The role of industry and economic context in open innovation: evidence from Nigeria*

Abiodun Egbetokun, Omolayo Oluwatope, David Adeyeye, Maruf Sanni

National Centre for Technology Management [Federal Ministry of Science and Technology], PMB 012, Obafemi Awolowo University, Ile-Ife, Nigeria

Email: abiodun.egbetokun@nacetem.gov.ng; aaegbetokun@gmail.com [Egbetokun], omolayo.oluwatope@nacetem.gov.ng [Oluwatope], david.adeyeye@nacetem.gov.ng [Adeyeye], maruf.sanni@nacetem.gov.ng [Sanni]

Abstract

Using innovation survey data on a sample of UK manufacturing firms, Laursen and Salter [2006] documented a non-monotonous relationship between external search strategies and firm-level innovative performance. We find partially similar results in a combined sample of Nigerian manufacturing and service firms. A major discrepancy is that external search appears not to matter for radical innovation in our sample. Based on multiple research streams including economics of innovation and development economics, we develop and test new hypotheses on sectoral differences and the role of the economic context. We find that in a developing context, a wider range of innovation obstacles implies broader external search and more intense obstacles require deeper search. We explore the implications of these results for management research and theory.

Keywords: open innovation; search strategies; innovation obstacles; technological and non-technological innovation; Nigeria

JEL Codes: L14, O32, C30

* The data used in this paper is the first output of an exploratory research grant provided by the Private Enterprise Development for Low-Income Countries (PEDL), joint initiative of the Centre for Economic Policy Research (CEPR) and the Department for International Development (DFID). The research benefitted from Egbetokun's research stay at the United Nations University-Maastricht Economic and social Research institute on Innovation and Technology [UNU-MERIT], Maastricht, the Netherlands. Comments and suggestions from Pierre Mohnen, Micheline Goedhuys and participants at the Joint UNU-MERIT/Maastricht Graduate School of Governance Seminars are gratefully acknowledged. An earlier version of the paper is at www.merit.unu.edu/publications/wppdf/2014/wp2014-073.pdf.

Introduction

Innovation is a systemic phenomenon that is strongly related to the use of external knowledge [Tomlinson, 2010, Enkel et al., 2009, Chesbrough, 2003, Lundvall, 1988]. There are two well-known empirical regularities on this relationship, as demonstrated by extensive research evidence. The first one is based on the seminal work of [Cohen and Levinthal, 1990] and [Cohen and Levinthal, 1989] on absorptive capacity. A firm tends to be more or less innovative depending on its ability to appropriate external knowledge [Lin et al., 2012, de Jong and Freel, 2010, Todorova and Durisin, 2007, Lane et al., 2006, Lane et al., 2002, Zahra and George, 2002, Lane and Lubatkin, 1998]. The second empirical regularity, which builds upon the first, stems from the groundbreaking work of [Laursen and Salter, 2006] [henceforth LS]. The broader and deeper a firm searches, the more innovative it tends to be, but search diversity[1] is subject to decreasing returns [de Leeuw et al., 2014, Oerlemans et al., 2013, Garriga et al., 2013, Duysters and Lokshin, 2011, Jiang et al., 2010, Chiang and Hung, 2010].

Our analyses are directed towards re-evaluating and extending the second empirical regularity described above. In this light, our specific objectives are two-fold. First, we explicitly replicate the analyses of LS, for the first time ever on a combined pooled cross-sectional sample of service and manufacturing firms from a developing country in Africa. For this purpose, we use a novel dataset on service and manufacturing firms in Nigeria, which is one of Africa's largest economies. Our dataset has a key advantage: instead of single cross-sections of manufacturing firms that are commonly used in previous studies, we pool a sample of manufacturing and service firms over two periods. The completely different sample and economic context help us to deliver additional insight to the strategic management literature on innovation and knowledge search behaviour beneath the frontier. Second, we extend the analyses of LS by taking a multidimensional view of innovation, and considering sectoral differences and the role of the economic context. In particular, we combine insight from the economics and management literatures to develop new hypotheses

[1] A clarification of terminology is essential at this point. [Harrison and Klein, 2007] make an extensive discussion of the diversity concept in the context of management research. [Stirling, 2007] presents a stylised framework of different aspects of diversity: variety ('how many types of thing do we have?'), balance ('how much of each type of thing do we have?') and disparity ('how different from each other are the types of thing that we have?'). Clearly, the notions of search breadth and depth used in Laursen and Salter (2006) reflect the aspect of variety. The term 'diversity' applied in other related research such as [de Leeuw et al., 2014, Oerlemans et al., 2013, Duysters and Lokshin, 2011] actually reflects only the aspect of balance. Throughout this paper, we align ourselves with Stirling's broad framework and terminology.

that link the firm's external search strategy to its sector of operation and the magnitude of innovation obstacles experienced. In the above respects, our analyses differ from and complement the recent replications of LS by [Garriga et al., 2013] and [Oluwatope et al., 2014].[2]

In the next section, we highlight the main concepts and results of LS, and draw attention to the specific issues that create the basis for our own analyses. After that, we describe our data, variables and some descriptive results before describing the estimation technique and results. We discuss the results as well its implications for management theory and research in the final section.

Relating External Knowledge to Innovation: a Critical Discussion of [Laursen and Salter, 2006]

The existing literature is coherent on the positive benefits of alliances or external knowledge search for innovation. From a resource-based view of the firm, the so-called portfolio approach, whereby multiple sources are combined, is thought to be very useful [Faems et al., 2005, Jiang et al., 2010]. The mechanism behind this hypothesis is the notion of diversity, which essentially implies different kinds of sources or partners. It is believed that diverse sources or partners tend to hold non-monotonous resources and are, therefore, better in combination than any single source. However, diversity has its limits. A smaller portfolio is easier to manage but holds less innovative potential. By contrast, a larger portfolio gives the firm access to diverse resources but is considerably more difficult to manage. Consequently, the relationship between firm-level innovation and diversity[3] of knowledge sources or alliance portfolio is curvilinear.

