Learning and Product Innovation Performance in Informal Enterprises: Evidence from Urban Ghana

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Abstract

Recognising that enterprises learn how to produce goods and services in the informal economy, this paper examines the effect of two learning processes (apprenticeship and 'formal interactions') on the product innovativeness of informal enterprises in Ghana. Employing unique survey data on 513 enterprises and the Type II Tobit model, our analyses reveal that apprenticeship, on the one hand, enhances the technological capability of enterprises leading to product innovativeness, while competitive formal interactions, on the other hand, provide important market feedback that enhances the innovativeness of enterprises. The paper concludes by discussing the policy implications of these findings.

Keywords: Innovation; Informal Sector; Learning; SMEs; Ghana; sub-Saharan Africa (SSA).
JEL Codes: D22; L25; M53; O12; O17; O31.

1. Introduction

Learning processes generate knowledge key for the development of firms' capabilities (Lall, 2000; Bell and Albu, 1999; Malerba, 1992).[1] Learning processes are also critical in shaping and directing the technological and productive paths of firms (Oyelaran-Oyeyinka and Lal, 2006; Malerba, 1992). While enterprises in sub-Saharan Africa (SSA) learn how to organise, and produce goods and services through cumulative and diverse ways, empirical evidence examining the effect of these processes on the innovation activities of informal enterprises remains scant and anecdotal. In line with the growing literature on Doing, Using and Interacting mode (DUI-mode)[2] of learning (see, for instance, Jensen et al., 2007; Apanasovich et al., 2016), this paper provides a micro-level evidence that examines the effects of apprenticeship and formal-informal sector interactions ('formal interaction' hereafter) on the innovation performance of informal enterprises using a unique data from urban Ghana.[3]

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The informal economy remains dominant in most developing countries, where it contributes significantly to employment and output (Ulyssea, 2018; Internationa Labour Organization (ILO), 2018; La Porta and Shleifer, 2014).[4] As a result, the informal economy and the activities of informal enterprises in SSA have regained academic and policy interest in recent years. In particular, studies analysing the innovation activities of informal enterprises have gained some traction. The evidence emerging from this burgeoning literature suggests that incremental innovations, largely defined by local demand and needs, and driven by knowledge acquired through 'alternative', non-R&D-based learning processes, are pervasive in informal enterprises in SSA (Bull, Daniels, Kinyanjui, and Hazeltine, 2016; Kraemer-Mbula, 2016; Fu, Zanello, Owusu Essegbey, Hou, and Mohnen, 2014; Gebreeyesus and Mohnen, 2013; Konte and Ndong, 2012; McDade and Malecki, 1997; Dawson, 1992). In fact, informal enterprises in SSA are seen to learn to innovate through apprenticeship and mutual formal interactions (Kawooya, 2014). For instance, Frazer (2006), Velenchik (1995), and Bas (1989) both found apprenticeship to be popular in the informal sector and seen to play a key role as an institution of learning and training, especially among small enterprises. Oyelaran-Oyeyinka and Lal (2006) also found apprenticeship to serve as a major source of knowledge as well as a medium through which the transfer of both codified and tacit knowledge occurs for use in the local context. Conversely, informal enterprises are linked to the formal economy with mutual interactions (Ulyssea, 2018; Kawooya, 2014). Other studies also identified the importance of interactions with external actors in the innovation process (Robson, Haugh, and Obeng, 2009; Oyelaran-Oyeyinka and Lal, 2006; Murphy, 2002; McDade and Malecki, 1997), and the role interactions serve as a conduit through which knowledge essential for innovative activity flows between firms in SSA (Goedhuys, 2007; Murphy, 2002).

Yet, the economic literature examining the role that apprenticeship plays in building and enhancing the capabilities of informal enterprises remains scant in SSA.[5] Also, empirical evidence assessing the role that formal interactions play in the innovation activities of informal enterprises remains under-researched in SSA (see, for instance, Kraemer-Mbula and Tau, 2014). Available empirical evidence on interaction has mainly focused on horizontal interactions in informal clusters (see for instance Van Dijk, 2002; McDade and Malecki, 1997; Dawson, 1992) or between registered enterprises (see for instance, Barr, 1999; Murphy, 2002; Goedhuys, 2007; Robson et al., 2009).[6]

This paper contributes to the DUI-mode of learning, informality, and innovation literature in three main ways. First, while literature on apprenticeship - its nature and characteristics - in SSA exists,

it remains underdeveloped (Teal et al., 2008) and descriptive (Frazer, 2006), and fails to analyse its effect as a critical learning process on the innovation activities of informal enterprises. Also, the related empirical literature available concentrates on learning-by-doing[7] and on manufacturing enterprises, and remains inconclusive (see Gebreeyesus and Mohnen, 2013; Oyelaran-Oyeyinka and Lal, 2006). This paper fills these gaps in the literature by specifically examining apprenticeships, and by broadening the definition of apprenticeship, suggesting that, through apprenticeship, enterprises may also acquire 'new' knowledge that challenges the traditional ways of doing things, and that may lead to new or significantly improved products.[8] Second, we extend the analyses in Gebreeyesus and Mohnen (2013), Robson et al. (2009), and Goedhuys (2007) by looking beyond the propensity to innovate, to how technological innovations actually perform on the market. To the best of our knowledge, only a few studies in the literature analyse formal interactions and how they affect the innovative activities of informal enterprises (see for example Kraemer-Mbula and Wunsch, 2016; Kawooya, 2014; Gebreeyesus and Mohnen, 2013). By modelling both collaborative and competitive interactions between informal and formal-sector enterprises, this paper differs by looking at how different interactive strategies affect the innovativeness of informal enterprises. Third, we employ a unique informal survey data set from urban Ghana (Accra and Tema) covering 513 informal enterprises in both the manufacturing and service sectors. The study of informal enterprises and their innovation activities is rare in the literature, and the analyses of informal enterprises in both the manufacturing and services sectors, including retail enterprises, where significant economic activity occurs in SSA, add to the currently thin literature.

The results from the Type II Tobit model regression reveal that apprenticeship and formal interaction both have a significantly positive effect on enterprises' innovation performance. Distinguishing between competitive and collaborative types of formal interactions, we found that informal enterprises with competitive interactions with formal sector enterprises tend to perform better with innovations, while enterprises with collaborative interactions with formal sector enterprises tend to have a strong negative effect on innovation performance.

The rest of the paper is structured as follows: Section 2 presents a review of relevant literature on informality, informal innovations, and learning mechanisms - apprenticeship and formal interaction - largely in the context of SSA. Section 3 presents discussions of the survey data and the methodology employed in the empirical analysis. Section 4 presents and discusses the results, and section 5 provides the concluding remarks.

