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This research was partly or entirely supported by funding from the research initiative Private Enterprise Development in Low-Income Countries (PEDL), a Department for International Development funded programme run by the Centre for Economic Policy Research (CEPR).

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Innovation and Development

ISSN: 2157-930X (Print) 2157-9318 (Online) Journal homepage: http://www.tandfonline.com/loi/riad20

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To cite this article: Abiodun Egbetokun, Pedro Mendi & Robert Mudida (2016) Complementarity in firm-level innovation strategies: a comparative study of Kenya and Nigeria, Innovation and Development, 6:1, 87-101, DOI: 10.1080/2157930X.2015.1085185

To link to this article: http://dx.doi.org/10.1080/2157930X.2015.1085185

Innovation and Development, 2016
Vol. 6, No. 1, 87–101, http://dx.doi.org/10.1080/2157930X.2015.1085185

Routledge
Taylor & Francis Group

Complementarity in firm-level innovation strategies: a comparative study of Kenya and Nigeria

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We present and analyse firm-level innovation data from Kenya and Nigeria. We test for the existence of complementarities between internal R&D and external innovation activities, and between organizational and marketing innovations. Some evidence is found on the existence of complementarities between internal and external technological innovation strategies in the case of Kenya, but not in the case of Nigeria. However, organizational and marketing innovations do not appear to be complementary in innovation either in Kenya or in Nigeria.

Keywords: innovation; internal R&D; external R&D; complementarities

1. Introduction

In order to reach the final goal of technological upgrading, that is the introduction of new products and processes, firms usually combine different activities conductive towards innovation. Understanding the way firms introduce new products and processes is crucial to boost productivity, which is the direct consequence of technological progress. Indeed, Hall and Jones (1999) finds that cross-country differences in per capita incomes may be largely explained by differences in total factor productivity, and Mendi (2007) finds evidence of trade in disembodied technology positively affecting the importing country's total factor productivity. This is particularly important in the case of developing countries. In fact, as pointed out by Evenson and Westphal (1995), no least developed country has to date achieved rapid economic growth without continued technological investment.

Innovation activities may be classified into two main categories, those that the firm carries out internally and those that are external to the firm. These two categories have typically been referred to as 'make' or 'buy' strategies. Specifically, firms may rely on their internal R&D efforts, which could be of a more basic or more applied nature. Firms might also outsource their R&D efforts in order to come up with new products or processes. Alternatively, firms may purchase technology developed by third parties, whether in a disembodied form, such as in the case of a license, or embodied in new machinery or in personnel. Internal and external innovation activities are expected to reinforce one another, especially if the innovation process is relatively complex: while the firm may develop internal capabilities conductive towards innovation, it is likely that

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some external agent specializes in the provision of a share of the innovation inputs. Complementarity or the absence of complementarity is informative of the degree of development of a country. In particular, we expect firms that combine innovation inputs to perform better than firms that concentrate their innovation strategies.

The presence of complementarities relies heavily on the role played by internal R&D activities. In fact, R&D is regarded to be, on the one hand, a source of internally developed innovations, and, on the other, as a determinant of the firm's absorptive capacity, see Cohen and Levinthal (1990) or Zahra and George (2002). According to this literature, it is expected that the combination of the firm's internal R&D activities with external knowledge yields higher return than if the activities are conducted in isolation. This article contributes to the literature by analysing this question in the context of developing countries, specifically Nigeria and Kenya. In a developing country environment, absorptive capacity benefits technological imports and these technological imports increase the efficiency of in-house R&D efforts.

Studying complementarity is relevant because it allows us to understand how firms combine innovative inputs. Additionally, a lack of complementarity may be pointing at the existence of inefficiencies in the technology-generation process. Reliance on internal R&D only may reflect underlying difficulties in accessing relevant outside knowledge. Reliance on external sources only may suggest that firms mostly imitate. By combining internal and external knowledge, firms leverage both internal and external resources and are more likely to generate truly novel innovations. These issues are even more important in the context of a developing country. As a limitation of the present analysis, we are unable to assess the quality of innovations. Hence, a lack of complementarity points at the existence of a problem, but finding evidence of complementarity does not mean that the country has a strong innovation system, since internal R&D and external R&D may be far from the frontier.

In order to test for the presence of complementarities, we could consider two approaches. On the one hand, activities that are complementary tend to be correlated. This is the approach in Arora and Gambardella (1990), Ichniowski, Shaw, and Prennushi (1997) or Miravete and Pernías (2006). Alternatively, one could consider how a given objective function is affected by the joint presence of activities that may be complementary, as in Mohnen and Röller (2005), Cassiman and Veugelers (2006) or Schmiedeberg (2008). Mohnen and Röller (2005) study the relevance of different obstacles to innovation. Schmiedeberg (2008) uses cross-sectional German CIS data to perform both direct and indirect complementarity tests. Cassiman and Veugelers (2006) test for complementarity and for the effect of contextual variables that affect complementarity using Belgian CIS data. Using patent counts as the performance variable, Hagedoorn and Wang (2012) find that the degree of complementarity among pharmaceutical firms depends on the intensity of internal R&D activities. More recently, Ballot et al. (2015) explore the relationship between product, process and organizational innovation among French and UK firms to fail to obtain evidence of complementarities among all these innovation activities, but some evidence on complementarities in several pairs of activities, depending on the specific country.