Perhaps the most influential study on this subject, to date, is the one by LS.[4] This is evidenced by the rapid diffusion of the breadth and depth concepts that the study popularised as well as the extensive forward citations [Figure 1]. In fact, as of April, 2014, LS has been cited more than 1700 on Google Scholar [an average of roughly 20 citations every month], more than 500 times in CrossRef and over 650 times in Scopus. Based on a sample of UK

[2] In fact, in [Oluwatope et al., 2014], the major objective was not to explicitly replicate LS. Hence, some of the LS variables were inevitably omitted.
[3] By this we encompass variety (breadth/depth), balance and disparity. See footnote 1.
[4] GKS recently noted that the analyses and results are highly significant for the research on innovation management and more specifically, open innovation.

manufacturing firms, the study showed that using multiple external sources has an inverted U-shaped relationship with innovative performance. Their breadth and depth constructs, which reflect, respectively, the sheer number of external sources and the number of highly important ones, essentially capture the variety of external knowledge that the firm accesses. Comparing incremental [new-to-the-firm] and radical [new-to-the-world] innovations, they demonstrate that search breadth impacts more on the former while search depth impacts more on the latter. [Chiang and Hung, 2010], [Garriga et al., 2013] and [Oluwatope et al., 2014] document similar results for manufacturing firms in Taiwan, Switzerland and Nigeria respectively.

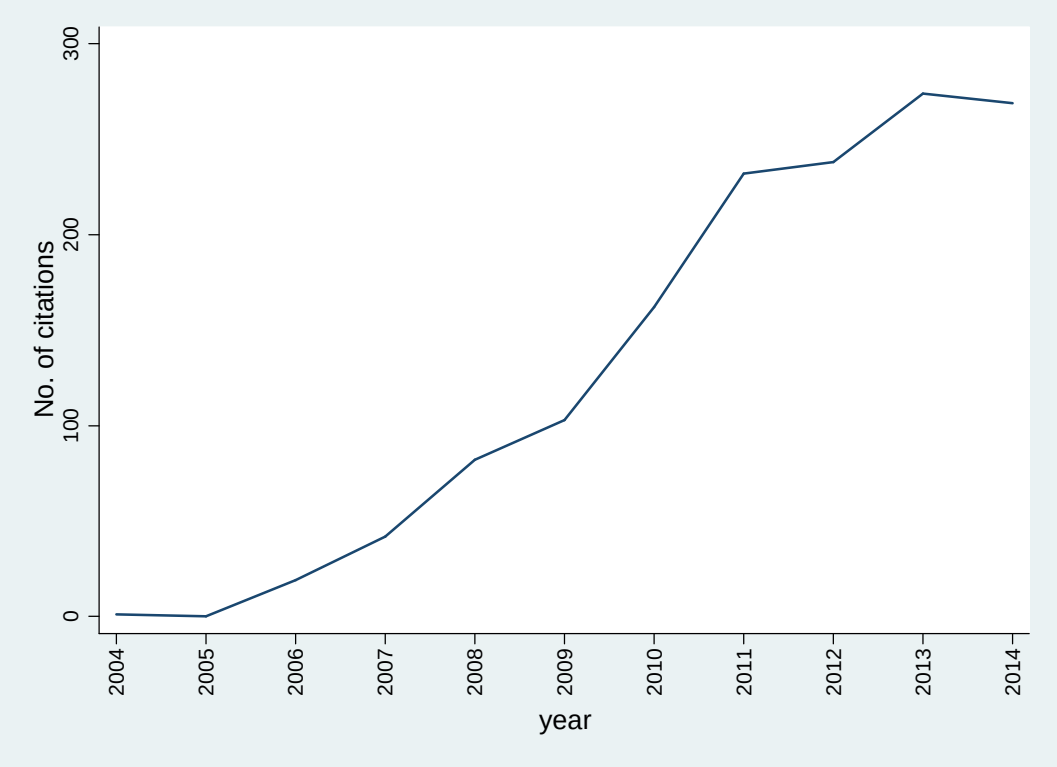

Figure 1: Trend of Google Scholar citations to Laursen and Salter (2006) since it first appeared online in 2004

Note: Search string "OPEN FOR INNOVATION THE ROLE OF OPENNESS IN EXPLAINING INNOVATION PERFORMANCE AMONG UK MANUFACTURING FIRMS" ensures that the search returns articles that contain LS in the reference list. Search conducted on September 12, 2014 at 1pm GMT+1. The 2014 data is as at this date and the 2006 data was discounted by 1 to remove LS itself. In total, the plot includes 1,422 articles.

It is of note that LS is based on only the manufacturing sector in a developed country, UK. Thus, the external validity of the results and implications is debatable, particularly from the perspective of a developing country. This limitation is shared almost without exception, by later similar studies. For instance, the studies of [Chiang and Hung, 2010] and [Oluwatope et al., 2014] are based only on the manufacturing sector; the [Garriga et al., 2013] paper replicates and extends LS by including a sample of service firms and considering the firm's contextual factors but is still limited in geographical scope. Moreover, to capture innovation performance, most studies in the LS tradition employ a measure of innovative sales, that is, the share of total sales that accrue from new-to-firm or new-to-market products. The narrow scope of this performance measure poses a problem for research in a less developed context. A focus on technological product innovation alone offers only partial insight on firm-level innovative performance. No doubt, firms make profit through the sale of their products, but the process, marketing and organisational capabilities that make production possible are just as important [Carvalho et al., 2013].

