developing and improving upon innovations as well as to problem solving. Descriptive analysis showed that a total of 133 respondents had engaged in research collaboration within the past ten years. A minimum of 40 and a maximum of 108 multiple responses were received on the extent to which collaborative research findings contributed to various types of innovation and problem solving. The respective descriptive statistics, presented in Table 1, revealed some key findings based on scores below the tolerable limits of skewness (±2) and kurtosis (±7) (Schmider et al., 2010).

Table 1: Perceived Contributions of Collaborative Research Findings to Innovation and Problem Solving

	N	Min.	Max.	Mean	SD	Skewness	Kurtosis
Innovation:							
Product innovation	46	1	7	4.73	1.328	-1.069	.606
Service innovation	94	1	7	5.53	1.250	-1.372	2.330
Technological innovation	40	1	6	4.17	1.430	-.891	-.144
Process innovation	89	2	7	5.39	1.174	-.945	.581
Administrative innovation	52	1	7	4.45	1.412	-.453	.510
opportunity-related innovation	61	1	7	4.53	1.557	-.525	.620
Problem solving	108	1	7	5.73	1.212	-1.295	2.043

The extent to which collaborative research findings were perceived to have contributed to problem solving had the highest mean score of 5.73 followed by service innovation with a mean score of 5.53 (Table 1). Except for service innovation and process innovation which had mean scores of 5.53 and 5.39, respectively, the remaining innovation types recorded relatively lower mean scores with technological innovation recording the lowest mean score of 4.17, as shown in Table 1. Thus, whereas collaborative research findings were perceived to have made quite high contributions to problem solving, service innovation and process innovation, the perceived contributions to product innovation, technological innovation, administrative innovation and opportunity-related innovation were relatively lower.

Interview results revealed that the collaborative research findings of the eight key informants, from the various academic disciplines, made some contributions to innovation. A landmark innovation was the development of conflict map, which according to an interviewee, is a "commercialised" invention from research collaboration. Another major innovation was the development and commercialisation of the integration of clay with other materials which has led to reduction in overreliance on wood for artwork and ceramic production. An interviewee expressed satisfaction with this development by stating that:

> "…they make the mugs. How can we come in there? The mugs, they cut wood to develop that well or mould. But wood if they could produce about 1000 different mug shapes or designs, that means 1000 different designs of wooden moulds and that will have an impact, that is negative impact, on the environment. The integration of the wood…will affect the eco-biodiversity. Clay is one material that is in abundance in the whole world. So how can we come in? So, we make the moulds with clay. As for clay you can smash it and reuse it."

Test of Differences across Academic Disciplines

Kruskal-Wallis tests were conducted to examine whether academic researchers from the STEM, Social Sciences and Arts, differ in the extent to which their collaborative research findings were perceived to be beneficial to the six types of innovation outlined in the conceptual framework of the study (Figure 1). The tests were necessitated by emerging debates such as those by Bakhshi et al. (2008) and Hughes et al. (2011), in the literature on university interaction with external entities, which argue for policy attention for all academic disciplines besides the STEM. The STEM has been the priority of policy interventions due to the perception that this discipline, by its nature, is relatively more useful to innovation (Bakhshi et al., 2008; Hughes et al., 2011). The Kruskal-Wallis tests were performed on the six types of innovation presented in the conceptual framework of this study.

Firstly, the extent to which the perceived collaborative research findings contributed to product innovation was analysed with a total of 45 responses (Table 2). Inspection of Table 2 shows that the STEM recorded the highest mean rank (25.16) while the Arts had the lowest mean rank (23.00). However, assessment of the median scores, as presented in Table 2, revealed that collaborative research findings from the Social Sciences (*M* = 4.75) made the least perceived contribution to product innovation whilst the highest perceived contribution came from the STEM (*M* = 5.50). That is, collaborative research findings from the Social Sciences were considered less beneficial to product innovation while that from the STEM was considered relatively more beneficial to product innovation. Nevertheless, results of the Kruskal-Wallis test indicated the absence of statistically significant differences in the extent to which collaborative research findings from the three academic disciplines were perceived to be beneficial to product innovation [(Group 1, n = 25: STEM, Group 2, n = 14: Social Sciences, Group 3, n = 6: Arts), x^2 (2, n = 25) = 1.938, *p* = .379].