2. Literature Review and Hypotheses

2.1 Informality and Innovation in SSA

Recent decades have seen rising informality of economic activities around the globe. In developing countries, the informal economy remains a 'success', a 'universal feature', and a source of livelihood to many, especially urban dwellers (Hart, 2006). The informal economy is heterogeneous (Ulyssea 2018; Sindzingre, 2006), composed largely of micro, small, and medium enterprises (MSMEs) that often have dynamic mechanisms that can adjust quickly to local needs and changes in demand (Leliveld and Knorringa, 2018). Despite their recognition, informality and activities of informal enterprises remain largely seen as negative on the economy (see for example, Avenyo et al., 2020; La Porta and Shleifer, 2008, 2014).

While a universally accepted definition is missing in the literature, informal enterprises are generally considered to be those 'that are not registered and are legally outside the tax net' (Guha-Khasnobis, Kanbur, and Ostrom, 2006, p. 4). In Ghana, for example, an informal enterprise is defined as an enterprise not registered at the Registrar General's Department. This definition, as was found during the survey, does not imply that informal enterprises are outside the reach or mechanisms of official governance. On the contrary, the research found that a majority of enterprises that are not registered - i.e., those without official business operation certificates - pay local municipal taxes and property taxes. The idea that informality is equivalent to tax avoidance may therefore be questionable.

Innovation, on the other hand, remains a key driver of structural change and economic development (Avenyo et al, 2019; Fagerberg et al, 2005; Dosi et al, 1988; Schumpeter, 1934). As a result, innovation has gained both policy and research interests in Africa over the last decade. However, these interests focus largely on formal sector innovations in Africa. That is, innovation activities are considered as the sole prerogative of registered firms, research institutions and universities through research and development (R&D). While Charmes et al. (2016), for instance, suggested policy redirections towards including informal innovations in the science, technology and innovation (STI) intiatives implemented through the NEPAD African Science, Technology and Innovation Indicators (ASTII) Initiative, these policies only promote and drive innovation in formal institutions in Africa.

As a result, available empirical evidence on innovation in SSA focuses mainly on formal enterprises (see for example, Murphy, 2002; Mahemba and Bruijn, 2003; Oyelaran-Oyeyinka and Lal, 2006;

Goedhuys, 2007; Robson et al., 2009; Avenyo et al., 2019). This may be explained by the availability of, and improvements in firm-level data on innovation across African countries. The majority of this research concentrate on manufacturing enterprises. Adding to the thin literature on both manufacturing and service sector enterprises, researchers have analysed the effects of various entrepreneurial and firm-level characteristics - for instance, Robson et al. (2009) examined these effects on seven proxies of innovation. Distinguishing between two main types of innovations as novel and incremental, the authors found incremental innovations to be most prevalent in Ghana. Avenyo et al (2019) also identified a positive impact of product innovation on employment in Democratic Republic of Congo, Ghana, Tanzania, Uganda, and Zambia.

Innovation activities in the informal economy remain largely missing in both the policy and research spheres (Kraemer-Mbula and Wamae, 2010b; De Beer et al., 2013; Cozzens and Sutz, 2014; Kraemer-Mbula and Konte, 2016). According to De Beer et al. (2014, p. 16), the lack of understanding of the informal economy and informal innovations hinders the understanding of innovation in Africa as a whole. Despite the neglect, research on the innovation activities of informal enterprises in SSA continue to gain some attention.[9] While evidence still remains sparse, recent case studies in SSA indicate the widespread nature of innovations in the informal economy (see Dawson, 1992; McDade and Malecki, 1997; Van Dijk, 2002; Konte and Ndong, 2012; Fu et al., 2014; Bull et al, 2016; Kraemer-Mbula and Wunsch-Vincent, 2016). Exploring the innovation activities of informal enterprises producing home and personal products in South Africa, Kraemer-Mbula (2016) found the presence of both product and process innovations. Kraemer-Mbula (2016) found these innovations to be incremental, systemic, and mainly aimed at satisfying customer needs. Similar conclusions were drawn from related case studies in the informal herbal industry of Ghana (see Essegbey and Awuni, 2016) and in the informal metalworking sector in the Kenyan capital Nairobi (see Bull et al., 2016). Similarly, summary conclusions from the Diffusion of Innovation in Low Income Countries (DILIC) project - a survey of 500 firms from both formal and informal sectors across Ghana - indicate the prevalence of incremental innovations in the informal sector (Fu et al., 2014). This paper adds to this growing literature.

2.2 Informality and Learning Processes in SSA

The role of knowledge, technology adoption and adaptation in accelerating economic progress in developing countries is widely emphasised in development economics. Local capability development and enhancement through learning is found to be critical in this process (Cohen and Levinthal, 1989; Lall, 2000; Romijn, 2002).

The literature on firm learning processes acknowledges that various sources of knowledge have different effects on the technological trajectory of firms (see Malerba, 1992; Oyelaran-Oyeyinka and Lal, 2006). Malerba (1992) identifies and summarises learning processes into two main broad classifications: as 'internal' and 'external' sources. Internal learning is defined as originating from the day-to-day activities of firms, and includes 'learning by doing', 'learning by using' and 'learning by searching' (R&D), while external learning is generated outside of the firm's internal day-to-day activities and includes 'learning by interacting', 'learning from inter-industry spillovers' and 'learning from advances in science and technology' (Malerba, 1992, p. 848). These different types of learning processes are not exclusive since firms may simultaneously adopt a mix of internal and/or external learning sources (Malerba, 1992). In other words, complementarity may exist between multiple learning processes that may thus reinforce the innovation activities of firms.

In developing countries, the empirical literature has identified several combinations of learning processes - such as R&D (Goedhuys, 2007), training (Oyelaran-Oyeyinka and Lal, 2006), interactions and networks (Robson et al., 2009; Goedhuys, 2007; Mahemba and Bruijn, 2003; Murphy, 2002), and learning-by-doing (Gebreeyesus and Mohnen, 2013; Oyelaran-Oyeyinka and Lal, 2006) - as being important for firms' innovation activities. However, the available literature on firm learning-for-innovation focuses mainly on formal enterprises and tends to neglect the dual economic structure that may define learning in SSA. An exception is Gebreeyesus and Mohnen (2013), who introduced 'learning-by-doing' and 'network' into their analysis when seeking to understand the product innovation activities of informal clusters in Addis Ababa, Ethiopia. Findings from the literature, when taken together, present a somewhat inconclusive picture. Mahemba and Bruijn (2003), for instance, found a positive and significant effect of skilled workers on firm innovativeness. Robson et al. (2009), Goedhuys (2007), and Mahemba and Bruijn (2003) found training to have only an insignificant effect on the tendency of the enterprise to innovate. Robson et al. (2009) found that enterprises whose owners had higher educational attainments tended to be much more innovative.