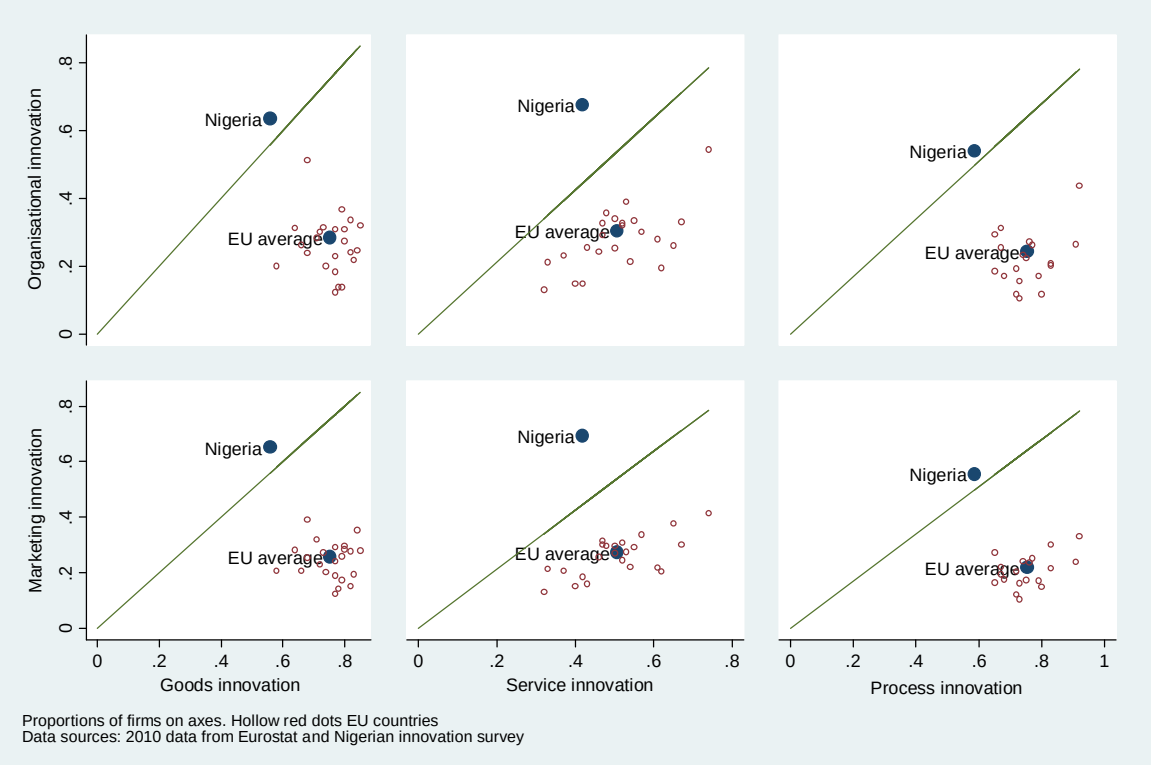

Figure 2: Organisational and marketing innovation versus goods, service and process innovation in Nigeria and the EU

As Figure 2 illustrates, the aspects of marketing and organisational innovation are especially important in a developing country. For our study context, Nigeria, and several EU countries, the figure compares the rate of technological product and process innovation [x-axes] in 2010 with the rate of non-technological marketing and organisational innovation [y-axes] in the same year. For clarity, we highlight only the study context and the EU average. In all cases, Nigeria is above the 45-degree line, suggesting that non-technological innovation occurs more frequently than technological innovation. The reverse is true for the EU countries, which are relatively more developed. Although this observation reflects the level of innovative capabilities in the latecomer firms, it is also strongly indicative of firms' innovation behaviour in the face of strong obstacles and in backward economic contexts [see Section 2.2 of Annex A in [OECD, 2005]].

Building Upon the [Laursen and Salter, 2006] Model

Considering the issues discussed above, a re-examination of the empirical regularity that LS championed becomes crucial, and we find opportunities for extensions in at least two main directions. We draw inspiration from three bodies of research: economics of innovation, open innovation, innovation management and development economics.

Sectoral specificity

Studies on the economics and management of innovation have repeatedly argued that the innovation processes differ between manufacturing and services [Vega-Jurado et al., 2009, Castellacci, 2008, Hoffman et al., 1998]. Recent contributions to the open innovation literature echo this view e.g., [Garriga et al., 2013]. However, in relation to external search for knowledge, the two broad sectors are thought to be very similar [Carvalho et al., 2013, de Jong and Marsili, 2006, Archibugi, 2001]. For instance, based on Italian innovation survey data, [Evangelista, 2000] highlighted the strong relevance of user-producer interactions in both manufacturing and services.

Nevertheless, given the nature of service activities, there are reasons to expect open innovation to work differently from manufacturing [Chesbrough, 2011]. For instance, the intangible nature of services implies that customers often cannot precisely stipulate their

needs. Moreover, because the quality of services is hard to determine, suppliers are susceptible to a high risk of error and consumers often cannot provide reliable feedback. In addition, the non-storable nature of services often requires that producers, consumers and other actors in the value chain maintain doubly coincident schedules. More often than not, the offering of a service cannot be delayed and, therefore, any input, including knowledge, into the creation of the product must be available as and when needed. Thus, the "need to sustain a pattern of interaction over time, building up a shared understanding and common ways of working together" [LS, p.136] is more intense for service firms. This difference will reflect in external search depth, leading to the following hypothesis:

> Hypothesis 1: External search depth is more strongly related to innovative performance among service firms than manufacturing.