Most of the references in the literature make use of data from developed countries. The analysis in the context of developing countries is much more limited, essentially because of a lack of suitable data. In this paper, we focus on two Sub-Saharan African countries, Nigeria and Kenya, for which firm-level innovation data are available. In both cases, the survey methodology was comparable with that of the Community Innovation survey. Use of a similar methodology makes comparison of the data possible. In addition, this is an interesting comparison because the structures of the Nigerian and Kenyan economies are quite different and could provide some lessons on how complementarities vary in different economic structures. The Nigerian economy, for example, has an important oil and natural gas sector which contributes 14.4% of GDP after re-basing. Nigeria ranks 13th in the World for its oil production and holds the

second highest proven oil reserves on the continent after Libya (World Bank 2014). The mining sector is virtually non-existent in Kenya despite the discovery of oil and natural gas which have not yet been commercialized. Nigeria also became Africa's largest economy in 2014 after re-basing while Kenya became Africa's ninth largest economy after re-basing in the same year. This also implies that the Nigerian domestic market is much larger than that of Kenya thereby providing an interesting comparison. The two economies are also in two distinct regional African environments with the Nigerian economy being part of the Economic Community of West African States (ECOWAS) bloc while Kenya is part of the East African Community. These different regional environments could potentially exert different pressures on innovation. The institutional environments in Nigeria and Kenya and the associated innovation ecosystems are also quite different, and it is interesting to assess how this could affect complementarities. In the case of Kenya, the World Bank financed the survey, and the questionnaire included a number of minor additions to adapt it to the Kenyan context. NEPAD and the Nigerian government jointly funded the Nigerian survey and the CIS questionnaire was also modified to tailor it to the local context. We search for the existence of evidence consistent with complementary effects in innovation strategies. We find that, consistent with the findings in Cassiman and Veugelers (2006), there are complementarities between internal R&D and acquired knowledge in the case of Kenya. Such complementarity was not found in the case of Nigeria. In both cases, we are unable to find evidence of complementarities between organizational and marketing innovations. As an extension of existing analyses, we consider organizational and marketing innovations. This is indirect evidence of fundamental innovations from the perspective of the firm (it is really innovations causing marketing and organizational innovations). It is a signal of dynamism on the side of the firm, although the absence of evidence does not necessarily mean evidence of the absence of an effect. Analysing the available data, we are unable to find evidence of complementarities between organizational and marketing innovations.

The remainder of the paper is organized as follows. Section 2 describes how the survey was conducted and the data. Section 3 carries out an econometric analysis of the data, and finally section 4 presents some concluding comments.

2. Data and descriptive statistics

2.1. Data

As earlier pointed out, in the case of both countries, innovation surveys were conducted using the same methodology as the Community Innovation Survey (CIS), which was first launched in 1993 and is now carried out in 27 Member States of the European Union, as well as in other EFTA and candidate countries. The CIS is based on the Oslo Manual (OECD 2005), which introduces general guidelines for collecting and interpreting innovation data.

An important feature of the Oslo Manual is that it defines minimum coverage as those innovations that are at least new to the firm. The manual distinguishes between technological product and process innovations. A technologically new product is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such innovations can involve radically new technologies, can be based on combining existing technologies in new uses, or can be derived from the use of new knowledge. A technologically improved product is an existing product whose performance has been significantly enhanced or upgraded. A simple product may be improved (in terms of better performance or lower cost) through use of higher performance components or materials, or a complex product which consists of a number of integrated technical sub-systems may be improved by partial changes to one of the sub-systems. Examples of product innovation in services include the introduction of internet banking for a bank, CT scans in a hospital and point of sales software for a firm providing

software information technology solutions. Examples of product innovation in industry include use of new industrial oils for a firm that manufactures lubricants or production of new account books for a printing press.

On the other hand, technological process innovation is the adoption of technologically new or significantly improved production methods, including methods of product delivery. These methods may involve changes in equipment, or production organization, or a combination of these changes, and may be derived from the use of new knowledge. The methods may be intended to produce or deliver technologically new or improved products, which cannot be produced or delivered using conventional production methods, or essentially to increase the production or delivery efficiency of existing products. Examples of technological process innovations in services include the introduction of a computerized purchasing system for a firm dealing with the supply of laboratory equipment and the use of a new material control system in a hotel. Examples of technological process innovations in industry include the introduction of Adobe Illustrator 4 for a printing press or the use of a continuous fermenting process in tea manufacturing.

The structure of the questionnaire used in the Kenyan survey, covering the period between 2010 and 2012, is identical to other CIS-based questionnaires. Specifically, it is divided into 10 sections, namely:

(1) General information about the enterprise,
(2) product innovation,
(3) process innovation,
(4) ongoing or abandoned innovations,
(5) innovation activities and expenditures,
(6) sources of information and cooperation for innovation activities,
(7) effects of innovation during 2010–2012,
(8) factors hampering innovation activities,
(9) intellectual property rights and
(10) organizational and marketing innovations.

Except that it covered a different period (2005–2007 and 2008–2010 in two separate surveys) and included two additional sections (that is, questions on firms' motivation for innovation and government policy), the Nigerian questionnaire is similar to the one used in Kenya.

In the case of Kenya, the survey team requested a random stratified sample of 500 firms from the Kenya National Bureau of Statistics, distributed among six counties: Nairobi, Kiambu, Nakuru, Uasin Gishu, Kisumu and Mombasa. The rest of the counties were combined into a single category, and only 50 firms were selected due to large geographical dispersion. Each county represents a stratum. Firms within each stratum were then divided into five categories, according to number of employees, specifically: 0–9, 10–19, 20–49, 50–99 and 100 or above. The number of firms in each stratum was selected proportional to the size of the categories and stratum so that the firms are self-weighting within a stratum. The firms not selected for the other stratum were distributed proportionally among the remaining strata. The overall response rate was 62%.