Learning processes in developing countries are, in part, influenced by the learning processes and experiences of informal enterprises that dominate these economies (Kraemer-Mbula and Wamae, 2010d). In this section, we examine two often-neglected DUI-mode learning processes in informal enterprises: apprenticeship (an internal learning process) and formal interaction (an external learning process). [10]

2.2.1 Apprenticeship and Informal Innovations in SSA

Apprenticeship is an internal learning process that serves as a source of knowledge in developing countries (Oyelaran-Oyeyinka and Lal, 2006). This process creates skills, and serves to transfer and exchange local knowledge, thereby improving local capacities and abilities. Local capabilities and competencies provide an opportunity to satisfy local needs through innovation (Kraemer-Mbula and Wamae, 2010d).

In Africa, apprenticeship is widespread in the informal economy, where it plays a key role as an institution of learning (Bas, 1989; Velenchik, 1995; Frazer, 2006). It is integral to African societies (Bas, 1989) and can be considered as a cultural interactive learning and knowledge accumulation process where business practices and skills are embedded into younger apprentices. It is shown to be most prevalent in West Africa (Velenchik, 1995). Teal et al. (2008) found apprenticeships to provide socio-economic benefits for a large pool of young people, helping them obtain jobs with which to earn a living (and indeed often support an entire family). The mostly practical knowledge and skills provided in the apprenticeship system can help solve many local problems that confront Africa today.[11] Kawooya (2014) also found several examples of informal artisans to have developed specific technical skills for solving problems, skills that those with formal-sector training lack.

In Ghana, the share of apprentices in the labour force is about 25% (Teal et al., 2008). Statistics cited in Frazer (2006, p. 263) also put the percentage of entrepreneurs in the manufacturing sector of Ghana who had gone through apprenticeship at 55.6%. Apprenticeship therefore remains widespread, and typically involves training in a particular enterprise and/or skill, using specific business practices and/or a unique technology, over a specified period of time (Frazer, 2006; Teal et al., 2008), usually four years.[12] The institution of apprenticeship is important for small enterprises (Velenchik, 1995), but also serves as a support mechanism for family, relatives and friends in both economic and social terms. By providing prospects for young people to acquire practical market skills and knowledge, apprenticeship creates livelihood opportunities.

Today, despite the expansion of formal and vocational education, and the perception that it is for the less intelligent, apprenticeship as a cultural system of training persists and remains relevant in transmission of skills at low cost (Bas, 1989). Formal technical and vocational institutions are criticised for their theoretical approach and failure to transfer comprehensive knowledge and relevant skills for the local context (Bas, 1989; Frazer, 2006). Apprenticeship, however, has been found to be practical and less theoretical (Frazer, 2006; Kawooya, 2014; Bas, 1989), and found to

teach business and customer practices such as bargaining, buying and selling, social skills, etc. relevant for enterprises (Bas, 1989). Apprenticeship institution seems to know and understand the perculiar nature of demand, technologies and the learning required for solving local problems. Examples can be cited from Kawooya (2014), where he found that informal artisans had specific technical skills for solving problems that are even lacking in the formal sector.

Despite the importance of apprenticeship in Africa, its significance is often neglected in the economic literature (Velenchik, 1995; Frazer, 2006; Teal et al., 2008). Studying apprenticeship contracts, small enterprises, and credit markets, in manufacturing enterprises in Ghana, Velenchik (1995) found apprenticeship to be widespread and critical in transferring entrepreneurial skills. Velenchik (1995) also found apprenticeship to be a critical source of capital for enterprises, particularly financially constrained enterprises with limited access to financial markets. In the context of manufacturing enterprises, Frazer (2006) formulated a theoretical framework, based largely on Becker (1962), examining apprenticeship and the remuneration of the apprenticed in Ghana. Applying data to the model and using two groups of apprentices as 'self-employed former apprentices and employee former apprentices', the author found employee former apprentices to be more productive than apprenticed workers trained from elsewhere, emphasising the importance of the specific nature of the knowledge acquired from apprenticeship (Frazer, 2006).

While these studies advance our understanding, the role apprenticeship plays in generating new products in informal enterprises remain thin in the literature. Studies by Kawooya (2014), and McDade and Malecki (1996) found evidence of apprenticeship as a learning process for innovation in informal enterprises in SSA. Their evidence, however, remains descriptive. In an empirical study, Gebreeyesus and Mohnen (2013) found insignificant effect of on-the-job training and practical experience (defined as average monthly tenure of workers) on the intensity of innovation in a cluster of informal enterprises in Addis Ababa, Ethiopia.

In sum, the available evidence suggests that apprenticeship enhances the internal capabilities of enterprises. Based on the foregoing and the evidence that improvements in the internal capabilities of enterprises improve innovative activity (Cohen and Levinthal, 1990), we state our first hypothesis as:

H1. Informal enterprises in urban Ghana with higher number of apprentices tend to undertake and perform better with product innovative activities.

2.2.2 Formal interaction and Informal Innovations in SSA

The literature establishing innovation as an outcome of complex, systemic interactions between actors is ample and well advanced (see, among others, Lundval, 1988; Fu et al., 2013). Networks, interactions and relations between firms, research institutions and government agencies, among others, serve as a conduit through which knowledge flows. The knowledge transfer occuring through collaborative and competitive interactions can be accumulated, transferred and adapted to improve the production processes of the firm. The learning process that occurs through these interactions is known to generate knowledge fundamental for innovation (Lundvall, 1988; Murphy, 2002; Hausman, 2005; Kraemer-Mbula and Wamae, 2010c; Legros and Galia, 2011; Fu et al., 2013).

Despite, the interaction between actors is found to be generally weak in SSA's innovation system (McCormick and Atieno, 2002; Oyelaran-Oyeyinka and Lal, 2006; Kraemer-Mbula and Wamae, 2010b). A plethora of evidence, however, exists indicating the importance of interactions in SSA (see Dawson, 1992; McDade and Malecki, 1997; Barr, 1999; McCormick and Atieno, 2002; Murphy, 2002; Van Dijk, 2002; Mahemba and Bruijn, 2003). Empirical studies show that interactions between firms are particularly important for innovation (Murphy, 2002; Goedhuys, 2007; Robson et al., 2009). Using data sets from firms in Tanzania, for example, Goedhuys (2007) analysis the effect of different learning mechanisms on the product innovation of local- and foreign-owned firms. The author finds intensive collaboration to be a critical learning mechanism driving product innovation, particularly in local firms in Tanzania. Comparing the effect of local collaboration between locally-owned firms, on the one hand, and foreign-owned firms, on the other hand, Goedhuys (2007) finds that local collaborations drive product innovations in locally-owned firms. Similar conclusions, based on primary data were also found by Murphy (2002) in Mwanza, Tanzania.