The role of economic context

The context in which the firm is embedded affects both its innovativeness and external search strategies.[5] For instance, [Garriga et al., 2013] showed that the abundance of innovation resources, especially knowledge, in the firm's environment tends to motivate external search. However, the environment in most developing countries is characterised by a wide range of obstacles to innovation, ranging from paucity of human capital and knowledge resources to poor infrastructure [Biggs and Shah, 2006, Oyelaran-Oyeyinka, 2006, Wignaraja, 2002, Hadjimanolis, 2000]. The negative impact of these obstacles varies in intensity [Radwan and Pellegrini, 2010]. The variety in both the nature and intensity of the innovation obstacles affect the external search strategies of the firms in a unique manner.

Faced with diverse innovation obstacles, it becomes much more essential for the firms to search a wider technological or cognitive space. One way of doing this is to combine diverse sources in order to maximise potential external knowledge [Goedhuys, 2007]. This is particularly true given the fact that only limited resources are accruable from any single source. For instance, while customers may carry ideas for significant product improvements, they are of limited relevance in overcoming institutional or infrastructural constraints. However, industry associations are considerably helpful in making up for state failures and

[5] Interestingly, the latter aspect has not been extensively studied in developing countries. There have been a few studies of South African firms [Oerlemans et al., 2013], [de Leeuw et al., 2014] but none of them accounts for the economic context.

dealing with infrastructural constraints [Oyelaran-Oyeyinka, 2007]. Moreover, most firms do not perform in-house R&D [Ilori et al., 2000, Egbetokun et al., 2009] and inter-firm knowledge spillovers are thereby limited. In addition, the knowledge generating institutions like universities and research institutes often do not sufficiently create knowledge that is relevant to the domestic private sector [Oyebisi et al., 1996]. Thus, it seems reasonable to anticipate that as the range of innovation obstacles increases, particularly in a developing country context, firms feel the need to draw upon an increasing variety of external sources in order to minimise redundancy.

Moreover, as obstacles become more intense, it may seem logical for firms to repeatedly use the same sources that have been successful in the past. This partly explains why industry associations have become highly important in some sectors [Egbetokun et al., 2012, Egbetokun et al., 2010]. In addition, small firms, in the face of intense competition particularly from foreign imports and large enterprises, form repeated/persistent inter-firm linkages [or, co-opetition strategies, as they have come to be known] [Oyelaran-Oyeyinka, 2005]. The above discussion is combined in the following hypotheses:

> Hypothesis 2a: A wider variety of innovation obstacles is associated with broader external search
>
> Hypothesis 2b: A higher intensity of innovation obstacles is associated with deeper external search

Data, Measures and Descriptive Results

Data

The Nigerian innovation surveys are based on the Oslo Manual and, hence, share the core set of questions with the Community Innovation Surveys [CIS] of Europe. Hence, the datasets include information on the innovation investments, sources, obstacles and outcomes in the firms as well as detailed firm characteristics including size, human capital, age, location and export status. So far, there have been two surveys, both of which were inspired by the African Science, Technology and Innovation Indicators Initiative [ASTII]. Some aggregate results from the second survey are reported in [AU-NEPAD, 2014]. The ASTII facilitated a process to make the Oslo Manual framework more relevant for Africa.

As already recognized in previous studies [e.g., [Adeoti, 2012], it is hard to plan a stratified sample in Nigeria due to non-availability of a consistent and reliable register of firms. Notwithstanding, the survey attempted a stratified sample based on the list of establishments with at least 10 employees obtained from the National Bureau of Statistics [NBS] and the Nigerian Stock Exchange. The Stock Exchange list includes only formal firms whereas the NBS list includes both formal and informal firms. These two sources were cross-referenced and any firm listed in both sources was automatically selected into the sample. The logic behind this is that if a firm was listed on the stock exchange then it must still be in the market. This criterion is important considering the fact that firm exit rate is particularly high in Nigeria, a factor that partly makes it difficult to compile a consistent register of all firms.

To ensure a fair geographical and sectoral distribution in the final sample, the population of firms was stratified into geographical zones and sectors [in the first wave ISIC Rev 3.1 was used and in the second wave ISIC Rev. 4]. The final sample [about 1500 in each round of the survey] was then selected based on proportional probability, with a combined response rate of approximately 45%. The survey instruments were delivered by hand to all the firms, and in many instances, some of the selected firms did no longer exist. In every possible case, the missing firm was substituted with another one in the same sector and geographical location. The two waves of the survey represent two repeated cross sections. Although it was ensured that every firm that responded in the first wave was contacted for the second wave, the response was particularly low, necessitating a re-sampling. Nonetheless, the amount of information contained in the datasets and their comparability with data from other countries make them very useful for rigorous empirical analyses. Table 1 gives a breakdown of our final sample, which includes a total of 1359 service and manufacturing enterprises.

Table 1: Sectoral distribution of final sample

Year	Manufacturing	Services	Total
2007	521	207	728
2011	371	260	631
Total	892	467	1359

Measures

Our main variables are fashioned as closely as possible after LS. Three different proxies capture innovative performance. The first two, INNMKT and INNFIRM reflect the proportion of the firm's revenue from new-to-market or new-to-firm products respectively. Our dataset does not include any information on new-to-the-world innovation, so we are restricted to INNMKT as the proxy for radical innovation and INNFIRM as proxy for incremental innovation. It has been repeatedly observed that developing country firms exhibit a higher propensity for incremental and non-technological innovation than their developed country counterparts [Ernst and Kim, 2002, Mytelka, 2000, Lall, 1992, Oyelaran-Oyeyinka, 2005, Oyelaran-Oyeyinka et al., 1996]. To reflect this reality, we employ an alternative multidimensional measure of innovative performance that takes into account both technological and non-technological innovation. This third measure, SINNO [Cronbach's alpha = 0.66], is a categorical variable indicating the scope of the firm's innovative outcome, and ranges from zero [for a firm that carried out no innovation] to four [for a firm that implemented all of product, process, marketing and organisational innovations]. Similar measures have been applied in previous studies like [Gronum et al., 2012], and it makes it possible to rank firms in terms of overall innovative outcome rather than by financial performance on only one aspect of innovation.[6]