The Nigerian sample was randomly selected 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. Subsequently, all other firms were stratified

into six geographical zones (north-east, north-west, north-central, south-west, south-east, south-south) and sector of activity. Similar to the Kenyan case, the final sample was selected by proportional probability. The survey questionnaire was 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 survey was first carried out in 2008 (initial sample of 1000 firms) and then repeated in 2011 (initial sample of 1500 firms). The final pooled sample includes 1359 firms, an overall response rate of 54%.

2.2. Variables

The information in the questionnaire was processed to produce the variables used in the econometric analysis (Table 1). As performance variable, we focus on two variables that measure how important products that were introduced between 2010 and 2012 are, relative to the total sales of

Table 1. Description of the variables employed in the analysis.

Variable	Definition
Dependent variables	
SNFMPROD	Percentage of sales from innovative products that are new to the firm or to the domestic market
SNMPROD	Percentage of sales from products that are new to the domestic market
Independent variables	
PROCINN	Dummy variable taking a value of 1 if at least one new process in the three years prior to the survey introduced and 0 otherwise.
SERVICES	Dummy variable taking a value of 1 firm's main activity is in a services industry and 0 otherwise
LNEMPLOY	Logarithm of the number of employees in the year of the survey
GROUP	Dummy variable taking a value of 1 if the firm belongs to a group of firms and 0 otherwise.
EXPORT	Dummy variable taking a value of 1 if the firm has exported during the three years prior to the survey and 0 otherwise.
COOPER	Dummy variable taking a value of 1 if the firm has cooperated in innovation during the three years prior to the survey and 0 otherwise.
MAKE AND BUY	Dummy variable taking a value of 1 if the firm has engaged in internal R&D and procured external knowledge during the three years prior to the survey and 0 otherwise.
BUY ONLY	Dummy variable taking a value of 1 if the firm has procured external knowledge but not engaged in internal R&D during the three years prior to the survey and 0 otherwise.
MAKE ONLY	Dummy variable taking a value of 1 if the firm has engaged in internal R&D but not procured external knowledge during the three years prior to the survey and 0 otherwise.
NO MAKE OR BUY	Dummy variable taking a value of 1 if the firm has neither engaged internal R&D nor procured external knowledge during the three years prior to the survey and 0 otherwise.
MKT AND ORG	Dummy variable taking a value of 1 if the firm has implemented both marketing and organizational innovation during the survey period and 0 otherwise.
MKT ONLY	Dummy variable taking a value of 1 if the firm has implemented only marketing innovation during the survey period and 0 otherwise.
ORG ONLY	Dummy variable taking a value of 1 if the firm has implemented only marketing innovation during the survey period and 0 otherwise.
NO MKT OR ORG	Dummy variable taking a value of 1 if the firm has implemented neither marketing nor organizational innovation during the survey period and 0 otherwise.

the firm. On the one hand, SNFMPROD is defined as proportion of sales from products that are innovative from the perspective of the firm, which includes products that are new to the firm or new to the market. On the other hand, SNMPROD is the proportion of sales from products that are new to the firm and to the market. Notice that the latter variable considers a more restrictive criterion to define innovation, and excludes the introduction of products that already exist in the domestic market, even if they are new to the firm.

Regarding the innovation activities variables, we follow Mohnen and Röller (2005) and Cassiman and Veugelers (2006) and focus on a pair of strategies captured in dummy variables. This way, we define mutually exclusive categories, depending on whether one and/or the other strategy is adopted. The first pair of dummies concern whether a firm chooses to innovate by making (i.e. to develop through continuous in-house R&D) or buying (i.e. to acquire from external sources through licensing, the acquisition of external R&D results or the purchase of new machinery/equipment) new technology. Based on these, we construct the four categories MAKE ONLY, BUY ONLY, MAKE AND BUY and NO MAKE OR BUY as defined in Table 1. The other pair of dummies indicates whether a firm introduced marketing or organizational innovation during the reference period. Using these dummies, we constructed the mutually exclusive categories MKT ONLY, ORG ONLY, MKT AND ORG and NO MKT OR ORG (Table 1).

The different estimations whose coefficients will be reported in the next section include a number of control variables drawn from the innovation literature (see, for instance, Cohen 2010; Acs and Audretsch 1988). Firm size is the logarithm of the number of employees (LNEMPLOY), this variable is included because larger firms are expected to be more likely to introduce new products. We also include SERVICES, which is a dummy variable that takes value one if the firm is in a services industry, zero otherwise. This is intended to control for differences between services and other industries regarding innovation activities and outcomes. We also include GROUP, which is a dummy variable that takes value one if the firm belongs to a group of firms, zero otherwise. Firms that belong to a group of firms are likely to take advantage of technology developed elsewhere within the group. Exporting activities are usually found to be positively correlated with innovation strategies and outcomes, and for this reason, we include EXPORT, which is a dummy variable that takes value one if the firm exported in 2010–2012, zero otherwise. Finally, we include in the different specifications dummy variables that indicate whether the firm cooperates in innovation activities (COOPER), and whether the firm introduced a process innovation in 2010–2012 (PROCINN).