The available empirical evidence in SSA, however, largely fails to consider formal interactions. Recent evidence in SSA reveals the nature of formal interactions to be 'highly complex' and 'symbiotic' (Kawooya, 2014). For instance, a recent case study conducted by Kawooya (2014) on the Gatsby Garage (a registered entity) of the Makerere University College of Engineering, Design, Art and Technology (CEDAT) in Kampala, Uganda, confirmed formal interaction as a critical mechanism resulting in innovation in formal enterprises. Gebreeyesus and Mohnen (2013) also found results confirming the interactive nature of innovation in informal clusters in Addis Ababa.

These authors found small and informal firms with dense networks (measured as the number of suppliers, buyers and competitors that firms engage with in terms of exchange of information and experience) to have a more statistically positive probability of introducing innovation.

First-hand experiences of the symbiotic nature of formal interactions were realised during our field survey. We found during the fieldwork that interactions between formal and informal enterprises were highly structured and transcend supply interactions. The interactions were also sometimes complementary, and took forms like sub-contracts where formal enterprises hire informal enterprises to provide specific services. During these interactions, informal enterprises learn of some new designs that are often later incorporated into their products, leading to innovations. While these relationships exist in many other forms in SSA, the empirical analysis of the effects of these complex interactions (co-operative and competitive) as a conduit for knowledge and innovations in informal enterprises remain missing in the empirical literature.

Based on the foregoing discussion of the role of formal interactions on innovation, we propose the second hypothesis:

H2. Formal interaction in urban Ghana positively affects innovations in informal enterprises.

In highly concentrated markets where a few large firms dominate, incentives to innovate tend to be low as new products are easily imitated (Aghion et al., 2005; Hausman, 2005; Sorescu et al., 2003). As a result, market leaders may collaborate and use 'laggard' firms as channels for distribution. Empirical evidence indicates that 'channel relationships' between large and small firms exist and are used as a medium by the former to influence the innovativeness of the latter (Hausman, 2005). For example, some retailers indicated during the survey that their suppliers specifically prevented them from expanding their product range to competitive and non-competitive products on the side. The inability to diversify the range of products sold by small firms reduces their innovativeness (Hausman, 2005). On the other hand, markets in which firms are 'neck-and-neck' tend to be more competitive, leading to greater innovativeness as new innovations provide the incumbent with some competitive urge, the so-called 'escape competition effect' (Aghion et al., 2005; Hausman, 2005).

The foregoing suggests that informal enterprises with collaborative formal interactions operate in 'laggard-lead' firm markets and tend to have low incentives to innovate, while enterprises with

competitive formal interactions operate in 'neck-to-neck' markets where firms innovate to escape competition. These lead to the following hypotheses:

H3a. Informal enterprises in urban Ghana with competitive formal interactions tend to be more innovative than otherwise.
H3b. Informal enterprises in urban Ghana with collaborative formal interactions tend to be less innovative than otherwise.

3. Methodology

3.1 Empirical Model

The objective in this paper is to test how learning processes affect the innovation activities of informal enterprises. This section presents the model used in the analyses. We formulate separate econometric frameworks for each variable of interest, as described below.

3.1.1 Formal Interaction Equation

The definition of formal interaction in the context of this paper refers to informal enterprises that had a form of relationship with at least one registered enterprise over the last 3 fiscal years from 2013 to 2015. Formal interaction is hence a dummy variable.[13] We proceed accordingly to specify a probit model as:

$$Formal\ Interaction_i^* = z_i\ \delta_1 + \sigma_i \quad (1.1)$$

$$Formal\ Interaction_i = \{^{1\ if Formal\ Interaction_i^*=1}_{Otherwise} \quad (1.2)$$

where $Formal\ Interaction_i^*$ is a latent variable indicating whether enterprise i has any form of interaction with the formal economy, and z_i is a vector of enterprise, location, and industry-specific covariates that affect the interaction status of an enterprise. $Formal\ Interaction_i$ is a dummy variable with 1 indicating that an enterprise has an interaction with the formal economy and 0 indicating otherwise.

Enterprise-specific characteristics in z_i are a set of exogenous variables, including dummies, capturing whether the (informal) enterprise would like to formalise ('formal'), and whether lack of access to finance is a major obstacle to the business ('lack of access to finance'). 'Formal' is a dummy variable capturing whether the enterprise would like to formalise or otherwise. The variables 'formal' and 'lack of access to finance' are believed to be positive determinants of formal interaction: enterprises with the desire to formalise in the future are more likely to make alliances

with formal businesses than their 'informal' counterparts are. Enterprises with financial constraints are also more likely to form strategic links with formal businesses, in order to expand their credit options.

3.1.2 Apprenticeship Equation

In order to explore apprenticeship as a learning process, our survey asked respondents how many apprentices were in the enterprise in both 2013 and 2015. Measuring apprenticeship as the logarithm of the total number of apprentices in 2013, we formulated a log-linear regression model as:

$$Apprenticeship_i = x_i \ \delta_4 + \varepsilon_i \quad (2)$$

where $Apprenticeship_i$ is a continuous variable indicating the logarithm[14] of the total number of apprentices in the enterprise in 2013, and x_i refers to a vector of firm, location, and industry-specific covariates that affect apprenticeship in an enterprise. δ_4 is a vector of parameters to be estimated. ε_i term is a multivariate normally distributed error term.

Firm-specific covariates in x_i are motivated by Velenchik (1995) and Teal et al. (2008). In addition, we also introduced covariates such as 'formal' and 'apprenticed owner'. Enterprises that hope to formalise in the future may tend to train more apprentices as a transition mechanism, while enterprises owned by former apprentices ('apprenticed owner') may tend to be more involved in apprenticeship.

3.1.3 Innovation Equation

Several definitions of 'product innovation' exist in the literature. In this paper, product innovation is defined broadly following the Oslo Manual (see OECD and Eurostat, 2005: para. 156). Following Van Dijk and Sandee (2002), the study further broadened the Oslo Manual definition to capture the local understanding of product innovation in terms of: new or significant changes to product design; new pricing strategies; introducing completely new product stock; and new service delivery methods.[15] During the survey, respondents were asked extensive questions on product innovation. Enterprises were first asked if they introduced new or significantly improved products between 2013 and 2015 (The response to this question is either a yes or a no). Product-innovative enterprises were then asked to estimate the percentage of total sales from all innovative products introduced from fiscal years 2013–2015.

Based on this question, we followed Legros and Galia (2011), and Mairesse and Mohnen (2002) to construct the performance variable, 'Performance Innovation', defined as the logarithm of the share of real total sales per worker in 2015 due to product innovation.

