Innovation complementarities in small and micro-enterprises in Johannesburg, South Africa

Godfrey Kamutando and Fiona Tregenna

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Abstract

Innovation is important to firms' productivity, competitiveness, agility, resilience and growth. The success of a firm's innovation strategy depends in part on how it combines and absorbs different innovation activities. This paper analyses complementarity between various innovation activities, for the case of small and micro manufacturing firms in Johannesburg, South Africa. Specifically, we analyse the extent and determinants of complementarity between types of innovation (product and process innovation) and between innovation sources (internal and external innovation). The empirical analysis utilises rich new firm-level survey data which, unlike most firm surveys, includes micro as well as informal enterprises. This contributes to the innovation complementarity literature that is very limited in the African context, and even internationally only sparsely covers small and micro firms, and informal firms. We extend the specifications used in previous studies to take account of the contextual setting. Our results show complementarity between product and process innovations but not between internal and external innovation. The results suggest that the capital intensity of the firm, firm age, ownership, research and development (R&D), main markets and financial constraints are key variables associated with complementarity.

Keywords: Innovation complementarities, product innovation, process innovation, research and development (R&D), small and micro-enterprises, South Africa.

JEL codes: D22, L60, O14, O30, O32, O33

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1. Introduction

The importance of innovation in strengthening firms' productive capabilities, competitiveness, productivity and overall performance is now widely recognised (Dosi et al. 1988; Fagerberg and Godinho, 2005; Gunday et al., 2011; Gebreeyesus and Mohnen, 2013; Guarascio and Pianta 2017). It is therefore critical to understand firms' innovation strategies, particularly of small and micro-enterprises (MSEs) in developing countries, which are seen as important for growth and employment creation (McPherson, 1996; Miravete and Pernías, 2006; Li & Rama, 2015).

Technological innovations include product and process innovations, while sources of innovation can be internal or external to a firm, also referred to as 'make' or 'buy' innovation routes. An established body of literature considers different types of innovation (product and process) or sources of innovation (internal and external) as distinct activities with separate and different effects on firm performance (Fristch & Meschede, 2001; Baldwin & Lin, 2002). An area of growing interest in the literature concerns the possible interrelationships between various firm innovation activities. The integrative theory of innovation argues that different kinds of innovation are interdependent on one another, and that the success of a firm's innovation strategy can be enhanced if a firm implements several forms of innovations simultaneously (Das & Teng, 2003; Guisado-González & Coca Pérez, 2015). In essence, firm innovation types and sources might not function in isolation, but may either complement or substitute each other. For instance, while transaction cost theory regards the choice between sourcing innovation internally or externally as substitutes, recent literature points to the possible complementarity between internal and external innovation (Cockburn & Henderson, 1998; Cassiman & Veugelers, 2006; Schmiedeberg, 2008). Recognising the potential complementarities in firm innovation activities can shed light on the relational phenomena of firm synergies and how these affect firm performance.

What seems critical, particularly for MSEs, is how to integrate innovation activities within a firm's broad innovation capabilities to harness the positive spillovers from each innovation activity. Complementarity between firm innovation strategies may increase the probability of success of these activities (Battisti and Stoneman 2010; Damanpour et al. 2009; Cassiman and Veugelers 2006). Firms that blend innovation activities may therefore outperform firms that only implement one strategy. Establishing complementarity, and identifying what influences the adoption of complementary innovation activities, is therefore important for managing a successful firm innovation strategy.

A growing body of literature has thus started to empirically investigate the notion of innovation complementarities, generating heterogeneous and case-specific results (Cassiman & Veugelers, 2006). However, there is still a paucity of studies devoting attention to understanding the complementarity of innovation types and sources in MSEs specifically, and even less so in developing country contexts. It is thus pertinent to test this empirically in specific contexts.

This paper analyses the extent to which types of innovation (product and process) and sources of innovation (internal and external) are complementary to each other, for the case of South African manufacturing MSEs. Specifically, we ask the following questions: (1) Are innovation strategies complementary? (2) What firm characteristics influence whether a firm undertakes complementary innovation activities?

Adapting the estimation approach of Cassiman and Veugelers (2006), we formally identify complementarity by investigations differences in firm performance outcomes are associated with whether or not firms combine their innovation strategies. We extend the Cassiman and Veugelers (2006) approach by including contextual variables relevant to MSEs (including informal enterprises) in developing countries. The presence of innovation complementarity is tested for using ordered probit and Heckman selection regressions (research question 1 above), while a multinominal logit model is estimated to identify the determinants of complementary innovation activities (research question 2).

We utilise a novel dataset from a firm-level survey of manufacturing MSEs in the City of Johannesburg. Johannesburg is the economic centre of South Africa, accounting for 16% of GDP and 10% of the country's population (City of Johannesburg, 2021). South Africa provides an interesting context to assess innovation complementarity for MSEs. Small, medium and micro-enterprises (SMMEs) contribute about a third of South Africa's GDP and employ around 50–60% of the country's workforce (World Bank & IFC, 2018). South Africa's National Development Plan (NDP) envisages that SMMEs will account for up to 80% of GDP growth and could contribute up to 90% of new employment by the year 2030. However, South African SMMEs face various obstacles, including lack of access to finance, barriers to entry and difficulties in accessing markets, and poor infrastructures.

Despite the voluminous literature on various aspects of firm innovation, there generally is a lack of studies on innovation complementarities in Africa, and more broadly a scarcity of evidence on this topic for small and especially for micro-enterprises. This is largely due to the paucity of firm-level data that covers these types of enterprises while also including innovation variables in sufficient depth. Furthermore, unlike most datasets and hence the extant literature, our study includes informal enterprises, allowing us to analyse whether formality is associated with innovation complementarity. This is particularly important in light of the importance of the informal economy in Africa and in developing countries more widely, especially among MSEs. We also extend specifications from the extant literature to include variables (such as firm ownership, financial access constraints and informality) that can be especially relevant in this context.

The rest of the paper is structured as follows. Section 2 reviews the theoretical and empirical literature focusing on innovation complementarity. In section 3 we set out the empirical strategy used to identify complementarity. Section 4 gives an overview of the data and provides some descriptive analysis. The empirical results are presented and discussed in section 5, and section 6 concludes.