2.3. Descriptive statistics

Tables 2 and 3 contain descriptive statistics for the Nigerian and Kenyan cases, respectively. Out of the 310 firms in the Kenyan sample, 270 of them are in services industries, whereas only 40 are in other industries, including manufacturing. Of the 1359 firms in the Nigerian sample, 469 are in service industries. The level of representation of services industries in the sample is consistent with the overall share of firms in services industries in the Kenyan and Nigerian economies.[1] On average, the Nigerian firms are larger and more innovative. Average size in the Kenyan sample is 14 employees as against 47 in the Nigerian sample. This partly reflects the fact that the Nigerian survey targeted firms with at least 10 employees. The rate of product and process innovation is also considerably higher in the Nigerian sample. Marketing innovation is more prevalent than organizational innovation among the Nigerian firms. The reverse is true for the Kenyan firms.

It is interesting to note that internal R&D appears to be more common among the Kenyan firms. On average, only about 1% of the Nigerian firms, in contrast to 7% of Kenyan firms, rely purely on in-house R&D for technology development. This is somewhat surprising since

Table 2. Descriptive statistics, Nigerian subsample.

Variable	*N*	Min	Mean	Max	Std Dev
PRODINN	1336	0	0.548	1	0.498
PROCINN	1332	0	0.631	1	0.483
SNFMPROD	734	0	0.397	1	0.349
SNMPROD	733	0	0.173	1	0.226
SERVICES	1359	0	0.345	1	0.476
LNEMPLOY	1341	2.079	3.865	9.741	1.328
GROUP	1359	0	0.205	1	0.404
EXPORT	1359	0	0.167	1	0.373
COOPER	984	0	0.262	1	0.440
MAKE AND BUY	1190	0	0.220	1	0.415
BUY ONLY	1190	0	0.446	1	0.497
MAKE ONLY	1190	0	0.012	1	0.108
NO MAKE OR BUY	1190	0	0.322	1	0.467
MKT AND ORG	1359	0	0.506	1	0.500
MKT ONLY	1359	0	0.125	1	0.331
ORG ONLY	1359	0	0.077	1	0.267
NO MKT OR ORG	1359	0	0.292	1	0.455

Nigerian firms are generally larger and could potentially therefore have more resources to invest in R&D. This might have to do with credit constraints since R&D is costly. According to the World Bank (2007), it seems easier to get credit in Kenya than in Nigeria. Also, the strength of intellectual property protection might create a demand for more R&D. In that sense, Kenya surpasses Nigeria, being ranked far higher in the 2014 Intellectual Property Rights Index both globally and in the sub-Saharan African region. Where intellectual property regimes are less developed, firms face greater risks that any technology they develop will be appropriated by others (World Bank 2010). Nevertheless, in both the Kenyan and Nigerian contexts, a lot more firms acquire rather than develop new technologies in-house. This is consistent with earlier research which suggests that developing country firms do little R&D (Romijn 1997; Ilori, Oke,

Table 3. Descriptive statistics, Kenyan subsample.

Variable	*N*	Min	Mean	Max	Std Dev
PRODINN	310	0	0.413	1	0.493
PROCINN	310	0	0.332	1	0.472
SNFMPROD	180	0	0.614	1	0.408
SNMPROD	179	0	0.093	1	0.222
SERVICES	310	0	0.871	1	0.336
LNEMPLOY	304	0	2.645	8.70	1.63
GROUP	310	0	0.31	1	0.463
EXPORT	306	0	0.252	1	0.435
COOPER	212	0	0.505	1	0.501
MAKE AND BUY	199	0	0.437	1	0.497
BUY ONLY	203	0	0.35	1	0.478
MAKE ONLY	199	0	0.065	1	0.248
NO MAKE OR BUY	202	0	0.173	1	0.379
MKT AND ORG	310	0	0.465	1	0.499
MKT ONLY	310	0	0.061	1	0.24
ORG ONLY	310	0	0.19	1	0.393
NO MKT OR ORG	310	0	0.242	1	0.429

and Sanni 2000). The reason for this could be that many firms in developing countries like Kenya and Nigeria are behind the global technological frontier and as such it makes more sense for them to buy or copy existing foreign technology which is generally cheaper than undertaking risky R&D. Domestic markets in developing countries are also generally less competitive and more segmented than in developed countries, and they therefore face less pressure to develop new technology and need to overcome more barriers to entry and exit (World Bank 2010). Greater internal R&D in Kenya could reflect the fact that with the formation of the Competition Authority there has been greater competitive pressure in the economy.

About 40% of revenue in the Nigerian sample arises from innovative sales. Sales of new-to-market products make up less than half of this. In the Kenyan sample, the gap between these two percentages is even wider, specifically from 61% to 9%. Tables 4 and 5 show how these relate to the innovation strategy of the firms in Nigeria and Kenya, respectively.

In Nigeria, firms that neither made nor bought new technology during the reference periods realized, on average, innovative sales below the sample average. The same is true of firms that implemented neither of marketing and organizational innovation. Interestingly, average innovative sales among firms that combined strategies (either making and buying technology or implementing both of marketing and organizational innovation) surpassed the sample average. More importantly, the innovative sales of these firms are slightly higher, on average, than for firms that adopted any single strategy in isolation. In Kenya, the combination of make and buy is also associated with the highest percentage of innovative sales from products new to the market or to the firm. The pattern that arises is similar to that in the Nigerian case, with the percentages being higher in the case of products new to the firm, and lower in the case of products new to the market. Taken together, these figures hint at mutual reinforcement of innovation strategies: in comparison to any one independent strategy, a combination of strategies yields superior returns. In the next section, this complementarity hypothesis is subjected to econometric tests.