Because of possible selection problems resulting from the survey design (see Mairesse and Mohnen, 2002), we proceed by following Legros and Galia (2011), and Mairesse and Mohnen (2002) to formulate a Type II Tobit model as:

Selection equation

$$Innovation_i^* = Apprenticeship_i\ \delta_5 + Formal\ Interaction_i \delta_6 + M_i \delta_7 + \rho_i \quad (3.1)$$

$$Innovation_i = \{^{1\ if\ Innovation_i^*=1}_{Otherwise} \quad (3.2)$$

Regression Equation

$$Performance\_Innovation_i = Apprenticeship_i \delta_8 + Formal\ Interaction_i \delta_9 + Q_i\ \delta_{10} + \mathcal{E}_i \quad (3.3)$$

where $Innovation_i^*$ is a latent variable indicating whether enterprise i introduced product innovation over the period 2013-2015. $Innovation_i$ is a dummy variable taking the value 1 if the enterprise innovated, and zero otherwise. $Performance\_Innovation_i$ is the log share of real total sales per worker in 2015 due to product innovation. $\rho_i\ and\ \mathcal{E}_i$ are multivariate normally distributed error terms. In line with Classen, Carree, Van Gils and Peters (2014), Gebreeyesus and Mohnen (2013), and Robson et al. (2009), M_i and Q_i are vectors of enterprise, location and industry-specific covariates that may affect respectively the innovation status and the performance of product innovations of an enterprise. In both the innovation and performance of innovation equations, we specifically included dummies indicating whether the owner of the enterprise was a former apprentice, and whether the enterprise lacked access to finance. Innovation is a costly process and access to finance has been found to be important for firm innovation (see, for example, Ayyagari, Demirgüç-Kunt, and Maksimovic, 2011). We, therefore, expect enterprises that have financial constraints to be less innovative and perform worse in terms of innovative sales.

3.2 Econometric Issues and Estimation Strategy

The decision to innovate is known to be non-random (Avenyo et al., 2019; Mairesse and Mohnen, 2002). Also, innovation activities are affected by a plethora of factors, and often only a fraction of firms innovate. The fact that only a fraction of enterprises actually innovate is confirmed in Table

1 (in section 3.3.1) where 27% of the sampled enterprises did not introduce any product innovation. To test for possible selection bias, we estimated equations (3.1) to (3.3) using two procedures: the Heckman two-step approach (see Heckman, 1979), and the Conditional Mixed Process (CMP) with selection (see Roodman, 2011). The Heckman procedure estimates the innovation equations in two steps to correct for possible selection bias in innovation performance, while CMP conducts a joint estimation of both the selection and regression equations. Estimation results are shown in Columns 1 and 2 of Table 2 (see Section 4). Results from both models indicate no problem of selection bias in the data.[16]

Formal interaction may be associated with the disturbance term (Gebreeyesus and Mohnen, 2013), and this may also be the case for apprenticeship (Teal et al., 2008). To test for possible endogeneity of the main regressors, we estimated using a two-step procedure, as in Cohen and Levinthal (1989), and Gebreeyesus and Mohnen (2013). In the first approach, we separately estimated probit and linear regression models on right-hand side variables, in addition to a set of explanatory variables deemed to affect formal interaction and apprenticeship respectively. Residuals from the first stage regressions were obtained and used as additional explanatory variables in each innovation equation. Bootstrapping standard errors in the second-stage estimations, we found the residuals from the first stage to be highly insignificant, indicating exogeneity of the main regressors- formal interaction and apprenticeship- in both innovation equations. This is an indication that we did not have a problem of unobservables.

However, typically distributed disturbance terms from separate unrelated equations (in this case, the innovation equations) 'can be correlated' (Roodman, 2011). We, therefore, proceeded by formulating the innovation equations into a system of equations with apprenticeship and interactions simultaneously explaining innovation. We followed Gebreeyesus and Mohnen (2013) to conduct a joint and simultaneous estimation, allowing for correlation of errors between all equations in CMP. The joint estimation approach, where disturbance terms from all equations share a 'multidimensional distribution', is found to offer efficiency advantages (Roodman, 2011: p. 168). The results from the joint estimation of the system of equations are shown in Columns 3 and 4 of Table 2. The results indicate a positive and strong significant correlation between error terms of the two innovation equations, indicating the appropriateness of the joint estimation approach. As a result, we proceeded to jointly estimate all models in CMP, allowing for free correlation of error terms between equations (3.1-3.3) in Maximum Likelihood (ML). The

estimation of the Type II Tobit model using maximum likelihood generates more efficient estimates than those obtained from the Heckman selection models (Amemiya, 1985).

3.3 Data

3.3.1 Description of Data

The paper uses a unique enterprise-level data collected on 513 non-farm, informal enterprises in urban Ghana, specifically Accra and Tema, in May and June 2016. Using zones identified in the World Bank's Ghana Informal Enterprise Survey (IFS) as 'area-based frames' at the first stage, the survey randomly selected 17 zones in both urban centres - nine zones from Accra and eight from Tema. These IFS-constructed zones were used due to the lack of sampling frame, and also because using the existing zones offered research-design advantages such as coverage of informal units, and time-effectiveness, thereby helping to minimise sampling errors. Our second stage of sampling involved the 'canvassing' of each selected zone, where we asked screening questions relating to details such as the registration status of the enterprise, in order to identify informal enterprises. Face-to-face interviews were conducted, based on survey recommendations by Charmes et al. (2016), with owners/care-takers using a standard semi-structured questionnaire.[17] This approach enabled the team to identify and gather data on the small informal units that are often ignored in larger surveys (International Labour Organization, 2013). Our focus was on the innovation activities of enterprises in the three-year period between 2013 and 2015.[18]

Table 1 presents some descriptive statistics from the data.[19] Out of the 513 enterprises interviewed, 337 firms (representing about 66%) were microenterprises-defined as enterprises with fewer than five workers (owner inclusive). The distribution also shows that 167 enterprises (32%) were small enterprises (5 to 10). Nine enterprises (about 2% of interviewed enterprises) were medium in size (10 to 20). Innovations were prevalent in the sampled enterprises, with 374 enterprises (about 73%) having introduced product innovations. The average percentage sales from all product innovations were about 20 percent.

Apprenticeships were found to be surprisingly few in the sample, with only about 16.2% of enterprises training apprentices in 2013. Apprenticeship was most prevalent among medium-sized enterprises, with about 33% of medium-sized enterprises training apprentices in 2013. Relatedly, the number of apprentices in MSEs was rather small, at about 14% and 19% respectively. This may be due to the low skill levels required to run some of these businesses or because of a lack of time resources to mentor other employees. This may also be, as found by Velenchik (1995),

because larger enterprises tend to provide significant levels of benefits to apprentices, compared with smaller enterprises.[20] Most importantly, the data indicated that apprentices served as a source of innovative ideas across all enterprises. Out of the 83 enterprises that had apprentices, nearly 60% indicated that their apprentices were a *source* of their innovative ideas. This is an indication that apprentices are important for innovation activities in informal enterprises.