2. Literature Review

2.1 Theory

The success of a firm's innovation strategy can be influenced by how it absorbs and combines different innovation activities to develop comparative advantage (Mantovani, 2006; Love & Roper, 2009; Hagedoorn & Wang, 2012). Several theoretical perspectives have been developed to hypothesise how combining different innovation strategies can affect firm performance.

First, the resource-based view hypothesises that firm performance is determined by a competitive advantage gained through developing, sustaining and combining firms' heterogeneous resources (Wernerfelt, 1984; Peteraf, 1993; Das & Teng, 2003; Guisado-González & Coca Pérez, 2015). In this theoretical approach, a combination of resources generates synergies such that the combined effect of firm resources or strategies on firm performance is 'greater than the sum of its parts'. This is in line with super modularity theory, which has been widely used to test innovation complementarity (Mohnen & Röller, 2005; Miravete & Pernías, 2006; Bianchini, Pellegrino & Tamagni, 2018). According to this theory, complementarities between various firm innovation strategies are key to enhancing competitive advantage and hence firm performance.

Second, transaction cost theory suggests that firms attempt to minimise uncertainty and transaction costs through risk-sharing. One way in which this can be achieved is through establishing strategic alliances between firms. Transaction cost theory predicts complementarity between internal and external innovation, where bundles of diverse technologies are converted into new products. For example, Oxley and Sampson (2004) posit that rather than opting for either internal or external innovation, adopting both internal and external innovation is an effective firm strategy as this minimises costs by sharing risks.

Third, the 'distinctive view' considers different kinds of innovation as compartmentalised strategies and hypothesises that different kinds of innovation (for instance, product vs. process, or internal vs. external) are determined by different variables and have a different effect on firm performance outcomes (Damanpour et al., 1989; Ackoff, 1999; Fritsch & Meschede, 2001). This theory does not expect complementarity between innovation strategies and instead argues that these strategies take place alternatively, with no interrelationships among them. This approach suggests that different resources need to be provided for different kinds of innovation strategies.

2.2 Empirical literature

Differences in the theoretical formulations have lent themselves to differences in the criteria and methodology used to identify the existence of innovation complementarity in the empirical literature (Aldieri et al., 2021; Arora & Gambardella, 1994; Mohnen & Röller, 2005;

Cassiman & Veugelers, 2006). Here, we review empirical literature that has tested complementarity between internal and external innovation (section 2.2.1) and between product and process innovation (section 2.2.2), before reviewing the scant literature on innovation complementarities in the African context (section 2.2.3).

2.2.1 Complementarity between internal and external innovation

A large body of literature explores innovation complementarity between internal and external innovation (Arora & Gambardella, 1990; Cassiman & Veugelers, 2006; Schmiedeberg, 2008; Love & Roper, 2009; Bianchini et al., 2018). Cassiman and Veugelers (2006) use firm-level data for Belgium manufacturing firms and apply the productivity and the adoption regression approaches to test for complementarity between internal and external innovation. They found significant evidence of innovation complementarity between internal and external innovation with respect to firm innovation performance. Furthermore, their analysis revealed that the strength of complementarity between activities is influenced by the extent to which innovation processes depend on R&D. They concluded that success in innovation does not depend only on complementarity, but also on establishing the right business environment.

Similarly, using the direct approach, Schmiedeberg (2008) explicitly analysed complementarity between internal and external R&D, drawing on cross-sectional data for German manufacturing firms. Hagedoorn and Wang (2012), in a case study of 83 pharmaceutical firms, identify complementarity between internal and external innovation where there are high levels of in-house R&D investment, but a substitution relationship if in-house R&D investment is low. Thus, whether internal and external innovation sourcing is complementary is contingent on the level of in-house R&D investment, which shapes firm absorptive capacity.

Arora and Gambardella (1994) find evidence supporting the complementarity hypothesis, suggesting that firm internal R&D orientation is key to driving the observed innovation complementarity between internal and external innovation, as also argued by Hagedoorn and Wang (2012). Other studies that found evidence of complementarity between internal and external innovation include Lokshin et al. (2008) for Dutch firms, and Love and Roper (2009) for German and UK firms.

In contrast, Schmiedeberg (2008) finds no evidence of innovation complementarity between internal and external innovation, refuting the resource-based hypothesis of complementarity. Other studies that have found no evidence of complementarity include those by Laursen and Salter (2006), Vega-Jurado et al. (2009) and Hess and Rothaermel (2011).

2.2.2 Complementarity between product and process innovation

A number of studies have empirically analysed the complementarity between product and process innovation at the firm level. Using panel data for Spanish manufacturing firms, Bianchini et al. (2018) tested the link between firm performance, as measured by sales growth, and the joint adoption of product and process innovation. The key question they addressed was whether performing two joint innovation activities increased sales growth compared to when innovation activities were undertaken separately. Their results show that separately implementing product and process innovation does not significantly affect firm growth, but that growth is enhanced when product and process innovation activities are undertaken jointly.

Miravete and Pernías (2006) developed a structural discrete choice model to distinguish between complementarity and correlation induced unobserved heterogeneity, using data for Spain. They found significant evidence suggesting the presence of complementarity between product and process innovation. Berulava and Gogokhia (2016) used micro-level data for several European countries, and also find support for the existence of complementarity between product and process innovation.

Using the 2003 World Bank Investment Climate Survey (ICS) data for manufacturing firms in Brazil, Goedhuys and Veugelers (2012) analysed factors affecting innovation performance and firm growth. Their findings provide evidence that innovative performance – in particular the joint adoption of both product and process innovation – drives firm growth. Other studies that support the hypothesis of product and process innovation complementarity, finding that product-process innovation complementarity aids firm performance more than innovation activities undertaken in isolation, include Kraft (1990), Reichstein and Salter (2006) for UK firms, and Ballot et al. (2011) for the UK and France. In contrast, Martin and Nguyen-Thi (2015) analysed whether firm productivity is enhanced through innovation complementarity and found no significant association between product and process innovation in affecting labour productivity in firms in Luxembourg.