Appendix 1 describes the usage of all nine external sources among the sampled firms. The variables BREADTH [Cronbach's alpha= 0.89] and DEPTH [Cronbach's alpha= 0.74] are constructed as in LS. They reflect, respectively, the number of external sources that a firm uses and the number of sources that are ranked as very important by the firm. To examine curvilinearity, we include the quadratic terms of search breadth [BREADTH2] and depth [DEPTH2]. Firms were asked in the survey to rank on a scale of 1 [low] to 3 [high], the extent to which each of 13 factors hampered their innovation efforts. A factor not experienced was rated zero. Appendix 2 presents a summary of the innovation obstacles. The VARIETY OF OBSTACLES [Cronbach's alpha = 0.92] was constructed as a combination of these items, each item taking a value of 1 if the firm experienced it [low, medium or high] and zero otherwise. The INTENSITY OF OBSTACLES [Cronbach's alpha = 0.83] was constructed as a combination of the same factors, each coded as 1 if the firm ranked it high

[6] The values of this variable have purely ordinal meaning; higher scores correspond only to a higher innovation scope but not necessarily to a better financial performance. For instance, a firm with an SINNO score of 4 is not necessarily twice as innovative as one with a score of 2 but clearly demonstrates higher innovative capability.

and zero otherwise. While the former reflects the number of innovation obstacles that a firm experienced, the latter includes only those that posed serious constraints to the firm.

To keep our specifications consistent with LS, we include dummies for whether a firm was founded within the preceding three years [STARTUP], has cooperation arrangements [COLLAB] and used customers as highly important source of information [USER]. We also control for firm SIZE [the logarithm of total number of employees], and the major markets for the firm's products [GEOMARKT equals 1 for local, 2 for national and 3 for international]. Contrary to LS, we proxy absorptive capacity by a measure of the quality of human capital [HUMAN CAPITAL] constructed as the ratio of employees with a university degree.[7] This better reflects the reality in the study context and is consistent with the research on the accumulation of capabilities in developing countries [Wignaraja, 2002, Romijn, 1997]. The dummy variable SERVICE takes the value of 1 for service firms and 0 for manufacturing firms.

Descriptive results

Descriptive statistics are given in Table 2. On average, 17.3% of the firms' revenue arises from new-to-market products and processes while 22.6% arises from products and processes that are new only to the firm. These figures are higher than those reported by previous studies for firms in developed countries [for instance, LS for UK firms and [Garriga et al., 2013] for Swiss firms]. A possible source of this discrepancy is that both of our variables capture imitative innovation, that is, innovative changes that are not novel beyond the firm's primary markets but rather rely on basic science and technology developed elsewhere. This type of innovation is often implemented as a response to explicit market demand and is more likely to generate high returns in a large market like Nigeria. Table 2 further shows that on average, about two different types of innovation co-occur in the firms. This suggests that firm-level innovation is not a compartmentalised phenomenon but one that has a multidimensional attribute. As such, future research requires a multidimensional view of innovation to be able to study the process of innovation within firms more accurately. So far, the research is heavily tilted towards technological product and process innovation, which, though easier to measure through R&D and patents, offer only a partial picture of how firms innovate.

[7] For this reason, our analysis excluded an evaluation of the Not Invented Here (NIH) syndrome which LS analysed.

Table 2: Descriptive statistics

Variable	No. of firms	Mean	S.D.	Median	Min	Max
INNMARKT	733	17.29	22.55	1	0	100
INNFIRM	734	22.56	24.54	20	0	100
SINNO	1359	2.39	1.36	2	0	4
BREADTH	1359	4.08	3.24	4	0	9
DEPTH	1359	1.64	1.91	1	0	9
VARIETY OF OBSTACLES	1359	8.26	4.35	9	0	13
INTENSITY OF OBSTACLES	1359	3.04	2.95	2	0	13
HUMAN CAPITAL	1025	0.24	0.27	0.15	0	1
USER	1190	0.17	0.38	0	0	1
SIZE	1341	3.86	1.33	3.58	2.08	9.74
STARTUP	1023	0.11	0.32	0	0	1
GEOMARKT	1359	1.47	0.78	1	0	3
COLLAB	1190	0.22	0.41	0	0	1
SERVICE	1359	0.35	0.48	0	0	3

In our sample, search depth is less common than search breadth. Firms use about four sources of knowledge for innovation but they use only one source deeply, on average. Of all the innovation sources, customers, suppliers and competitors are by far the most important [Appendix 1], indicating a pattern similar to what has been emphasised in the previous literature [NACETEM, 2010, Oyelaran-Oyeyinka, 2005]. Knowledge generating institutions like universities and research institutes are only weakly relevant to firms' innovation efforts. On average, firms experience up to eight different obstacles but only about three present major problems. These include infrastructural constraints and lack of funding both in-house and from external sources [Appendix 2]. This is consistent with the earlier observations of [Radwan and Pellegrini, 2010]. Appendix 3 compares innovativeness, external search and innovation obstacles across the manufacturing and service sectors.[8] It can be observed from the table that innovativeness and search strategies are not substantially different across service and manufacturing but obstacles seem to be more varied and intense in the manufacturing sector. One observation is worth highlighting here, though. By definition, new-to-market innovation is far less common than new-to-firm innovation across both sectors. This, as already explained above, is connected to the business context. In general, due to knowledge, infrastructural and capability constraints, most developing country firms are better able to implement innovative changes new to them but not necessarily new to the

[8] Possibly because the time horizon is rather short, the main variables did not appear to vary significantly between 2007 and 2010. Hence, we do not emphasise time variation in our analyses.

domestic innovation system [Radwan and Pellegrini, 2010, Mytelka, 2000, Oyelaran-Oyeyinka et al., 1996]. Notwithstanding, the fact that a non-negligible proportion of firms implemented new-to-market innovation suggests that innovation is not entirely beyond the reach of latecomer firms. Given that most of these firms do not perform R&D or secure patents, it will be instructive for future research to probe deeper into the sources of innovation in developing countries.