3. Econometric analysis

This section presents the results from the complementarity tests conducted using the Nigerian and Kenyan datasets. Following Cassiman and Veugelers (2006), we test whether make and buy innovation strategies are complementary. Additionally, we search for evidence of complementarities between organizational and marketing innovations.

As in Cassiman and Veugelers (2006), the theoretical basis for our econometric analysis is the concept of supermodularity, which implies that two activities are complements if adding an activity if the firm is already carrying out some other activity increases performance more than

Table 4. Relationship between innovation strategy and innovative sales, Nigerian sample.

	SNFMPROD ($n = 734$)		SNMPROD ($n = 733$)	
	Mean	Std. Dev.	Mean	Std. Dev.
MAKE AND BUY	0.429	0.356	0.194	0.228
BUY ONLY	0.410	0.343	0.169	0.228
MAKE ONLY	0.345	0.334	0.166	0.191
NO MAKE OR BUY	0.297	0.344	0.145	0.216
MKT AND ORG	0.440	0.350	0.184	0.234
MKT ONLY	0.369	0.335	0.156	0.195
ORG ONLY	0.337	0.352	0.160	0.223
NO MKT OR ORG	0.326	0.349	0.154	0.209

Table 5. Relationship between innovation strategy and innovative sales, Kenyan sample.

	SNFMPROD ($n = 180$)		SNMPROD ($n = 179$)	
	Mean	Std. Dev.	Mean	Std. Dev.
MAKE AND BUY	0.671	0.381	0.149	0.272
BUY ONLY	0.659	0.398	0.057	0.176
MAKE ONLY	0.323	0.393	0.019	0.038
NO MAKE OR BUY	0.519	0.44	0.067	0.199
MKT AND ORG	0.639	0.396	0.128	0.266
MKT ONLY	0.768	0.398	0.064	0.15
ORG ONLY	0.551	0.42	0.007	0.029
NO MKT OR ORG	0.592	0.444	0.083	0.209

adding that same activity in isolation. Specifically, if the two activities are make and buy technology, let MAKE_i and BUY_i be dummy variables that indicate whether the firm carries out these activities, and let $\pi(\text{MAKE}_i, \text{BUY}_i)$ be the performance indicator of interest, such as sales from innovative products. Then, make and buy are said to be complementary if:

$$\pi(1, 1) - \pi(0, 1) \geq \pi(1, 0) - \pi(0, 0).$$

In the econometric specifications, given estimators for the coefficients on the four mutually exclusive categories (for instance, make and buy, make only, buy only, neither make nor buy), we test for whether the difference between the sum of the coefficients of joint adoption plus no adoption of strategies is significantly greater than the sum of the coefficients of adoption of one strategy in isolation. This gives rise to a one-sided F or chi-squared test, depending on the specific econometric model. Notice that this is equivalent to testing whether the difference between the coefficient on joint adoption and the sum of the coefficients on adoption of each strategy in isolation is significant, in a model that includes a constant term and that excludes the category of adopting neither strategy.

In Tables 6 and 7, we report estimated coefficients using Nigerian and Kenyan data, respectively. In these specifications, the dependent variable is SNFMPROD, sales of products introduced in the three years prior to the survey as a proportion of firm sales (columns (i) and (ii)) and SNMPROD, sales of products new to the domestic market as a proportion of total sales (columns (iii) and (iv)). The independent variables include the four exclusive categories: make and buy, make only, buy only, and no make or buy.[2] We test for the existence of a significant difference between the sum of the coefficients of make and buy and no make or buy on the one hand, and make only and buy only on the other.

Columns (i) and (iii) in Tables 6 and 7 report estimated coefficients using a Tobit specification with zero as the lower limit and one as the upper limit of the dependent variable, whereas columns (ii) and (iv) make use of a Heckman selection model. Innovation strategies are observed for innovative firms only, and thus, a selection equation is introduced, where the determinants of selection are SERVICES, LNEMPLOY, EXPORT, GROUP and the three principal components of the obstacles to innovation variables. The coefficients on the variables in the selection equation are not reported. Additionally, since the dependent variable always takes values in the [0,1] interval, we have also estimated a fractional logit model (Papke and Wooldridge 1996, 2008). The overall results and the significance levels of the complementarity tests are similar to those found in the Tobit or Heckman specifications. For the sake of comparison with previous studies, in this paper we report the estimated coefficients from the Tobit and Heckman specifications.

Table 6. Complementarity between making and buying, Nigerian data.