Table 1: Description of Data

	ALL	**Micro**	**Small**	**Medium**
Number of enterprises surveyed	513	337	167	9
Product innovation				
No. of all firms	513	337	167	9
Innovators	372	215	149	8
Non-innovators	141	122	18	1
Sales from all product innovations (Mean %)	19.52	23.19	14.33	17.38
City of enterprise				
Accra	317	213	98	6
Tema	196	124	69	3
Sector of enterprise				
Manufacturing	49	34	13	2
Services	464	303	154	7
Formal interaction				
Yes	258	177	74	7
No	255	160	93	2
Type of formal interaction				
Compete	218	147	64	7
Collaborate	74	55	16	3
Type of interaction by innovative enterprise				
Compete	168	103	59	6
Collaborate	38	25	10	3
Apprenticeship				
Yes	83	48	32	3
No	430	289	135	6
Number of apprentices (Mean)	0.19	0.04	0.41	1.78
Apprentices, source of innovative ideas				
Yes	49	27	20	2
No	34	21	12	1

There are approximately equal numbers of enterprises engaged in formal interaction in the sample. Just over half of the enterprises interviewed indicated some form of relationship with the formal sector. This is consistent with the findings of Kraemer-Mbula (2016), who found 52% of sampled informal enterprises had no form of interaction with formal enterprises. This is an indication that informal enterprises do indeed interact with formal enterprises, at roughly equal rates. Enterprises were then asked to indicate the specific types of interactions they have with formal enterprises. The findings indicated that enterprises were mainly engaged in competitive formal interactions: 218 sampled enterprises indicated competitive interactions with formal enterprises, compared with

74 enterprises having collaborative interactions. This is an indication of weak collaborative interactions. An explanation may be that people running informal enterprises mostly prefer to collaborate with those running other informal enterprises, due to proximity, similarity of products and prices of products.

Finally, Table 1 also shows the locational, sectoral and ownership distributions found from the survey. The surveyed informal enterprises were mainly engaged in the service sector. Indeed, the vast majority of enterprises (about 90.45%) in the data were involved in the selling of goods or services, while only 9.55% were involved in manufacturing.

4. Empirical Results and Discussion

4.1 Main Results

This section presents and discusses the regression results examining the effects of apprenticeship and formal interactions, with extensions to collaborations and competition interactions, on the introduction and performance of product innovations in urban Ghana. Column 3 of Table 2 below is our preferred model, and it presents estimation outputs from the joint estimation of all four equations: product innovation, performance of product innovation, formal interaction, and apprenticeship equations.[21]

The results are consistent across all estimation procedures. The results (Column 3) show a strong positive effect of apprenticeship on the likelihood of introducing product innovation and on the performance of product innovation. In other words, informal enterprises with a higher number of apprentices were more likely to introduce product innovations onto the market. This effect was found to be monotonic: the higher the number of apprentices, the higher the probability of introducing product innovation. These enterprises also sold more of their innovative products per worker. In the course of apprenticeship, knowledge exchange occurs. The exchange of knowledge improves the internal absorptive capacity of enterprises and may enable enterprises to identify, imitate and transform knowledge into new or significantly improved goods and services. An apprentice-in-training also provides a free labour resource, and in some cases, financial resource, to the enterprise (Velenchik, 1995). These resources free up other resources of the enterprise, so the higher the number of apprentices, the higher the capacity of the enterprise to venture into doing new things that may result in product innovation, and in higher sales. The findings hence support hypothesis 1.

The results (Column 3) also indicate a strong positive effect of formal interaction on both product innovation performance and the probability to introduce product innovation, in line with our expectations. Specifically, informal enterprises with ties in the formal economy tended, on average, to have a higher probability of introducing product innovations. The results also show that innovative enterprises with formal-sector connections performed better in terms of sales of their innovative products per worker, compared to enterprises that did not have formal connections. This finding is consistent with evidence from the empirical literature in SSA, where various authors have also found that firms with dense networks tend to have a higher tendency to innovate. That is, local business interactions matter for innovation (Gebreeyesus and Mohnen, 2013; Robson et al., 2009). The results strongly support hypothesis 2, suggesting that formal interactions, on average, enhance the innovation process of informal enterprises.

To understand the relationship between product and process innovations, as well as to explore the robustness of the results, we extend the innovation variable to technological innovations (TPP) where the introduction of innovation refers to enterprises that have introduced product and/or process innovations. The results shown in Column 4 of Table 2 indicate the same conclusions as those resulting from product innovation, with formal interaction having a strong positive effect on both the performance of innovation and the probability of introducing technological innovations, while enterprises with higher a number of apprentices tended to have a higher likelihood of introducing product innovation. Enterprises with a higher number of apprentices also tended to have a higher probability of introducing product innovations and generate higher sales from innovative products.

Other significant covariates in the full model (Column 3 in Table 2) include, among others, real total sales, crime, access to finance, imitating formal firms, and firm marketing. The market size of the enterprise is critical for the performance of new products. Using real total sales (logged and lagged by three years) as a proxy for the market power of the enterprise, the results indicate that enterprises with larger market share sold more newly innovated products. However, it was found that market power had no significant effect on the probability of the enterprise introducing new products onto the market. Enterprises with financial constraints, as well as enterprises whose activities were hampered by crime, were found to sell fewer new products. Financially constrained enterprises also tended to have less probability of introducing product innovations onto the market.

Table 2: Effect of Interaction and Apprenticeship on Product Innovation Performance

Estimation method	Heckman two-step	Selection FIML[b]	Simultaneous equation FIML[b]	
	(1)	(2)	(3)	(4)
Performance of innovation				
Number of apprentice (log)	0.101	0.094	1.071***	2.446***
	(0.155)	(0.137)	(0.229)	(0.315)
Formal interaction	0.145	0.150	1.857***	2.891***
	(0.105)	(0.102)	(0.196)	(0.205)
Family business	0.092	0.091	0.055	0.058
	(0.128)	(0.108)	(0.219)	(0.220)
Real total sales_2013 (log)	0.763***	0.762***	0.341***	0.337***
	(0.043)	(0.045)	(0.067)	(0.077)
Crime	–0.284**	–0.251**	–0.505**	–0.365
	(0.136)	(0.114)	(0.208)	(0.242)
Lack of access to finance	–0.349***	–0.354***	–0.425**	–0.638***
	(0.116)	(0.114)	(0.210)	(0.243)
Apprenticed owner	–0.176	–0.184	–0.451**	–0.879***
	(0.143)	(0.134)	(0.222)	(0.229)
Number of innovations	0.021	0.021	0.097***	0.134***
	(0.017)	(0.016)	(0.026)	(0.027)
Imitate formal sector	0.232	0.231*	0.555***	0.308
	(0.168)	(0.122)	(0.186)	(0.290)
Firm marketing	0.543***	0.543***	0.617**	0.687**
	(0.184)	(0.201)	(0.275)	(0.344)
	Product innovation[a]			**TPP[a]**
Number of apprentice (log)	0.135	0.124	1.993***	2.455***
	(0.288)	(0.267)	(0.170)	(0.239)
Formal interaction	0.004	0.003	1.014***	1.083***
	(0.139)	(0.136)	(0.072)	(0.068)
Family business	0.002	0.001	0.180	0.111
	(0.174)	(0.169)	(0.111)	(0.105)
Real total sales_2013 (log)	0.009	0.011	0.023	0.017
	(0.043)	(0.040)	(0.033)	(0.032)
Crime	–0.337**	–0.346**	–0.068	–0.126
	(0.150)	(0.147)	(0.114)	(0.121)
Lack of access to finance	0.027	0.043	–0.428***	–0.307**
	(0.150)	(0.150)	(0.129)	(0.121)
Apprenticed owner	0.063	0.079	–0.389***	–0.571***
	(0.186)	(0.183)	(0.116)	(0.125)
Mills-lambda (prob.)	0.282 (0.637)			
sig_1		0. .924***	2.12***	2.45***
sig_4			0.289***	0.290***
rho_12		0. .020	0.812***	0.790***
N	499	499	499	499
Wald chi^2	549.68***	866.50***	3156.71***	1878.40***