2.2.3 Innovation complementarity literature in Africa

The literature on innovation complementarity is still very scarce in the context of Africa, yet there are some distinctive characteristics of firm-level innovation and innovation systems in African countries (Paus et al., 2022). An important constraint here is the lack of suitable firm-level data with relevant variables. In one of the few available studies, Egbetokun et al. (2016) analysed complementarity between internal and external innovation using survey data for Kenya and Nigeria. Drawing on Cassiman and Veugelers' (2006) methodology, they found evidence consistent with the hypothesis of innovation complementarity between internal and external innovation in the case of Kenya, but not for Nigeria. Unlike most studies in the literature that use firm productivity as an indicator of firm innovation performance, they used a measure of the percentage of sales from innovation activities. Their study points to the importance of differences in the context of country economies in shaping firm performance through complementing innovation activities. In a closely related study, Okumu, Bbaale and Guloba (2019) estimated the link between employment growth and innovation using the World Bank Enterprise Survey (WBES) data for 27 African countries. They also tested whether complementarity between product and process innovation was associated with employment growth. Their results show evidence in support of the complementarity hypothesis.

Our paper differs from these other studies on African countries in several ways. First, our study focuses on MSEs in the manufacturing sector, also including informal enterprises. Second, utilising the richness of our new dataset that includes a range of innovation variables as well as variables on other firm characteristics, we are able to adapt and extend our specifications to include relevant considerations such as informality, firm ownership and financial access constraints. These factors are of particular relevance in the African context, especially when considering formal and informal MSEs.

While the empirical literature provides some important insights, it is clear that the subject of innovation complementarity is far from settled. As with the diversity in theoretical perspectives and predictions, the results from the empirical evidence on whether firm innovation strategies are complementary are mixed and inconclusive. It seems that differences in methodology and economic contexts account for the differences in findings observed across the existing literature. This context-specificity of findings underscores the importance of empirical analysis in African and other developing country contexts.

As noted, most of the empirical literature on innovation complementarities focuses on developed countries (Schmiedeberg, 2008; Love & Roper, 2009; Hagedoorn & Wang, 2012). Generally, there is a lack of studies on innovation complementarities in Africa, due in part to the paucity of suitable firm-level data. Yet the subject of innovation is particularly important for developing countries that are far from catching up to the productivity levels of developed economies.

Further, there is very little coverage of MSEs, despite these firms being recognised as important for growth, entrepreneurship and employment creation in developing countries. This research thus helps to fill a gap in the literature by using a developing country in Africa and focusing on MSEs, including informal enterprises, and by extending previous econometric specifications to take account of these contextual specificities.

3. Estimation strategy

3.1 Identifying the existence of complementarity

To empirically identify whether innovation complementarity exists, we adopted the direct or productivity approach followed by Cassiman and Veugelers (2006) and Schmiedeberg (2008). The advantage of this approach is that it allows us to test for complementarity directly, rather than just relying on conditional correlations between residuals of the reduced form estimations, as is the case with the indirect or adoption approach. The productivity approach is implemented by regressing firm performance measures on indicators of firm innovation activities. In this study, we test, first, complementarity between product and process innovation and, second, complementarity between internal and external innovation.

We first created an indicator variable that shows whether a firm adopted either process or product innovation, or both. Similarly, we created another indicator variable indicating whether a firm adopted either internal or external innovation or both. Our sample excludes firms that did not undertake any of these innovation activities. The productivity approach was implemented by separately estimating the following specifications:

$$Y_i = \alpha_0 + \beta_1 Prod\_inno_i + \beta_2 Proc\_inno_i + \delta_0 (Prod\_inno_i \times Proc\_inno_i) + \rho_0 X_i + \upsilon_i \quad (1)$$

$$Y_i = \alpha_1 + \beta_3 Int\_inno_i + \beta_4 Ext\_inno_i + \delta_1 (Int\_inno_i \times Ext\_inno_i) + \rho_1 X_i + \varepsilon_i, \quad (2)$$

where Y_i is firm performance (measured as change in revenue), $Prod\_inno_i$ is a dummy for product innovation only, $Proc\_inno_i$ is a dummy for process innovation only, Int_inno_i is a dummy for internal innovation only, and Ext_inno_i is a dummy for external innovation only. X_i is a vector of controls that affect firm performance. All variables are discussed in more detail in section 4.2.

Complementarity is identified by the coefficient of the interaction terms, δ_0 and δ_1, in equations 1 and 2 for product/process and external/internal innovation, respectively. Complementarity is indicated if the coefficient of an interaction term is positive and statistically significant. A negative and significant coefficient suggests that the respective innovation activities are substitutes. Because the dependent variable is an ordered categorical variable (see section 4.2 for more details), we estimated equations 1 and 2 using the ordered probit model.

Because we restricted our sample size to only innovative firms when using the productivity approach, it was possible that we could encounter a dummy variable trap problem. This is because our sample does not contain firms that adopt none of product, process, internal or external innovations. One way to solve this, which we followed, is to drop one dummy variable when running the estimations. Another problem when testing for complementarity is possible selection bias. This problem arises because we only included innovative firms in the estimations, but these firms may differ from non-innovative firms in terms of performance. To account for possible selection bias, we used the conventional method in the literature, the Heckman two-stage selection model.

3.2 Determinants of complementary innovation strategies

After identifying complementarity (as set out in 3.1 above), next we analyse drivers of innovation activities and identify variables that could influence the joint adoption of innovation activities, and thus complementarity. To achieve this, we performed the multinomial logit regression specified below (based on Cassiman and Veugelers 2006).

$$\Pr(y_i = j) = \frac{\exp(z_i)}{\sum_{m=1}^{4} \exp(z_{m,i})} \quad (3)$$

j ∈ internal only (1); external only (2); joint internal and external (3), alternatively

j ∈ product only (1); process only (2); joint product and process (3),

where z_i is a vector of characteristics of firm *i*.