Dependent variable:	SNFMPROD		SNMPROD	
Estimation method:	Tobit (i)	Heckman (ii)	Tobit (iii)	Heckman (iv)
SERVICES	−0.0760**	−0.0675***	−0.0992***	−0.0616***
	(0.0299)	(0.0253)	(0.0262)	(0.0149)
LNEMPLOY	−0.0186	−0.0132	0.00142	0.0130**
	(0.0117)	(0.00983)	(0.00996)	(0.00634)
GROUP	−0.0578*	0.0787***	−0.0362	−0.0368**
	(0.0334)	(0.0278)	(0.0287)	(0.0174)
EXPORT	0.0443	−0.00336	0.0370	0.0333*
	(0.0356)	(0.0306)	(0.0300)	(0.0201)
COOPER	0.00259	0.0123	0.0205	0.0141
	(0.0292)	(0.0196)	(0.0256)	(0.0158)
PROCINN	0.147***	0.0831**	0.116**	0.0706***
	(0.0544)	(0.0332)	(0.0488)	(0.0206)
MAKE AND BUY	0.302***	0.469***	0.117*	0.0855**
	(0.0791)	(0.0545)	(0.0676)	(0.0344)
BUY ONLY	0.292***	0.470***	0.0458	0.0784***
	(0.0724)	(0.0518)	(0.0624)	(0.0304)
MAKE ONLY	0.176	0.365***	−0.0149	0.0539
	(0.120)	(0.0711)	(0.0905)	(0.0486)
NO MAKE/BUY	0.186**	0.452***	−0.000615	0.101***
	(0.0735)	(0.0516)	(0.0619)	(0.0321)
Observations	660	731	659	731
Log likelihood	−341.388	−316.142	−242.988	−128.513
Complementarity	.0372	2.9471	1.2849	1.5193
p-Value	.8472	.086	.2574	.2177

Notes: Standard errors in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Considering total innovative sales among the Kenyan firms in the sample, the evidence is in support of a complementary relationship between internal technology development and external technology acquisition. However, this evidence disappears in the Nigerian sample where the complementarity test is only significant at the 10% level (column (ii) of Table 6). Furthermore, no evidence of complementarity is found when the analysis is restricted to the sales of products new to the domestic market both in Nigeria (the complementarity test is insignificant in columns (iii) and (iv) of Table 7) and Kenya (complementarity test is significant only at the 10% level in column (iv) of Table 7).

The next step is the analysis of complementarities in marketing and organizational innovations, using the same dependent variables as in the case of make and buy strategies. The econometric techniques are also the same as in the previous case. In both cases, there is absence of evidence of a complementarity relationship between marketing and organizational innovations, using sales of products new to the firm and products new to the market. The Tobit (columns (i) and (iii)) and Heckman (columns (ii) and (iv)) estimations reported in Tables 8 and 9 suggest no such evidence, only in columns (iii) and (iv) of Table 9 the test is significant at the 10% and 5% levels, respectively.

4. Discussion and conclusion

We find that, consistent with the findings in Cassiman and Veugelers (2006), there are complementarities between internal R&D and acquired knowledge in the case of Kenya. Such

Table 7. Complementarity between making and buying, Kenyan data.

Dependent variable:	SNFMPROD		SNMPROD	
Estimation method:	Tobit (i)	Heckman (ii)	Tobit (iii)	Heckman (iv)
SERVICES	−0.508**	−0.219***	0.188	0.0313
	(0.208)	(0.0850)	(0.240)	(0.0633)
LNEMPLOY	−0.0377	−0.0251	0.0144	−0.00183
	(0.0391)	(0.0216)	(0.0412)	(0.0123)
GROUP	−0.191	−0.0249	0.102	0.00406
	(0.136)	(0.0798)	(0.130)	(0.0405)
EXPORT	−0.102	−0.00788	0.0546	−0.0152
	(0.133)	(0.0739)	(0.153)	(0.0438)
COOPER	−0.00675	0.0196	0.375**	0.0849**
	(0.124)	(0.0635)	(0.151)	(0.0362)
PROCINN	0.234*	0.128**	−0.188	−0.0349
	(0.123)	(0.0631)	(0.145)	(0.0419)
MAKE AND BUY	1.445***	0.765***	−0.696**	0.126
	(0.278)	(0.149)	(0.311)	(0.0787)
BUY ONLY	1.440***	0.733***	−0.840***	0.0608
	(0.259)	(0.136)	(0.317)	(0.0836)
MAKE ONLY	0.857***	0.339**	−0.944**	0.0159
	(0.284)	(0.152)	(0.376)	(0.0765)
NO MAKE/BUY	1.340***	0.708***	−0.987***	0.0606
	(0.283)	(0.154)	(0.342)	(0.0880)
Observations	175	255	174	254
Log likelihood	−157.0097	−225.5139	−98.7716	−143.2065
Complementarity	3.3014	8.1063	.1019	3.669
p-Value	.071	.0044	.75	.0554

Notes: Standard errors in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

complementarity was not found in the case of Nigeria. These could be explained in a number of ways. Firstly, differences in complementarities could arise from the structure of the Kenyan economy versus the Nigerian economy. In Kenya, there is a larger dominance of the service sector which makes up approximately two-thirds of GDP compared to Nigeria (although the importance of the service sector in Nigeria increased after re-basing in 2014 to 52% of GDP). Complementarities between internal and external R&D are more important in services since even if R&D is purchased in services there is usually a need to adapt it to the local context, especially local needs and customs of the local economy. This therefore necessitates some degree of complementarity between internal and external sources of innovation in services. It is more difficult to simply buy R&D in services. In Nigeria, industry, especially extractive industry is critical in the economy and it is easier in this case to, for example, simply buy relevant machinery without considerable adaptation to the local context.

Another factor that potentially explains different degrees of complementarities in Nigeria and Kenya is the degree of product versus process innovation in the two countries. Owing to the different characteristics of product and process innovations, firms should benefit less from complementing internal and external innovations for process than for product innovations in terms of knowledge creation (Krzeminska and Eckert 2015). In Nigeria, more firms engage more in process innovation compared to product innovation compared to Kenya which implies that they probably benefit less from complementarities. The fact that product innovation predominates among Kenyan firms explains why possibly there is a greater need for complementarities.