Estimation Procedure and Results

For all estimations involving the variables INNFIRM and INNMARKT, we applied a log-transformed Tobit specification as in LS. A Tobit specification is appropriate because the variables are double-censored. Specifically, we created a latent variable INN* for each of the dependent variables as follows: INN* = ln[1+INN] where INN is either of INNFIRM or INNMARKT. The latent variable is then assumed a function of a firm's search strategies and a number of control variables including quality of human capital and market orientation. For estimations involving SINNO, we employed an ordinal logit specification given the rank-ordered nature of the variable. The purpose of this estimation is to examine whether a multidimensional view of innovation delivers results similar or opposed to the stylised LS results. Ordinal logit regeression equations were estimated for BREADTH and DEPTH since they are also rank-ordered. With these equations, we present new results on how the economic context affects open innovation. Pairwise correlations among our variables are contained in Appendix 4.

The results of our attempt to replicate the canonical results of LS are given in Table 3. Significant coefficients are flagged based on two-tailed t-tests (same as in the remaining tables). In general, our effect sizes in Models I and II are much smaller than those found by LS. For radical innovation, search breadth and depth are not statistically significant and the signs on the coefficients generally go in opposite directions to those found by LS [Model I]. The coefficients of search breadth and depth are statistically significant only for incremental innovation. Moreover, the directions of the effects are similar to those found by LS only in the case of incremental innovation. We also find an inverted U-shaped relationship between search strategy and innovative performance only for incremental innovation [Model II]. The corresponding turning point is four sources as against 11 sources reported by LS. Overall, our results on the relationship between search strategy and innovative performance partly

confirm and partly oppose the findings of LS. LS showed that the effect of search breadth reduces as innovation becomes more radical, and our results go along with this. In the analyses of LS, the effect of search depth increases as innovation becomes more radical. However, in our analysis, search depth is more strongly associated with incremental innovation.

Table 3: Explaining innovative performance among Nigerian firms by external search

Model	I [Tobit]		II [Tobit]		III [Ordinal logit]	
Dependent variables	INNMARKT		INNFIRM		SINNO	
Independent variables	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
BREADTH	0.002	0.026	0.041*	0.023	0.709***	0.107
DEPTH	-0.003	0.024	0.068***	0.021	0.035	0.128
BREADTH2	0.001	0.002	-0.005**	0.002	-0.049***	0.010
DEPTH2	0.001	0.003	-0.005*	0.003	0.006	0.017
HUMAN CAPITAL	-0.123**	0.056	0.010	0.048	0.761**	0.307
USER	0.004	0.069	0.008	0.062	0.109	0.392
SIZE	0.026**	0.013	-0.029***	0.011	-0.072	0.062
STARTUP	0.011	0.052	0.039	0.044	0.133	0.219
GEOMARKT	0.033	0.022	0.029	0.019	-0.029	0.105
COLLAB	-0.013	0.065	-0.062	0.058	0.372	0.366
SERVICE	-0.169***	0.048	-0.008	0.039	-0.399**	0.193
No. of obs. uncensored	408		409		702	
No. of left-censored obs	196		150			
No. of right-censored obs	0		0			
Log likelihood	-171.57		-145.84		-823.28	
Chi-square	49.27***		45.55***		240.69***	
Pseudo R^2	0.126		0.135		0.128	

* p<0.10, ** p<0.05, *** p<0.01

As is obvious from our data and methodological discussions above, the data generation process and the methods applied in this study are similar to those in the LS paper. This implies that one or both of the national context and cross-industry effects are responsible for the observed differences in results. Specifically, our sample is smaller and includes both manufacturing and service firms. Thus, smaller parameter effects and lower significance resulting from higher variance are to be expected. Moreover, as we have defined it, radical innovation is at the frontier of the firm's primary markets. It is worth noting that the primary markets in our sample are predominantly domestic—that is, local and national [see the descriptive statistics for the variable GEOMARKT in Table 3]. As such, even though radical innovation could benefit significantly from external search beyond the national boundaries,

the impact of searching within the domestic innovation system may be limited. However, since incremental innovation represents a movement towards the frontier already defined by new-to-market innovations, it tends to be more responsive to external knowledge.

Our new multidimensional variable that captures the scope of innovation in a firm confirms the results for search breadth discussed above [Model III]. In fact, the parameter effects are considerably larger than for both unidimensional variables and are more comparable to the effect sizes obtained by LS. However, search depth is not significantly associated with scope of innovation. In other words, a wider scope of innovation is strongly associated curvilinearly with broader search for knowledge within the domestic innovation system but not with deeper search. The turning point is about seven sources, suggesting that external search breadth starts to yield decreasing returns when the firm uses more than seven sources. Taken together with the corresponding turning point in the case of new-to-firm innovation, this result suggests that diminishing returns to external search sets in earlier in the Nigerian context than in the relatively more developed UK context.

In Table 3, the dummy variable SERVICE that sorts firms into service and manufacturing has a significant negative coefficient in the case of new-to-firm innovation as well as the scope of innovation. This indicates that on average, radical innovation and the overall scope of innovation are higher among manufacturing firms. Nonetheless, it says nothing about sectoral differences in the link between external search and innovative performance. This aspect is addressed in our Hypothesis 1which states that search depth is more strongly connected to innovative performance in the service sector. To examine this hypothesis, we included interaction terms, DEPTHXSERVICE alongside the dummy variable SERVICE. To balance the analyses, we add an interaction term also for search breadth. The results of the estimations are reported in Table 4. We find no support for this hypothesis as the parameter of DEPTHXSERVICE is significant only in the case of radical innovation, and its direction is opposed to expectation [Model IV].