The multinomial logit model identifies determinants of exclusive combinations of the various innovation activities, specifically of the joint adoption of innovation activities. That is, variables that are statistically significant in the multinomial logit results for joint internal and external or joint product and process, but that are not significant for innovation strategies that involve only one innovation type (product or process but not both) or innovation source (external or internal but not both). These determinants can help in explaining the observed correlation between, for example, internal and external innovation, or product and process innovation, and can thus be identified as contextual variables influencing complementarity.

4. Data and descriptive analysis

4.1 Data

We exploit a novel cross-sectional firm-level dataset covering manufacturing MSEs, that was collected in Johannesburg, South Africa in 2019. Part of this richness of this dataset lies in the inclusion of (1) micro-enterprises and (2) informal enterprises, that are generally excluded from firm-level surveys. This is the first survey in South Africa that covers these categories of enterprises and that also collects detailed information on innovation, and there are few similar surveys in other developing countries (especially lacking in Africa), enabling empirical analysis of firm-level innovation that was not previously possible.

The survey was undertaken under the DSI/NRF South African Research Chair in Industrial Development, through the project 'Community of Practice in Innovation and Inclusive Industrialisation'. The survey followed the Oslo Manual in measuring and investigating firm innovation (OECD, 2018). While focused on innovation, the survey collected relevant data on a broader set of firm characteristics and behaviour. The survey included 74 questions, and the firm interviews were conducted by a professional survey company over the period June-August 2019.

The survey collected detailed data on MSEs, classified as those with 50 or fewer workers (based on official definitions of MSEs). The survey covered all enumerator areas (EAs) that were designated for commercial or industrial use within the urban development zone (UDZ) of the City of Johannesburg; any additional EAs that were classified as industrial in the 2011 Census; and adjacent residential EAs where manufacturing activities had extended across EA boundaries. In the selected EAs, a census was conducted of all businesses operating in each EA to construct a sample frame, from which manufacturing businesses could then be selected. The data is representative of manufacturing MSEs in Johannesburg.

Of the 711 firms in the full sample, 54% were found to have undertaken some form of innovation. As discussed, the sample is restricted to innovative firms for the empirical analysis. Our final sample thus constitutes 382 firms.

4.2 Variables

Here, we set out (1) how we measure innovation and specifically innovation complementarity; (2) our dependent variable measuring firm performance; and (3) our control variables. Variables are summarised in Table 1 below and discussed further thereafter.

Table 1: Description of variables

Variable	Variable type	Definition/construction
Dependent variable		
Change in revenue	Ordered categorical	Change in revenue from the previous financial year. 1 if revenue decreased, 2 if there was no change, and 3 if revenue increased
Explanatory variables		
Product only	Dummy	1 if the firm engaged in product innovation but not process innovation, and 0 otherwise
Process only	Dummy	1 if the firm engaged in process innovation but not product innovation, and 0 otherwise
Product and process	Dummy	1 if the firm engaged in both product and process innovation, and 0 otherwise.
Internal only	Dummy	1 if the firm engaged in internal but not external innovation, and 0 otherwise
External only	Dummy	1 if the firm engaged in external but not internal innovation, and 0 otherwise
Internal and external	Dummy	1 if the firm engaged in both internal and external innovation, and 0 otherwise
Firm size	Continuous	Total number of workers a firm employs (log)
Firm age	Categorical	Age of the firm, categorised as 0-5 years, 6-15 years, 16-30 years, and >30 years.
Capital intensity	Continuous	Ratio of capital stock to labour (log)
Formality	Dummy	1 if the firm is registered (formal), and 0 if it is unregistered (informal)
Financial constraints	Dummy	1 if the firm reports that financial factors limit its growth, and 0 otherwise
Ownership	Dummy	1 if a firm is owned by a South African citizen, and 0 otherwise
R&D	Dummy	1 if the firm engaged in R&D activities during the last financial year, and 0 otherwise
Market	Categorical	Indicates the main market for the firm: 1 if individuals, 2 if small businesses, 3 if medium-sized businesses and 4 if large businesses.
Industry	Categorical	Industry is clustered into four groups according to the NACE-Rev. 1 classification[1] (1) Low-tech; (2) Medium low-tech; (3) Medium high-tech; and (4) High-tech.

[1] The NACE-Rev. 1 refers to the industrial classification that link the European classification with the ISIC Rev. 3 (UN-DESA, 2008).

4.2.1 Innovation complementarity

We investigate innovation complementary along two separate dimensions of innovation activities: complementary between different types of innovation (referring to product and process innovation), and complementary between different sources of innovation (referring to internal and external innovation).

Firstly, in terms of innovation types, product innovation involves creating new products or services that differ significantly from existing products and also involves upgrading or improving the existing version of the products to enhance performance or lower costs. Process innovation involves the adoption of new or significantly improved production techniques. This may include changes in methods of manufacturing, delivery or distribution, equipment or use of new knowledge, among others, with the intention to produce or increase production of new or existing products. Firms were asked in the survey whether they had done innovation by introducing any of the following: entirely new products; significantly improved products; introduced entirely new services; significantly improved services; introduced entirely new processes; significantly improved processes; or none of these. From the responses, we generated three binary variables indicating whether (among our sample of innovative firms): (1) a firm only undertook product innovation, (2) a firm only undertook process innovation, and (3) a firm undertook both product and process innovation. We are interested in how these responses correlate with each other.

Secondly, with regard to innovation sources, we consider complementarity between internal and external sources of innovation. Internal innovation refers to a firm using in-house R&D to develop its technology, while external innovation involves acquiring technology from outside the firm boundaries (OECD, 2018). This may involve 'buying' technology from other organisations or subcontracting. In the survey, firms were asked by whom the firm innovation improvements were developed. From the firm responses, we created three binary variables indicating whether: (1) a firm was involved in only internal innovation, (2) a firm was involved in only external innovation, and (3) a firm was involved in both internal and external innovation.

4.2.2 Dependent variable: firm performance

Based on the production approach, we use change in revenue as the dependent variable measuring firm performance. Change in revenue is an ordered variable, coded 1 if revenue decreased, 2 if there was no change and 3 if the revenue increased.