Thus, academic researchers from the STEM, Social Sciences and Arts did not differ, significantly, in the extent to which they perceived their collaborative research findings to be beneficial to product innovation. Interview results showed that collaborative research findings from the STEM contributed, for example, to the development of new varieties of crops, solar panels and production of biodiesel while that from the Arts were very beneficial to innovations in the creative industry. One landmark product innovation from the Social Sciences was the development of conflict map for Ghana, which according to an interviewee happened to be a new-to-the-world innovation.

Table 2: Perceived Contributions of Research Collaboration to Innovation across Academic Disciplines

Academic Discipline	N	Mean Rank	Chi-square	Asymp. Sig.	Median Scores
Product Innovation			1.938	.379	
STEM	25	25.16			5.50
Social Sciences	14	19.14			4.75
Arts	6	23.00			5.00
Total	*45*				*5.00*
Service Innovation			6.778	.034	
STEM	55	51.47			6.00
Social Sciences	29	36.95			5.00
Arts	7	40.50			6.00
Total	*91*				*6.00*
Technological Innovation			.032	.984	
STEM	23	20.00			5.00
Social Sciences	12	19.71			4.50
Arts	4	20.88			4.50
Total	*39*				*4.50*
Process Innovation			.0647	.724	
STEM	49	44.17			6.00
Social Sciences	30	41.22			6.00
Arts	7	48.57			6.00
Total	*86*				*6.00*
Administrative Innovation			.311	.856	
STEM	29	25.10			4.50
Social Sciences	19	26.87			5.00
Arts	3	29.17			5.00
Total	*51*				*4.50*
Opportunity-related Innovation			4.188	.123	
STEM	35	32.93			5.00
Social Sciences	19	28.00			4.50
Arts	5	17.10			3.00
Total	*59*				*5.00*

Secondly, the perceived contribution of collaborative research findings to service innovation was assessed. The assessment was based on a total of 91 responses (Table 2). Results of the assessment showed that the STEM recorded the highest mean rank (51.47) followed by the Arts (40.50) and Social Sciences (36.95), respectively. In addition, the STEM and the Arts recorded higher median scores of 6 each, than the Social Sciences which had a median score of 5 (Table 2). Results of the Kruskal-Wallis test revealed statistically significant differences in the extent to which collaborative research findings from the three academic disciplines were perceived to have contributed to service innovation [(Group 1, n = 55: STEM, Group 2, n = 29: Social Sciences, Group 3, n = 7: Arts), χ^2 (2, n = 55) = 6.778, *p* = .034]. Some service innovations which benefited from the collaborative research findings of some interviewees were in the educational sector, agricultural sector and media work. An example was the use of language in the media landscape and some educational institutional discourses which, in the view of the interviewee, was becoming domineering and needed to change for enhanced service delivery.

Thirdly, with a total of 39 responses, the extent to which collaborative research findings were perceived to have been useful to technological innovation was analysed. Results of the analysis, presented in Table 2, showed close mean ranks with the Arts and the STEM recording similar mean ranks of 20.88 and 20.00, respectively, while the Social Sciences recorded a relatively lower mean rank of 19.71. The Social Sciences and the Arts recorded the same median score (*M* = 4.50) whilst the STEM had a higher median score of 5.00. The median scores indicate that collaborative research findings from the Social Sciences and the Arts were perceived to be relatively less beneficial to technological innovation than those from the STEM. However, Kruskal-Wallis test results did not show statistically significant differences in the extent to which collaborative research findings were considered to have contributed to technological innovation, across the three academic disciplines [(Group 1, n = 23: STEM, Group 2, n = 12: Social Sciences, Group 3, n = 4: Arts), χ^2 (2, n = 39) = .032, *p* = .984].

In other words, academic researchers from the STEM, Social Sciences and Arts did not differ, significantly, in the perceived usefulness of their collaborative research findings to technological innovation. One key observation is that most technological innovations by interviewees from the STEM still need widespread commercialisation. Follow up questions revealed that relatively huge capital outlays are needed for large-scale commercialisation and efforts to secure risk capital from government and private sources have proven futile.