Notes: Robust standard errors in parentheses. [a]The reported estimates are probit regression coefficients. [b]Full-information maximum likelihood. Used CMP Stata package for FIML estimations. All regressions include 22 zones, firm size, sector, city, and ownership dummies. TPP refers to technological product and process innovation. * p < 0.10, ** p < 0.05, *** p < 0.01.

These findings are consistent with the literature and may be explained by the reluctance of formal financial institutions to advance loans and credit to micro- (and particularly informal) enterprises. This finding, however, remains surprising given the rapid growth of the informal financial market and informal sources of finance and credit in developing countries. The innovative process is known to be costly, and, as a result, abnormally high interest rates on loans and credit may imply a lack of financial resources for innovation. Informal enterprises with imitated innovations perform better in sales than enterprises that do not. Enterprises owned by former apprentices tend to have a lower probability of introducing product innovations, and also tend to perform less well in terms of sales of innovative products. This may be because these owners tend to be conservative regarding new ideas, and the adoption and adaptation of new technologies. As a result, they tend to reject new designs and new products, thus leading to less innovation. The marketing of firms' products helps to make those products visible, and this enhances sales of new products. This is indicated by the results showing that enterprises that undertake marketing perform better, on average, in sales of new products.

4.2 Extension to Types of Formal Interaction

According to Hausman (2005), the specific type of interaction matters for innovations in small businesses. We extend the analyses by decomposing formal interaction into competitive and collaborative interactions, in order to analyse their separate effects on product innovation performance. Table 3 below shows the estimation results from the baseline estimation to the full model, where we introduced interactions to capture possible indirect mechanisms. The results from the full model, shown in Column 1 of Table 3, indicate a strong positive effect of competitive formal interaction on the performance of product innovation, in support of hypothesis 3a. That is, informal enterprises that competed with formal enterprises in product markets were more likely to introduce innovations and perform better in terms of sales in the face of formal competition.

This result may be explained by the fact that informal enterprises have some basic understanding of what sells and what does not sell, particularly in local product markets. This basic understanding of the domestic market niche, in addition to the low cost of production due to the use of local resources, close customer relations, and the ability to adapt easily to the changing demands of consumers (particularly at the bottom of the pyramid through new, cheaper products), may provide an incentive and a valuable competitive advantage for informal enterprises. This result is in line with Dawson, (1992), Legros and Galia (2011), Kraemer-Mbula (2016), and Avenyo et al.

(2020) but it is contrary to Mahemba and Bruijn (2003), who found market competition to have no significant effect on the innovation activities of enterprises.

Collaborative interactions are found to be important for small enterprises that often require supplies of goods and services on credit (Mahemba and Bruijn, 2003). The majority of enterprises in the sample acknowledged access to finance as a major obstacle to their business. Collaborative formal interaction, as a result, is expected to be very useful for innovation activities of informal enterprises. The results, however, indicated that informal enterprises with collaborative footholds in the formal economy tended to have a lower probability of introducing product innovations than enterprises without this type of interaction, in strong support of hypothesis 3b. This result is contrary to Fitjar and Rodríguez-Pose (2013), who found collaboration to matter for firms in Norway. The difference in our results may be explained by our analysis of collaboration between formal and informal enterprises, while Fitjar and Rodríguez-Pose (2013) considers collaboration between formal entities.

In addition, the results show that enterprises owned by families tend, on average, to have a higher probability of introducing product innovations, even when other factors were held constant. This is practical in the context, as family businesses may have more resources available for innovation than enterprises with sole owners. We also analysed possible indirect mechanisms that might affect the innovation variables by introducing an interaction term in Column 2 of Table 3 above. The results show that enterprises that had competitive interactions and considered access to finance as an obstacle tended to perform less well in terms of sales per worker and in product innovations than their counterparts that competed without financial constraints. That is, financially constrained informal enterprises that competed with formal enterprises in product markets tended to perform poorly with their new products, compared to their counterparts who were not financially constrained. This may be explained by the bias against informal enterprises in the financial market. It may also indicate the strong financial capability required for informal enterprises to compete with formal enterprises.

Table 3: Effect of Competition, Collaboration and Apprenticeship on Product Innovation Performance

Estimation method	**Full-information maximum likelihood (FIML)**	
	(1)	(2)
	Performance of innovation	
Number of apprentice (log)	1.964***	1.921***
	(0.577)	(0.558)
Type of formal interaction		
Compete	3.154***	3.571***
	(0.378)	(0.478)
Collaborate	–1.886***	–1.926***
	(0.621)	(0.663)
Family business	0.141	0.107
	(0.235)	(0.233)
Real total sales_2013 (log)	0.384***	0.388***
	(0.077)	(0.079)
Crime	–0.056	–0.048
	(0.252)	(0.256)
Lack of access to finance	–0.526**	–0.296
	(0.254)	(0.270)
Apprenticed owner	–0.205	–0.212
	(0.228)	(0.243)
Number of innovations	0.101***	0.101***
	(0.022)	(0.023)
Imitate formal sector	0.258	0.247
	(0.236)	(0.239)
Firm marketing	0.509*	0.504*
	(0.269)	(0.265)
Compete* Lack of access to finance		–0.558*
		(0.292)
	Product innovation[a]	
Number of apprentice (log)	2.195***	2.182***
	(0.538)	(0.525)
Type of formal interaction		
Competitive	1.045***	1.058***
	(0.203)	(0.210)
Collaboration	–0.672***	–0.679***
	(0.257)	(0.255)
Family business	0.229**	0.224**
	(0.103)	(0.104)
Real total sales_2013 (log)	0.042	0.042
	(0.031)	(0.033)
Crime	–0.146	–0.136
	(0.125)	(0.125)
Lack of access to finance	–0.362***	–0.349***
	(0.110)	(0.110)
Apprenticed owner	–0.219*	–0.216*
	(0.130)	(0.130)
sig_1	2.451***	2.490***
sig_4	0.292***	0.291***
rho_12	0.860***	0.857***

N	499	499
Wald chi^2	2538.21***	2676.81***

Notes: Robust standard errors in parentheses. FIML estimation used CMP Stata package. [a]The reported estimates are probit regression coefficients. All regressions include 22 zones, firm size, sector, city, and ownership dummies. * p < 0.10, ** p < 0.05, *** p < 0.01.