4.2.3 Control variables

Drawing on the literature, extending this with reference to the local context, and taking account of data availability, we included relevant control variables. Including a measure of formality allows us to assess the difference in innovation strategies between formal and informal sector firms. We include ownership, to account for differences between firms owned by South Africans and those owned by citizens of other countries. Financial access constraints can affect firm innovation strategies, and we control for this by including a measure of financial constraints. We also include a variable indicating whether a firm is engaged in R&D. R&D plays a critical role in firm innovation strategies, and we expect that firms that engage in R&D could be more complementary in their innovation strategies. Furthermore, we control for the firm's industry, to account for heterogeneity across the industries of manufacturing. We classify industries according to their technology intensity, drawing on the UN-DESA (2008) ranking of industries, as low-tech; medium low-tech; medium high-tech and high-tech firms. Firms in relatively high-tech industries are typically more likely to adopt complementary innovation strategies.

4.3 Descriptive statistics

Table 2 presents the descriptive statistics. With regard to our dependent variable, change in revenue, the results presented show that 41% of firms experienced a decrease in sales, while 32% of firms had an increase in sales, relative to the previous financial year. Looking at innovation variables, Table 2 suggests that 79% of firms engage only in product innovation, 9% engage only in process innovation and 12% engage in both product and process innovation. 43% of firms use only external sources of innovation, 39% use only internal sources, while 18% use both internal and external sources.

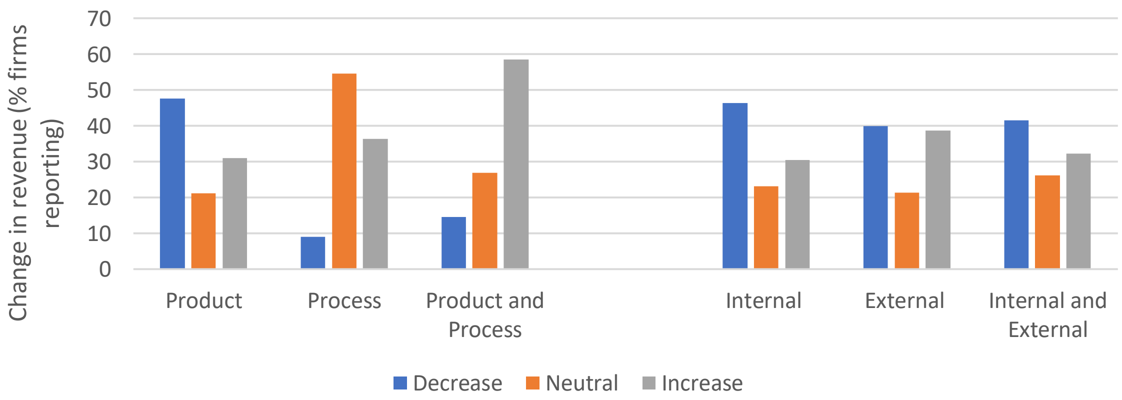
The average firm size is about eight workers, while 40% of firms are up to five years old. 42% of the firms in the sample are formal enterprises. Financial access constraints seem to be a major obstacle, as 67% of firms reported being constrained. Most firms (67%) are owned by South African citizens. 21% of firms reported engaging in R&D activities. The majority of firms (72%) report that individuals are the most important market for their products. Most of the firms are in low-technology industries (77%).

Figure 1 presents descriptive patterns of firm innovation strategies (product/process and internal/external) and firm performance (measured as change in revenue from the previous financial year). Looking at product and process innovation, Figure 1 suggests that a higher proportion of firms that engage in both product and process innovation report an increase in revenue than firms that engage in only product or process innovation. However, it seems there is no obvious pattern between change in revenue and engaging in both internal and external innovation. This is shown by the fact that the proportion of firms reporting an increase in sales is not different for firms that engage in both internal and external innovation and those that only engage in internal or external innovation.

Table 2: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Change in revenue (dependent variable)					
1.Decrease	351	0.41	0.49	0	1
2. Neutral	351	0.26	0.44	0	1
3. Increase	351	0.32	0.47	0	1
Innovation variables					
Product	351	0.79	0.36	0	1
Process	351	0.09	0.16	0	1
Product and process	351	0.12	0.33	0	1
Internal	351	0.39	0.49	0	1
External	351	0.43	0.50	0	1
Internal and external	351	0.18	0.38	0	1
Firm size	351	7.72	8.61	1	45
Firm age					
0-5	351	0.40	0.49	0	1
6-15	351	0.34	0.48	0	1
16-30	351	0.17	0.38	0	1
>30	351	0.08	0.28	0	1
Capital (R'000)	351	1 979.38	9 879	0	80 000
Formality	351	0.42	0.49	0	1
Financial constraints	351	0.68	0.47	0	1
Ownership	351	0.67	0.47	0	1
R&D	351	0.21	0.41	0	1
Market					
1. Individual bus.	351	0.72	0.45	0	1
2. Small bus.	351	0.15	0.36	0	1
3. Medium bus.	351	0.07	0.26	0	1
4. Large bus.	351	0.05	0.21	0	1
Industry					
1. Low tech	351	0.76	0.43	0	1
2. Med-low tech	351	0.18	0.38	0	1
3. Med-high tech	351	0.06	0.24	0	1

Figure 1. Relationship between innovation activities and firm performance



4.4 Correlation of innovation activities

In Table 3, we descriptively explore innovation complementarity using pairwise correlations between innovation activities. Positive significant pairwise correlations suggest innovation complementarity, while negative correlations suggest a substitution relationship. Column 1 presents the non-exclusive frequencies of innovation activities. It shows that an overwhelming majority of firms (96.9% of our sample of innovating firms) engaged in product innovation, while 14.7% have engaged in process innovation. In terms of innovation sources, the majority of firms (61.3%) acquire innovation externally, while a slightly lower proportion (56.6%) undertake innovation internally. Table 3 also presents unconditional and conditional correlations between firstly product and process innovation, and secondly internal and external innovation. The conditional correlations are derived from the residuals of a bivariate probit model.