It is essential to note that students were instrumental in knowledge and technology development and transfer through internships and research collaborations that involved faculty, students and industry. A typical example from an interviewee was the development of mini-cassava grater powered by biodiesel for commercial processing of cassava into *gari*, a Ghanaian food staple. An interviewee from the Arts highlighted the importance of collaboration to knowledge exchange: "We do a lot of collaboration with industry…they have the machinery…if you want to do something…you go and access their machinery. Sometimes, we design for them for international exhibitions."

Fourthly, the perceived contribution of collaborative research findings to process innovation was examined with a total of 86 responses. Inspection of the descriptive statistics, presented in Table 2, revealed that the Arts (48.57) had the highest mean rank followed by the STEM (44.17) and the Social Sciences with the lowest mean rank (41.22). However, as illustrated in Table 2, the three academic disciplines recorded the same median scores (M = 6.00), which is an indication that respondents considered the use of their collaborative research findings in process innovation, as high. Kruskal-Wallis test did not show statistically significant differences in the extent to which collaborative research findings from the three academic disciplines were perceived to have benefited process innovation [(Group 1, n = 49: STEM, Group 2, n = 30: Social Sciences, Group 3, n = 7: Arts), χ^2 (2, n = 86) = .0647, p = .724].

Thus, academic researchers from the STEM, Social Sciences and Arts did not differ, significantly, in the extent to which they perceived the use of their collaborative research findings in process innovation (Table 2). Production processes and teaching methodologies were some areas that benefited from the collaborative research findings of interviewees. An interviewee shared his experience on his contribution to deficit irrigation for rice cultivation in some communities in the Central Region of Ghana:

> "…we were trying to sell the idea that you could do a second crop, vegetable…instead of letting the land remain fallow after the rice. …Normally, they don't go through the recommended practices of…planting rice. We went in to help… you plough the land, you harrow it, you construct your ponds, the ponds will trap the water… because rice is a water loving plant…But most crops will die…you have to take out the water."

Fifthly, with a total of 51 responses, the extent to which collaborative research findings from the three academic disciplines were perceived to have contributed to administrative innovation was assessed (Table 2). The assessment showed that the Arts recorded the highest mean rank of 29.17 whereas the STEM recorded the lowest mean rank (25.10). Median scores, presented in Table 2, indicated that collaborative research findings from the Social Sciences (M = 5.00) and the Arts (M = 5.00) were perceived to have been useful to administrative innovation while that from the STEM were perceived to have been less beneficial to administrative innovation. However, Kruskal-Wallis test did not reveal statistically significant differences in the extent to which collaborative research findings were perceived to have been useful to administrative innovation, across the three academic disciplines [(Group 1, n = 29: STEM, Group 2, n = 19: Social Sciences, Group 3, n = 3: Arts), χ^2 (2, n = 51) = .311, p = .856].

The test results indicate that academic researchers from the STEM, Social Sciences and Arts did not differ, significantly, in the extent to which they perceived their collaborative research findings to be beneficial to administrative innovation (Table 2). Some interviewees from the Social Sciences shared their experiences on the contribution of their collaborative research findings to the development of national and institutional policies and practices in the fields of development and education. One interviewee noted that collaborative research findings enhanced justice delivery in Ghana's chieftaincy system, while another pointed to development of manuals and policy briefs for administering educational leadership to promote quality and effective teaching and learning in Ghanaian schools.

Last but not the least, the perceived contribution of collaborative research findings to opportunity-related innovation was analysed with a total of 59 responses (Table 2). Inspection of Table 2 shows that the STEM recorded the highest mean rank (32.93). The lowest mean rank was recorded by the Arts (17.10). In the same way, median scores presented in Table 2 indicate that collaborative research findings from the STEM (M = 5.00) were considered to be relatively beneficial to opportunity-related innovation while that from the Social Sciences (M = 4.50) were considered less beneficial to the innovation. The perceived benefits derived from collaborative research findings from the Arts was quite low (M = 3.00).