Table 4: Explaining innovative performance among Nigerian firms by external search across the manufacturing and service sectors

Model	IV [Tobit]		V [Tobit]		VI [Ordinal logit]	
Dependent variables	INNMARKT		INNFIRM		SINNO	
Independent variables	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
BREADTH	0.010	0.008	-0.001	0.007	0.228***	0.039
DEPTH	-0.001	0.021	0.030***	0.009	0.120*	0.062
BREADTHXSERVICE	-0.004	0.018	-0.006	0.014	0.101	0.066
DEPTHXSERVICE	0.052**	0.023	0.007	0.019	-0.088	0.121
HUMAN CAPITAL	-0.137**	0.055	-0.001	0.048	0.618**	0.301
USER	0.007	0.069	0.005	0.064	0.005	0.393
SIZE	0.026**	0.012	-0.034**	0.011	-0.082	0.062
STARTUP	0.022	0.044	0.057	0.045	0.137	0.221
GEOMARKT	0.035	0.022	0.027	0.019	-0.012	0.105
COLLAB	-0.013	0.064	-0.057	0.059	0.518	0.365
SERVICE	-0.284***	0.105	0.002	0.080	-0.785***	0.261
No. of obs.	408		409		702	
No. of left-censored obs	196		150			
No. of right-censored obs	0		0			
Log likelihood	-168.70		-152.28		-834.55	
Chi-square	55.01***		32.66***		218.13***	
Pseudo R^2	0.140		0.097		0.116	

* p<0.10, ** p<0.05, *** p<0.01

We now turn to our analysis of the role of economic context in open innovation, the results of which are detailed in Table 5. On one hand, we have hypothesised that as the range of innovation obstacles experienced by the firm increases, the firm tends to search more broadly. On the other hand, we argue that as innovation obstacles become more intense, firms feel the need to search more deeply. These hypotheses find strong support in our sample. The parameter of VARIETY OF OBSTACLES has a positive and significant coefficient only in the case of search breadth [Model VII]. As well, the parameter of INTENSITY OF OBSTACLES has a positive and significant coefficient only in the case of search depth [Model VIII]. In alternative estimations [not reported due to space limitations], we checked for curvilinear effects by including the quadratic terms for variety and intensity of obstacles. No such effects were present in our sample. Quite interestingly, firms with better absorptive capacity—reflected in the quality of human capital—tend to search more broadly and deeply. The same is true for firms that have collaborative arrangements or treat their customers as a highly important source of information. The size of a firm as well as of its competition space [reflected in its primary markets] is significantly associated with search breadth but not depth.

Table 5: Explaining external search strategies among Nigerian firms by innovation obstacles

Model	VII [Ordinal logit]		VIII [Ordinal logit]	
Dependent variables	BREADTH		DEPTH	
Independent variables	Coefficient	S.E.	Coefficient	S.E.
VARIETY OF OBSTACLES	0.043**	0.021	-0.021	0.021
INTENSITY OF OBSTACLES	-0.001	0.028	0.093**	0.031
HUMAN CAPITAL	0.470*	0.253	0.459*	0.268
USER	0.773**	0.337	0.855**	0.347
SIZE	0.121**	0.059	0.038	0.060
STARTUP	0.104	0.214	0.121	0.212
GEOMARKT	0.169*	0.098	0.115	0.101
COLLAB	0.716**	0.314	0.687**	0.321
SERVICE	-0.404**	0.187	-0.067	0.182
No. of obs.	702		702	
Log likelihood	-1504.34		-1189.48	
Chi-square	117.65***		91.24***	
Pseudo R^2	0.038		0.037	

* p<0.10, ** p<0.05, *** p<0.01

Discussion and Conclusion

This paper contributes to the existing literature regarding external knowledge search for innovation by manufacturing and service firms. Based on a dataset constructed from the Nigerian innovation surveys, we explicitly re-considered the LS model in a developing country context. On its own, this attribute of our study responds to a clear call in the prior literature for more studies that use CIS-type data from other national contexts, as a way to understand further, open innovation strategies and performance effects [Garriga et al., 2013]. The results of the replication exercise are partially consistent with LS: both search breadth and depth are statistically significant for incremental new-to-firm innovation but not for the more radical new-to-market innovation. A possible explanation for this discrepancy, apart from the national context and the combined sample, has to do with the nature of the innovation process. By our definition, radical innovation occurs at the frontier of the domestic market since it is appearing for the first time. Such innovation is not likely to depend on an extensive search of the existing domestic technological space. In contrast, innovation that is new to the firm may benefit significantly from existing knowledge within the domestic innovation system because they lie below the technology frontier already defined by new-to-market innovations. Combining technological and non-technological innovation into a single measure, we find results similar to the existing literature only in the

case of search breadth. We suspect that the observed difference stems from the inclusion of other types of innovation in addition to what is normally done in the literature. However, this argument is only tentative because we did not analyse non-technological innovation separately. Thus, further empirical evidence on how external search relates to non-technological innovation is needed. We believe that such evidence, together with what we already know about technological innovation, will help in building a more robust theory of open innovation, particularly with relevance for developing countries where non-technological innovation is of remarkable importance.