The descriptive results in column 2 of Table 3 indicate a low but positive and significant correlation between product and process innovation, which could point to complementarity between these types of innovation. The correlation, however, becomes smaller and insignificant with the inclusion of control variables, as shown by the conditional correlation in column 3. Further, column 2 shows a negative and significant correlation between internal and external innovation, suggesting a possible substitution relationship between these innovation sources. The magnitude reduction and insignificance of the conditional correlation in column 3 also suggests that we may have accounted for possible variables that drive the relationship between internal and external innovation. The descriptive results in Table 3 are in line with several other studies in the literature (Cassiman & Veugelers, 2006; Schmiedeberg, 2008; Love & Roper, 2009; Hagedoorn & Wang, 2012).

Table 3. Correlations between innovation strategies

Innovation strategies	Frequency (1)	Unconditional correlations (2)	Conditional correlations (3)
Product	342 (95.2%)	0.177***	0.136
Process	56 (14.7%)		
Internal	201 (57.3%)	-0.286***	-0.060
External	213 (60.7%)		

5. Empirical results

5.1 Identifying complementarity

The correlations presented above provide only a preliminary investigation towards identifying and testing for complementarity and are not sufficient. To formally analyse complementarity, we first assess how combinations of product and process types of innovation, and separately of internal and external innovation sources, affect firm performance. This is estimated using the productivity approach specified in equations 1 and 2 and estimated through ordered probit and Heckman selection regressions.

Table 4 presents the main regression results for complementarity between product and process innovation, with our key variable of interest being the interaction between product and process innovation (product and process). Similarly, Table 5 presents the main results for internal and external innovation, where our key variable of interest is the interaction between internal and external innovation (internal and external). We dropped the dummies for product innovation and internal innovation in tables 4 and 5 respectively, due to the dummy trap problem noted earlier.

Table 4. Complementarity between product and process innovation

	(1)	(2)	(3)	(4)	(5)	(6)
	Ordered probit marginal effect			Heckman selection ME		
VARIABLES	Decrease	Neutral	Increase	Decrease	Neutral	Increase
Process	-0.158*	-0.009	0.167	-0.190	-0.006	0.196
	(0.094)	(0.019)	(0.112)	(0.134)	(0.028)	(0.162)
Product and process	-0.256***	-0.027	0.283***	-0.246***	-0.010	0.255***
	(0.060)	(0.021)	(0.078)	(0.069)	(0.018)	(0.084)
Firm size (log)	-0.108	0.008	0.100	-0.094	0.011	0.083
	(0.081)	(0.008)	(0.075)	(0.082)	(0.010)	(0.073)
Firm size squared (log)	0.028	-0.002	-0.026	0.026	-0.003	-0.023
	(0.024)	(0.002)	(0.022)	(0.024)	(0.003)	(0.021)
Capital intensity (log)	-0.003	0.000	0.003	-0.004	0.000	0.003
	(0.006)	(0.000)	(0.005)	(0.006)	(0.001)	(0.005)
Firm age						
2. 6-15	0.082	-0.002	-0.080	0.080	-0.006	-0.074
	(0.061)	(0.004)	(0.059)	(0.060)	(0.006)	(0.055)
3. 16-30	0.164**	-0.014	-0.150**	0.147*	-0.017	-0.130**
	(0.072)	(0.012)	(0.064)	(0.075)	(0.014)	(0.064)
4. >30	0.215**	-0.026	-0.189**	0.212**	-0.034	-0.178**
	(0.101)	(0.025)	(0.080)	(0.102)	(0.027)	(0.078)
Formality	0.002	-0.000	-0.002	0.020	-0.002	-0.017
	(0.057)	(0.004)	(0.052)	(0.057)	(0.007)	(0.050)
Financial constraints	-0.017	0.001	0.015	-0.015	0.002	0.014
	(0.057)	(0.005)	(0.052)	(0.056)	(0.007)	(0.049)
Ownership	-0.091	0.009	0.081	-0.094**	0.013	0.081**
	(0.059)	(0.008)	(0.051)	(0.043)	(0.010)	(0.039)
R&D	-0.106	0.003	0.103	-0.129**	0.007	0.121*
	(0.068)	(0.005)	(0.070)	(0.064)	(0.005)	(0.064)
Market						
2. Small bus.	-0.039	0.001	0.038	-0.022	0.002	0.020
	(0.075)	(0.002)	(0.074)	(0.071)	(0.005)	(0.066)
3. Medium bus.	0.217**	-0.048	-0.169**	0.217**	-0.052	-0.166**
	(0.109)	(0.037)	(0.074)	(0.103)	(0.036)	(0.069)
4. Large bus.	-0.097	-0.001	0.099	-0.034	0.002	0.032
	(0.112)	(0.011)	(0.122)	(0.115)	(0.006)	(0.110)
Industry						
2. Med-low tech	0.042	-0.004	-0.039	0.042	-0.005	-0.037
	(0.068)	(0.007)	(0.061)	(0.068)	(0.010)	(0.058)
3. High tech	0.135	-0.021	-0.115	0.116	-0.020	-0.096
	(0.114)	(0.027)	(0.088)	(0.114)	(0.027)	(0.087)
Observations	351	351	351	351	351	351

Note: The dependent variable is change in revenue, which is an ordered categorical variable (1=decrease; 2=neutral; 3=increase)