Nonetheless, results of the Kruskal-Wallis test did not show statistically significant differences in the extent to which collaborative research findings were perceived to have been used in opportunity-related innovation, across the three academic disciplines [(Group 1, n = 35: STEM, Group 2, n = 19: Social Sciences, Group 3, n = 5: Arts), χ^2 (2, n = 59) = 4.188, p = .123]. Thus, academic researchers from the STEM, Social Sciences and Arts did not differ, significantly, in the extent to which they perceived their collaborative research findings to have contributed to opportunity-related innovation (Table 2).

Three major opportunity-related innovations came up during interviews. These were the use of biodiesel to power vehicles, land reclamation for crop production and the development of artificial zeolites (which according to the researcher happens to be a new-to-the-world innovation for which patent was being sought) for water purification and fertilizer production. An interviewee emphasised the opportunities that have been created in the Ghanaian business environment through research collaboration with industry: "Now the integration has caught up, now everybody is saying integration. It started, all here…"

On the basis of the foregoing analysis, with the exception of service innovation, there is failure to reject the composite null hypothesis that there are no statistically significant differences in the extent to which collaborative research findings from the STEM, the Social Sciences and the Arts are beneficial to product innovation, technological innovation, process innovation, administrative innovation and opportunity-related innovation. The results further show that all the academic disciplines are relevant to innovation although some variations may occur.

Another major observation from the median scores in Table 2 is that, the STEM appeared to be a leader in all types of innovation except for administrative innovation and process innovation, while the Social Sciences were perceived to have made relatively lesser contributions to the various types of innovation, excluding administrative innovation. The Arts was a close follower of the STEM. Interview results from the Liberal Arts revealed that use of collaborative research findings, by relevant bodies, resulted more in the improvement of processes and service delivery by the users, while collaborative research findings from the Creative Arts yielded, relatively, more product innovations such as jewelry, furniture and other items for interior decoration.

Robustness Tests

The preceding results and analysis pointed to the absence of statistically significant differences in the extent to which collaborative research findings from the STEM, the Social Sciences and the Arts were perceived to have contributed to the different types of innovation, except service innovation. In order to control for Type 1 error, in the analysis of service innovation, post-hoc analysis was done with the Mann-Whitney U test with an Alpha level of .017 (Pallant, 2011).

The first Mann-Whitney U test was between the STEM and the Social Sciences. The test revealed a statistically significant difference, at $\alpha = .017$, in the extent to which collaborative research findings from the STEM ($Md = 6$, n = 55) and the Social Sciences ($Md = 5$, n = 29), U = 545, z = -2.504, $p = .012$, $r = .273$, were considered to have contributed to service innovation. The effect size, $r = .273$, was computed with the formula $r = z \div \sqrt{N}$ (Pallant, 2011). Using Cohen's criteria (.1 = small; .25 = medium; .40 = large) for effect size interpretation (Cohen, 1992;

Pallant, 2011), it can be concluded that a medium, statistically significant difference existed between the STEM and the Social Sciences in the extent to which they perceived their collaborative research findings to have contributed to service innovation.

The second and third Mann-Whitney U tests were between the STEM and the Arts, on one hand, and the Social Sciences and the Arts, on the other. The test between the STEM and the Arts showed insignificant difference, at $\alpha = .017$, in the extent to which their collaborative research findings from the STEM (*Md* = 6, n = 55) and the Arts (*Md* = 6, n = 7), U = 144.000, z = -1.138, $p = .225$, were considered beneficial to service innovation. There was also no statistically significant difference between the Social Sciences and the Arts in the extent to which they perceived their collaborative research findings to have contributed to service innovation ($\alpha = .017$: Social Sciences (*Md* = 5, n = 29), Arts (*Md* = 6, n = 7), U = 91.500, z = -.433, $p = .696$).

On the basis of the fact that the STEM and the Social Sciences had significant differences in their perceived contributions to service innovation, there is failure to accept the null hypothesis that no statistically significant differences exist among the STEM, the Social Sciences and the Arts in the extent to which their collaborative research findings are beneficial to service innovation.