The results obtained from testing two new hypotheses deliver fresh insights on the relationship between a firm's external search strategy and its sector of operation, on the one hand, and the magnitude of innovation obstacles experienced, on the other hand. On these two aspects, the existing literature offers very limited insight. The aspect of obstacles is particularly important in developing countries as firms face diverse challenges in the innovation process. Firstly, we find that there is no discernible difference in the innovativeness and search approaches of firms across service and manufacturing. In fact, the link between innovative performance and external search varies only slightly between the two sectors. This is an interesting result given the recent rise of *servitisation,* whereby many manufacturing firms undertake product differentiation by bundling services with their products. The line between service and manufacturing has become blurred, and that is becoming apparent in the innovation and knowledge search process. Indeed, rather than support dissimilar firm-level strategies in service and manufacturing, our results suggest the absence of any strong differences in firms' open innovation behaviour and its link to innovative performance across the two sectors. Secondly, it seems that the economic context indeed influences the openness behaviour of firms. When firms face a wide range of obstacles, they feel the need to broaden their search horizon. This stands to reason because, as the technological or cognitive space within which a firm searches expands, so does the amount of knowledge it can potentially access. However, in the face of more intense obstacles, searching broadly becomes less useful as it can lead to redundancy. Under such circumstances, it may be more beneficial for firms to use a few sources deeply, more likely those that have been successful in the past. Finally, absorptive capacity also plays a role in open innovation. We show that firms with high quality human capital are better able to scan the environment both broadly and deeply. Thus, we highlight, from the perspective of open

innovation, the widely reported importance of human capital in the innovation process in developing countries [Wignaraja, 2002, Romijn, 1997].

Our results have further implications for management research and practice. For instance, it is instructive to note that, irrespective of sector, the type of innovation [radical or incremental] influences external search strategy. Nevertheless, this empirical observation begs further investigation. Future studies in different national contexts might confirm our results or uncover sectoral differences that we do not find in our sample. Furthermore, the point at which diminishing returns to external search for knowledge sets in is earlier in developing countries particularly in the case of new-to-firm innovation. This indicates that the domestic innovation system within which the firm is located affects both its innovativeness and external search strategies. Such effects may arise from variations in the abundance of external knowledge across national boundaries and, more importantly, from differences in the variety and intensity of innovation obstacles. In fact, as shown by [Garriga et al., 2013], abundance of external knowledge positively affects firms' search strategies. Thus, future empirical works that are cognizant of the national context, particularly in developing countries, are needed. For future studies, it will also be of interest to apply datasets spanning a longer period. This should help provide answers to the issue of generalization and time. Finally, most firms operating in developing countries are in close proximity either due to being in clusters or some industrial districts. The effect of such agglomeration on search strategies should be of interest to policy particularly because it affects the abundance and flow of knowledge resources.

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Appendices

Appendix 1: Sources of information for innovation among Nigerian firms, 2007 and 2010 pooled data [n=1359]

Knowledge source	Percentage			
	Not used	Low	Medium	High
Customers	26.0	8.5	26.5	39.0
Suppliers	28.2	10.1	27.1	34.6
Competitors	34.4	15.5	25.2	24.9
Private laboratory	53.8	16.9	18.0	11.3
Universities	66.2	13.3	13.6	6.9
Research institutes	66.1	16.5	12.0	5.4
Conferences	46.0	15.8	24.3	13.9
Journals/trade publications	54.3	18.2	18.3	9.3
Industry association	40.6	15.4	26.1	17.9

Appendix 2: Innovation obstacles among Nigerian firms, 2007 and 2010 pooled data [n=1359]

Obstacles	Percentage			
	Not experienced	Low	Medium	High
Lack of in-house funds	25.6	12.6	19.7	42.2
Lack of external financing	31.2	14.3	16.9	37.7
High costs of innovation	29.4	14.1	20.6	35.9
Lack of qualified personnel	42.4	26.4	19.9	11.3
Lack of information on technology	36.7	28.6	21.0	13.6
Lack of market information	39.8	28.8	20.2	11.2
Difficulty in finding cooperation partners	41.1	23.3	19.4	16.3
Competition from dominant large enterprises	33.8	21.8	27.0	17.4
Uncertain demand	35.6	25.2	23.8	15.4
Poor basic infrastructure	23.3	7.6	10.7	58.4
Inadequate facilities	38.0	14.6	19.1	28.3
No need for innovation due to prior innovation	42.2	25.7	22.4	9.7
Lack of in-house funds	40.8	28.2	21.6	9.4

Appendix 3: Innovation, search and obstacles by sector, 2007 and 2010 pooled data

Variable	**Manufacturing [n= 890]**	**Service [n= 469]**
Percent new-to-market innovators	15.6	13.0
Percent new-to-firm innovators	53.6	52.9
Average scope of innovation	2.3	2.5
Breadth Mean	3.9	4.4
Depth Mean	1.5	1.9
Average variety of obstacles	9.3	6.2
Average intensity of obstacles	3.7	1.7

Appendix 4: Pairwise correlations among independent variables

		1	2	3	4	5	6	7	8	9	10
1	BREADTH										
2	DEPTH	0.711*									
3	VARIETY OF OBSTACLES	0.022	-0.045								
4	INTENSITY OF OBSTACLES	-0.118*	-0.016	0.596*							
5	HUMAN CAPITAL	0.113*	0.135*	0.087*	-0.047						
6	USER	0.298*	0.307*	0.005	-0.036	0.113*					
7	SIZE	0.176*	0.118*	-0.093*	-0.196*	-0.040	0.095*				
8	STARTUP	-0.003	-0.033	0.004	-0.036	0.114*	-0.053	-0.123*			
9	GEOMARKET	0.187*	0.133*	-0.147*	-0.199*	-0.027	0.109*	0.290*	-0.047		
10	COLLAB	0.291*	0.288*	-0.036	-0.073*	0.103*	0.867*	0.138*	-0.091*	0.137*	
11	SERVICE	0.078*	0.107*	-0.336*	-0.327*	0.467*	0.010	-0.115*	0.122*	0.027	0.025