Table 5. Complementarity between internal and external innovation

	(1)	(2)	(3)	(4)	(5)	(6)
	Ordered probit marginal effect			Heckman selection ME		
VARIABLES	Decrease	Neutral	Increase	Decrease	Neutral	Increase
External	0.036	0.014	-0.051	-0.066	0.002	0.064
	(0.034)	(0.013)	(0.046)	(0.056)	(0.003)	(0.055)
Internal and external	0.043	0.012	-0.055	-0.002	0.000	0.002
	(0.042)	(0.009)	(0.049)	(0.071)	(0.003)	(0.068)
Firm size (log)	0.124***	0.053**	-0.177***	-0.092	0.004	0.088
	(0.044)	(0.022)	(0.058)	(0.080)	(0.005)	(0.077)
Firm size squared (log)	-0.026*	-0.011	0.037*	0.017	-0.001	-0.016
	(0.014)	(0.007)	(0.020)	(0.024)	(0.001)	(0.023)
Capital intensity (log)	-0.001	-0.000	0.001	-0.005	0.000	0.004
	(0.004)	(0.002)	(0.005)	(0.006)	(0.000)	(0.006)
Firm age						
2. 6-15	0.015	0.005	-0.020	0.117**	0.001	-0.118**
	(0.033)	(0.012)	(0.045)	(0.057)	(0.006)	(0.058)
3. 16-30	0.051	0.010	-0.060	0.197***	-0.010	-0.188***
	(0.045)	(0.010)	(0.050)	(0.072)	(0.013)	(0.065)
4. >30	-0.096***	-0.141	0.237**	0.208**	-0.012	-0.196**
	(0.034)	(0.087)	(0.116)	(0.100)	(0.020)	(0.085)
Formality	-0.019	-0.008	0.027	-0.002	0.000	0.001
	(0.029)	(0.014)	(0.043)	(0.055)	(0.002)	(0.053)
Financial constraints	0.071**	0.041*	-0.112**	-0.015	0.001	0.014
	(0.029)	(0.022)	(0.048)	(0.055)	(0.003)	(0.052)
Ownership	-0.003	-0.001	0.004	-0.080	0.005	0.076
	(0.030)	(0.012)	(0.042)	(0.059)	(0.006)	(0.054)
R&D	0.008	0.003	-0.011	-0.103	-0.001	0.104
	(0.039)	(0.014)	(0.053)	(0.063)	(0.005)	(0.066)
Market						
2. Small bus.	-0.091**	-0.051	0.142**	-0.065	-0.001	0.065
	(0.036)	(0.038)	(0.071)	(0.066)	(0.004)	(0.069)
3. Medium bus.	-0.137***	-0.153*	0.289***	0.202*	-0.036	-0.165**
	(0.033)	(0.084)	(0.111)	(0.105)	(0.031)	(0.076)
4. Large bus.	-0.128***	-0.125	0.253*	-0.121	-0.007	0.129
	(0.042)	(0.102)	(0.140)	(0.102)	(0.017)	(0.118)
Industry						
2. Med-low tech	-0.044	-0.025	0.069	0.021	-0.001	-0.020
	(0.036)	(0.029)	(0.064)	(0.067)	(0.004)	(0.064)
3. High tech	-0.041	-0.023	0.064	0.080	-0.007	-0.073
	(0.060)	(0.049)	(0.109)	(0.111)	(0.015)	(0.096)
Observations	351	351	351	351	351	351

Note: The dependent variable is change in revenue, which is an ordered categorical variable (1=decrease; 2=neutral; 3=increase)

Considering the coefficients on the interaction product and process in Table 4, we observe negative and significant marginal effects on the probability of a firm having a decrease in revenue (column 1) and positive and significant marginal effects on the probability of a firm having an increase in revenue (column 3). Both these sets of results in Table 4 suggest that undertaking both product and process innovation is positively associated with firm performance outcomes, compared to adopting only product innovation. These results support our hypothesis that complementarity in types of innovation (product and process) is associated with enhanced firm performance. To account of possible selection bias, columns 4 to 6 present the results of the Heckman selection model. These results corroborate our findings in columns 1 to 3: even after correcting for the selection of firms, the results indicate complementarity in types of innovation.

Looking at the marginal effects of the control variables in Table 4, firm age, ownership, R&D and market are statistically significant. For firm age categories 3 and 4, the marginal effects are positive and statistically significant in columns 1 and 4 and negative and significant in columns 3 and 6, indicating that older firms have an association with poorer performance outcomes. The results in column 4 and column 6 respectively indicate negative and positive marginal effects on ownership, indicating that domestically owned firms have less likelihood of reporting a decline in revenue than foreign-owned firms. The negative marginal effects of R&D in column 4 and positive results in column 6 both suggest a positive association between engaging in R&D and firm performance outcomes.

Turning to the complementarity between internal and external innovation, the results in Table 5 show the marginal effects for internal and external to be statistically insignificant across all columns. This suggests that there is no evidence of complementarity (nor of a significant substitution relationship) between internal and external sources of innovation. These results are in line with other studies in the literature that found no complementarity between internal and external innovation (Laursen & Salter, 2006; Schmiedeberg, 2008; Vega-Jurado et al., 2009; Hess & Rothaermel, 2011). It is nevertheless possible that these innovation sources are utilised in a complementary manner in some firms, and as substitutes in other firms. The results on control variables are broadly similar to Table 4.

Our results, therefore, provide evidence that suggests the existence of innovation complementarity between innovation types (product and process innovation), but no evidence of complementarity between internal and external innovation sources.

5.2 Determinants of complementary innovation strategies

Thus far, we have identified the existence of complementarity between product and process types of innovation, but not between internal and external innovation sources. Next, we identify possible variables that might be associated with different choices of innovation strategies: separate or combined types of innovation (product, process) and sources of innovation (internal, external).

Table 6 presents the results of the multinomial logit model specified in equation 3. Columns 1 and 2 provide the results for product and process innovation, while columns 3 and 4 provide the results for internal and external innovation. For the adoption of joint product and process innovation (column 2), the statistically significant variables are capital intensity, firm age, financial constraints, ownership, R&D and market. The positive coefficient of the variable capital intensity suggests that higher capital intensity is associated with a higher likelihood of adopting both product and process innovations, an association that does not hold for the likelihood of only adopting product innovation. Capital intensity can be associated with the capital stock and investment flows enabling joint innovation activities through more extensive and sophisticated equipment.

Regarding firm age, the negative coefficients indicate that older firms are less likely to simultaneously adopt product and process innovations compared to young firms (those aged between 0 and five years). This implies that young firms have a higher propensity for adopting complementary innovation strategies. As suggested in the literature, in a drive to increase firm performance, young firms typically undertake riskier innovation activities that may lead to higher productivity if successful (Schneider & Veugelers, 2010; Coad, Segarra & Teruel, 2016). Furthermore, young firms, as entrants, commonly invest more in innovation activities than incumbent firms in order to enter new markets (Cucculelli, 2018), suggesting that older firms may be less likely to undertake joint innovation activities than younger firms.