Table 8. Complementarity between organizational and marketing innovations, Nigerian data.

Dependent variable:	SNFMPROD		SNMPROD	
Estimation method:	Tobit (i)	Heckman (ii)	Tobit (iii)	Heckman (iv)
SERVICES	−0.110***	−0.0768***	−0.126***	−0.0657***
	(0.0298)	(0.0260)	(0.0265)	(0.0151)
LNEMPLOY	−0.0193*	−0.00904	0.00333	0.0126**
	(0.0112)	(0.00953)	(0.00950)	(0.00620)
GROUP	−0.0696**	−0.0868***	−0.0386	−0.0384**
	(0.0330)	(0.0275)	(0.0287)	(0.0174)
EXPORT	0.0557	0.0172	0.0479	0.0345*
	(0.0354)	(0.0305)	(0.0303)	(0.0203)
COOPER	−0.00136	0.00475	0.0274	0.0134
	(0.0282)	(0.0184)	(0.0251)	(0.0157)
PROCINN	0.133**	0.0776**	0.114**	0.0615***
	(0.0529)	(0.0313)	(0.0478)	(0.0199)
MKT AND ORG	0.377***	0.457***	0.100	0.104***
	(0.0712)	(0.0497)	(0.0609)	(0.0305)
ORG ONLY	0.228***	0.370***	−0.0240	0.0737**
	(0.0774)	(0.0548)	(0.0672)	(0.0350)
MKT ONLY	0.299***	0.444***	0.0501	0.0834**
	(0.0857)	(0.0704)	(0.0731)	(0.0370)
NO MKT/ORG	0.182**	0.386***	−0.00979	0.0836***
	(0.0709)	(0.0501)	(0.0601)	(0.0305)
Observations	660	731	659	731
Log likelihood	−327.6157	−311.1227	−238.9882	−127.8509
Complementarity	.164	.2773	1.0392	.7533
p-value	.6856	.5985	.3084	.3854

Notes: Standard errors in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

There is greater macroeconomic instability and a more adverse institutional environment in Nigeria than Kenya. This greater macroeconomic instability offers a lower incentive to undertake internal R&D since R&D is generally longer term business. Nigerian firms face higher interest rates and inflation than Kenyan firms. In addition, there is less rule of law, intellectual protection and the enforceability of contracts in Nigeria which also affects incentives to undertake R&D and hence reduces the complementarity of internal and external R&D. The institutional environment is generally worse in Nigeria with less support from government. As a consequence of this difficult macroeconomic and institutional environment, there is a higher exit rate of Nigerian firms than Kenyan firms. This greater uncertainty implies that investment made in developing complementaries is lower. Developing internal R&D simultaneously as external R&D requires taking a longer term perspective. Nigerian firms have a shorter planning horizon. Many Nigerian firms appear to have a shorter planning horizon.

The supporting policy environment for innovation and the innovation ecosystem is also more problematic in Nigeria compared to Kenya. In Kenya, the government has certain programs for supporting technology transfer or intellectual property rights although these tend to be small and mainly focused on providing relevant information to firms. In addition, there are some programs that target assistance for market access which also support innovation in the country by providing quality certification and information on new markets and technologies (Cirera 2015). This is in line with Cassiman and Veugelers (2006), who find that the degree of complementarity depends on other contextual variables.

Table 9. Complementarity between organizational and marketing innovations, Kenyan data.

Dependent variable:	SNFMPROD		SNMPROD	
Estimation method:	Tobit (i)	Heckman (ii)	Tobit (iii)	Heckman (iv)
SERVICES	−0.317*	−0.123	0.153	0.0650
	(0.176)	(0.0885)	(0.169)	(0.0542)
LNEMPLOY	−0.00944	−0.00257	0.0265	0.00480
	(0.0386)	(0.0230)	(0.0384)	(0.0124)
GROUP	−0.124	0.00980	0.0795	0.0105
	(0.138)	(0.0827)	(0.125)	(0.0388)
EXPORT	−0.216	−0.0659	−0.0359	−0.0399
	(0.132)	(0.0759)	(0.151)	(0.0457)
COOPER	0.107	0.0677	0.346**	0.0982**
	(0.123)	(0.0640)	(0.150)	(0.0416)
PROCINN	0.332***	0.176***	−0.255*	−0.0314
	(0.119)	(0.0627)	(0.138)	(0.0397)
MKT AND ORG	1.026***	0.482***	−0.616***	0.0535
	(0.218)	(0.135)	(0.215)	(0.0800)
ORG ONLY	0.947***	0.419***	−1.315***	−0.0663
	(0.236)	(0.150)	(0.341)	(0.0686)
MKT ONLY	1.464***	0.715***	−0.576**	0.0274
	(0.353)	(0.143)	(0.284)	(0.0784)
NO MKT/ORG	1.122***	0.491***	−0.635***	0.0345
	(0.232)	(0.143)	(0.227)	(0.0785)
Observations	175	255	174	254
Log likelihood	−158.7953	−228.9343	−93.4529	−141.9306
Complementarity	.4971	1.3038	2.9962	3.9183
p-Value	.4818	.2535	.0853	.0478

Notes: Standard errors in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

In both the case of Nigeria and Kenya, we are unable to find evidence of complementarities between organizational and marketing innovations. This implies that organizational and marketing innovations are probably more affected by other factors such as social networks. Social networks are a vital aspect of social capital and have been found to be important for the spread of innovations especially in developing countries. Agapitova (2005), for example, has argued that studies of innovative activities of individual actors and related institution-building processes are incomplete without taking into account social networks that underlie economic actions.