Discussion

From the conceptual framework of the study (Figure 1), it can be said that collaborative research output was considered to have contributed to service innovation and process innovation, while the output was considered quite beneficial to product innovation, opportunity-related innovation, administrative innovation and technological innovation. The findings buttress the relevance of university research to innovation as established in prior studies such as those by Costa and Teixeira (2005) in Portugal, Mueller (2006) in Germany and Robin and Schubert (2013) in France and Germany.

However, the lower mean and median scores for the extent to which collaborative research findings were perceived to be beneficial to product innovation, opportunity-related innovation, administrative innovation and technological innovation, coupled with the relatively lower percentage of academics who had engaged in research collaboration, imply that the collaborative research findings made less contribution to Ghana's knowledge-based economy. This condition creates the tendency for a wider knowledge filter which is the gap that exists when investment in knowledge creation yields new knowledge that is yet to be exploited and put to commercial use (Acs et al., 2013; Braunerhjelm et al., 2010).

Paradoxically, the general expectation is that collaborative research findings would make substantial contribution to innovation in a country, like Ghana, that is beset with low industrial R&D and an industrial sector that is characterised by a multitude of micro, small and medium-sized enterprises (MSMEs) that do not have the capacity for R&D (Abdulai et al., 2015; Dutta et al. 2018). Prior studies have pointed to rationally conflicting goals and expectations of academic researchers and the carriers of innovation (D'Este & Perkmann, 2011; Hughes & Kitson, 2012), as well as low absorptive capacity of MSMEs in Africa (Fu, Mohnen & Zanello, 2018; Onyeiwu, 2015).

Furthermore, the study has brought to light the importance of all academic disciplines to innovation driven by research collaboration. Although the various academic disciplines appear to have the tendency to be tilted towards certain types of innovation, the findings of this study agree with Hughes et al.'s (2011) and Bakhshi et al.'s (2008) position that the Arts and the Social Sciences or the Humanities are also important in advancing the knowledge base of an economy. This study, therefore, confirms the relevance of all academic disciplines to building the knowledge-based economy, through the contribution of their research findings to innovation, as generalised in the conceptual framework of the study (Figure 1).

Conclusion

The study was conducted with the aim of assessing the relevance of different academic disciplines to innovation within the context of research collaboration (between academics and the carriers of innovation) which is deemed a critical medium for the conduct of innovation-driven research. The major findings of the study were that there were no substantial differences in the extent to which academics from the STEM, the Social Sciences and the Arts perceived the use of their collaborative research findings in product innovation, technological innovation, process innovation, administrative innovation and opportunity-related innovation. However, a substantial difference occurred in favour of the STEM as against the Social Sciences in the perceived usefulness of their collaborative research findings to service innovation.

Although there were no substantial differences in the perceptions of academics across disciplines, the findings show that the STEM was a leader in all types of innovation except for administrative innovation and process innovation in which the Arts was perceived to have made relatively the highest contributions. The Arts was a close follower of the STEM in product innovation, service innovation and technological innovation while the Social Sciences was perceived to have made relatively lesser contributions to the various types of innovation, excluding administrative innovation in which it came after the Arts. It is, therefore, concluded that all academic disciplines can be relevant to innovation and that the STEM and the Arts are making relatively more contributions to the various types of innovation than the Social Sciences.

Acknowledging the importance of university research to regional and national innovation with eventual impact on economic growth and development, it is an imperative for the Ghanaian government, together with universities and other key stakeholders, to step up measures in support of university interactions with the carriers of innovation, particularly that which would translate into the use of collaborative research findings in the development of competitive innovations for national development. A critical point of departure from the norm is to design appropriate policies from the perspective of the indispensable roles that various academic disciplines must play in the national innovation system.

This study focused on academic researchers from two out of ten public universities in Ghana. Another limitation is the concentration of the study on the supply side of research collaboration to the exclusion of the carriers of innovation. These drawbacks can be the subject of future research together with a study of the contributions of research collaboration to innovation in the private, public and third sectors of the economy. Moreover, further studies can analyse institutional contribution to regional and national innovation as well as untested dimensions and feedback loops in the conceptual framework employed in this study.

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