Considering financial constraints, the results in column 2 show a negative and weakly significant coefficient, implying that financially constrained firms have a lower probability of adopting product and process innovation than only adopting product innovation. Thus, financial constraints have a negative effect on innovation complementarity, which is intuitive. Further, the positive and significant coefficient of ownership in column 2 indicates that domestically owned firms have a higher likelihood of engaging in both product and process innovation.

The results in column 2 also show a positive association between firms that undertake R&D spending and the probability of combining product and process innovation. Such results imply that engaging in R&D activities is important for engaging in complementary innovation strategies. Considering the variable market, the results indicate that firms that serve small businesses as their key market are more likely to adopt joint product and process innovation than firms that mainly sell to individuals.

Although the formality variable has the expected sign, it is statistically insignificant. This, therefore, implies that innovation strategies are not different in formal and informal firms. This may be related to the fact that our sample is of MSEs specifically, a segment for which characteristics, operating activities and the environment are similar for both registered and unregistered enterprises.

Turning to the results for internal vs. external innovation in columns 3 and 4, although our contextual variables have expected signs, they are largely insignificant in explaining firms' adoption of both internal and external innovation. This is not surprising, given that we did not find evidence of complementarity between internal and external innovation in Table 5. We thus do not observe the heterogeneity in drivers of innovation strategies when it comes to innovation sources that is evident in terms of types of innovation.

Table 6. Determinants of innovation strategies: Multinomial logit model

	(1)	(2)	(3)	(4)
	Product and process		Internal and external	
VARIABLES	Process only	Both product and process	External only	Both internal and external
Firm size (log)	2.810*	0.831	-0.135	0.058
	(1.653)	(0.865)	(0.400)	(0.502)
Firm size squared (log)	-0.562	-0.091	-0.094	-0.041
	(0.404)	(0.214)	(0.125)	(0.136)
Capital intensity (log)	0.008	0.126**	-0.033	0.010
	(0.063)	(0.052)	(0.030)	(0.035)
Firm age				
2. 6-15	-1.018	-0.828*	-0.354	-0.263
	(1.166)	(0.424)	(0.297)	(0.372)
3. 16-30	-0.905	-1.341*	-0.267	0.140
	(1.041)	(0.706)	(0.365)	(0.441)
4. > 30	-0.296	-0.283	-0.253	0.049
	(1.031)	(0.611)	(0.539)	(0.603)
Formality	-0.336	0.077	0.362	0.121
	(0.768)	(0.408)	(0.273)	(0.351)
Financial constraints	-0.516	-0.650*	-0.032	-0.385
	(0.913)	(0.376)	(0.280)	(0.328)
Ownership	0.411	0.149**	-0.120	0.402
	(0.260)	(0.076)	(0.280)	(0.360)
R&D	0.865	0.756*	-0.464	0.061
	(0.666)	(0.427)	(0.337)	(0.374)
Market				
2. Small bus.	2.176	0.962**	0.072	-0.420
	(1.419)	(0.465)	(0.351)	(0.452)
3. Medium bus.	2.914**	0.369	-0.435	-0.822
	(1.245)	(0.554)	(0.569)	(0.642)
4. Large bus.	3.770***	0.871	0.424	-13.950***
	(1.287)	(0.707)	(0.646)	(0.467)
Industry				
2. Med-low tech	-0.216	0.651	-0.506	-0.254
	(1.349)	(0.439)	(0.328)	(0.426)
3. High tech	2.390**	0.920	-0.920	-0.568
	(0.943)	(0.671)	(0.611)	(0.706)
Constant	-7.945***	-4.072***	0.977**	-0.370
	(1.928)	(0.921)	(0.463)	(0.590)
Observations	351	351	351	351

Notes: The base category for columns 1 and 2 is product innovation, while the base category in columns 3 and 4 is internal innovation. Robust standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1

6. Conclusion

Innovation complementarity can be important to the success and impact of firm innovation strategies, including on firm performance. We explore this empirically using novel survey data covering manufacturing MSEs in Johannesburg, South Africa. This data and setting contribute to the literature by providing evidence in an African context, and including micro and informal firms that are generally excluded from similar surveys and hence from the extant literature.

We extended specifications used in the literature to take account of factors that could be particularly relevant in this context.

First, we used the productivity approach to formally identify the presence of innovation complementarity. We achieved this by regressing firm performance (measured as change in revenue) on the interaction terms between product and process innovation, as well as internal and external innovation (along with covariates). The consistency in the central findings when using ordered probit and Heckman selection regressions, helps to corroborate the robustness of our results. We find a positive and significant association between combined product and process innovation and change in revenue (relative to either product or process innovation being undertaken separately), suggesting complementary between these types of innovation. However, we did not find evidence of complementarity between internal and external innovation.

We then used a multinomial logit model to identify variables that may drive a firm's decision to adopt joint innovation activities. The results suggest that capital intensity, firm age, R&D, financial constraints and main markets are key variables associated with the joint adoption of product and process innovation. However, these contextual variables are generally insignificant in explaining the joint adoption of internal and external innovation. The management of innovation activities based on understanding the key variables or characteristics is essential in achieving and implementing successful innovation strategies.

These results have relevance for fostering innovation as well as enhancing the impact of innovation on firm performance. Part of this relevance lies in the empirical evidence for MSEs specifically (including informal enterprises) and the African context. For firms, the finding of strong complementarity between product and process innovation points to the importance of undertaking both types of innovation (where feasible), in order to maximise the success of innovation in improving enterprise performance. For policymakers, this finding suggests that incentive and support systems intended to foster firm-level innovation, could give special attention to encouraging both types of innovation being undertaken jointly, rather than regarding these as alternatives. The results on the determinants of complementary innovation strategies, provide policy-relevant evidence as to the key factors that can influence firms jointly adopting product and process innovation.

While our study makes an important contribution to the literature on innovation complementarity, this research agenda could be advanced by searching for other contextual variables that affect complementarity. The effects of innovation on firm performance could furthermore vary over time, for which the use of panel data would be advantageous to investigate the lagging effects of innovation. Future research could also use direct measures of innovation performance (such as the proportion of sales from innovation or the effects of innovation on employment) and other measures of firm performance, that were not available in our dataset.

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