Organizational innovation is therefore not a pre-requisite for marketing innovation and vice versa. Organizational and marketing innovations in both Kenya and Nigeria are probably driven more by the competitive structure of the sector in which firms operate and access to social networks. The lack of complementarities in this area for both Kenyan and Nigerian firms may, however, ultimately limit the overall impact of both organizational and marketing innovations. This could partly explain why innovation in Nigeria and Kenya tends to be more incremental rather than radical since some of these potentially important complementarities are lacking.

Acknowledgements

We thank the editor, KJ Joseph, and two anonymous referees for their helpful comments, which have greatly improved the quality of this article. All errors remain our own. The views expressed in this paper are those of the authors and do not reflect the views of the World Bank or its affiliated organizations.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Pedro Mendi and Robert Mudida are grateful to the World Bank for financing the Kenya Innovation Survey. Pedro Mendi also gratefully acknowledges financial support from Fundación Caja Navarra and from Fundación Ramón Areces. Abiodun Egbetokun acknowledges funding from the Private Enterprise Development in Low-income Countries (PEDL).

Notes

1. Services are industries 4500–9900 in ISIC Revision 4, which is the industry classification used by the Kenya National Bureau of Statistics. Nigeria's National Bureau of Statistics also uses the same classification.
2. Multicollinearity does not appear to be an important issue, despite the inclusion of several dummy variables. VIF values are found to be within acceptable levels.

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References

Acs, Z. J., and D. B. Audretsch. 1988. "Innovation in Large and Small Firms: An Empirical Analysis." *The American Economic Review* 78: 678–690.

Agapitova, N. 2005. *The Role of Social Networks for National Innovation Systems' Dynamics*. Washington, DC: The World Bank.

Arora, A., and A. Gambardella. 1990. "Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology." *The Journal of Industrial Economics* 38 (4): 361–379.

Ballot, G., F. Fakhfakh, F. Galia, and A. Salter. 2015. "The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation in France and the UK." *Research Policy* 44: 217–232.

Cassiman, B., and R. Veugelers. 2006. "In Search of Complementarity in Innovation: Internal R&D and External Knowledge Acquisition." *Management Science* 52: 68–82.

Cirera, X. 2015. *Catching Up to the Technological Frontier?: Understanding Firm-level Innovation and Productivity in Kenya*. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/2015/03/24117673/catching-up-technological-frontier-understanding-firm-level-innovation-productivity-kenya

Cohen, W. M. 2010. "Fifty Years of Empirical Studies of Innovative Activity and Performance." *Handbook of the Economics of Innovation* 1: 129–213. North Holland: Elsevier.

Cohen, W., and D. Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35 (1): 128–152.

Evenson, R. E., and L. E. Westphal. 1995. "Technological Change and Technology Strategy." In *Handbook of Development Economics, Vol IIIA*, edited by J. Behrman, and T. N. Srinivasan. Amsterdam, The Netherlands, Elsevier.

Hagedoorn, J., and N. Wang. 2012. "Is there Complementarity of Substitutability between Internal and External R&D Strategies?" *Research Policy* 41: 1072–1083.

Hall, R., and C. Jones. 1999. "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *The Quarterly Journal of Economics* 114 (1): 83–116.

Ichniowski, C., K. Shaw, and G. Prennushi. 1997. "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines." *The American Economic Review* 87 (3): 291–313.

Ilori, M., J. Oke, and S. Sanni. 2000. "Management of New Product Development in Selected Food Companies in Nigeria." *Technovation* 20 (6): 333–342.

Krzeminska, A., and C. Eckert. 2015. "Complementarity of Internal and External R&D: Is there a Difference between Product Versus Process Innovations?" *R&D Management*. doi:10.1111/radm.12120.

Mendi, P. 2007. "Trade in Disembodied Technology and Total Factor Productivity in OECD Countries." *Research Policy* 36: 121–133.
Miravete, E., and J. Pernías. 2006. "Innovation Complementarity and Scale of Production." *The Journal of Industrial Economics* 54 (1): 1–29.
Mohnen, P., and L.-H. Röller. 2005. "Complemetarities in Innovation Policy." *European Economic Review* 49: 1431–1450.
OECD. 2005. OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data (Oslo Manual), Paris: Organisation for Economic Cooperation and Development.
Papke, L., and J. Wooldridge. 1996. "Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates." *Journal of Applied Econometrics* 11 (6): 619–632.
Papke, L., and J. Wooldridge. 2008. "Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates." *Journal of Econometrics* 145 (1–2): 121–133.
Romijn, H. 1997. "Acquisition of Technological Capability in Development: A Quantitative Case Study of Pakistan's Capital Goods Sector." *World Development* 25 (3): 359–377.
Schmiedeberg, C. 2008. "Complementarities of Innovation Activities: An Empirical Analysis of the German Manufacturing Sector." *Research Policy* 37: 1492–1503.
World Bank. 2007. *Doing Business 2007: How to Reform*. Washington, DC: The World Bank.
World Bank. 2010. *Innovation Policy: A Guide for Developing Countries*. Washington, DC: The World Bank.
World Bank. 2014. *Doing Business 2014: Understanding Regulations for Small and Medium Enterprises*. Washington, DC: The World Bank.
Zahra, S., and G. George. 2002. "Absorptive Capacity: A Review, Reconceptualization, and Extension." *Academy of Management Review* 27 (2): 185–203.