5. Conclusions

Learning generates positive economy-wide externalities. Despite the economic significance of informal enterprises, their learning activities, and the evidence of widespread incremental informal innovations, empirical studies examining the relationship between learning and the innovation activities of informal enterprises remain relatively scarce in sub-Saharan Africa (SSA). This paper examines the roles that two learning processes- apprenticeship and formal interactions- play on the innovation performance of informal enterprises.

Employing a unique survey data on 513 enterprises in urban Ghana, and estimating Type II Tobit model, the results show that formal interaction on the one hand, and apprenticeship on the other hand, are significant and positive determinants of innovation in informal enterprises. Analysing the types of formal interactions, the results also show that competitive interactions with the formal sector tend to enhance the likelihood of innovations, while collaborative interactions with the formal sector tend to inhibit innovations in informal enterprises. These results suggest that apprenticeship improves the technological capabilities of informal enterprises to create, adapt, and transform knowledge into new or significantly improved goods and services. In addition, informal enterprises with competitive formal interactions tend to have a better understanding of the domestic market in which they operate and are able to quickly adapt to changing demands of their consumers through new, comparatively cheaper products that sell easily in local product markets. The evidence also suggests that informal enterprises with formal-sector partners target upscale product markets and as a result, are less likely to be product innovators themselves.

These results have several implications for innovation policy in SSA. Evidence exists in the literature indicating the integral role of the informal economy in SSA, and that suppressing informal activities through laws - and, in recent years, through policy pushes toward 'formalisation' - are unlikely to be beneficial. Based on these results, there appears to be a need for novel policy directions in order to promote and enhance the vibrant enabling environment in which learning processes and local institutions incubate knowledge for innovations in informal enterprises.

Policies aimed at promoting interactions between formal and informal enterprises, for example, may help to nurture and more fully capture the value of these learning processes for innovation.

The analyses presented in this paper could be extended in several ways. Due to data limitations, the paper was not able to consider different types of apprenticeship contracts and forms of apprenticeship. It would be insightful for future research to consider the effects of specific apprenticeship contracts, and specific apprenticeship forms on the innovation activities of informal enterprises. Future research could also explore the extent to which variations in the degrees of informal enterprises' interactions, and the number of and frequency of interactions with formal entities affect innovation activities by the informal enterprises.

[1] Malerba (1992) identified and summarised learning processes (internal and external) into six taxonomies (p. 848). This is further discussed in the literature review section.

[2] The learning and innovation modes literature recognises that there is little evidence on the effect of 'Doing, Using and Interacting' mode (DUI-mode) of learning on the innovative performance of enterprises (see Jensen, et al., 2007; Apanasovich, et al,. 2016; among others), and we argue that this is more so for informal enterprises.

[3]Related studies are Gebreeyesus and Mohnen (2013) who studied the effect of network size in an Ethiopian footwear cluster on the intensity of innovations, and Kawooya (2014) who analysed the effects of formal-informal interactions on the innovative activities of formal enterprises in Uganda.

[4] The ILO (2018) statistics shows that the informal economy contributes about 70% of total employment in developing countries, and about 86% of employment in Africa.

[5] The only known exceptions include Velenchik (1995); Frazer (2006); Breyer (2006); Teal, Monk, and Sandefur (2008); Nubler, Hofmann, and Greiner (2009); and Aggarwal, Hofmann, and Phiri (2010).

[6] This is in exception to Gebreeyesus and Mohnen (2013); and Kawooya (2014).

[7] Learning-by-doing is defined as a process in which enterprises learn and practice to do better and more 'efficiently' what they already, in some degree, know how to do (Cohen and Levinthal, 1989, p. 570).

[8] Bas (1989) refers to apprenticeship in Africa as 'pure on-the-job-training' (p. 485).

[9] See Kraemer-Mbula and Wamae (2010b), and De Beer et al. (2013) for review of informal innovations in sub-Saharan Africa.

[10] Jensen, et al. (2007) identified these DUI-modes of learning as important for innovation.

[11] See Bas (1989), Velenchik (1995), Frazer (2006), and Teal et al. (2008) for deeper perspectives on apprenticeship in a developing-country context.

[12] In Germany, for instance, apprenticeship or on-the-job-training is found to be general; that is, skills learnt are not firm specific and are regulated by a formal agency (see Acemoglu and Pischke (1998)).

[13] Variations in the degree and content of interactions are recognised in the literature in SSA (see for example Gebreeyesus and Mohnen, 2013). Unlike these authors, we are unable to analyse the heterogeneity in the degree of interactions across enterprises due to data limitations.

[14] Logarithms are used to compress the scale.

[15] The definition was broadened after piloting the survey instrument.

[16] This conclusion is derived from the insignificance of both the inverse Mills Ratio - lambda from the Heckman model (Column 1) and rho_12 from the CMP model (Column 2).

[17] The survey instrument was prepared with reference to the guidelines of the Oslo Manual (3rd edition), with some adaptations based on similar projects such as the NEPAD-ASTII survey; the World Bank's IFS; the WIPO project; the DILIC project (Fu et al., 2014). The instrument covered a host of issues including total sales of products of the enterprise, costs of labour and raw materials, formal interaction and innovation activities.

[18] See Avenyo (2018) and Avenyo et al. (2021) for detailed description of the survey methodology and data.

[20] See Appendix A for definition and construction of all variables.

[20] These advantages may take several forms, such as provision of allowances, networking, etc.

[21] See Appendix B for estimation outputs for formal interaction and apprenticeship.

Conflict of interest statement:

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Appendices

Appendix A

Table 4: Definition and Construction of Variables

Variable name	Definition and construction
Product innovation	A binary variable taking the value of 1 if the enterprise has introduced product innovation over the last 3 fiscal years, and 0 if otherwise.
Performance of innovation	A continuous variable indicating the log share of product innovations in real total sales per worker. It is constructed as the share of total 2015 sales due to product innovations, deflated using implicit deflators from United Nations System of Accounts with base year 2005. Then the logarithm of real total sales due to product innovation is divided by the total number of workers in 2015.
TPP innovation	A binary variable taking the value of 1 if the enterprise has introduced either product or process innovations over the last 3 fiscal years, and 0 if otherwise.
Real total sales 2013 (log)	Constructed as the difference in the logarithm of deflated total sales of output in 2015 minus the logarithm of deflated total sales of output in 2013. Sales are deflated using implicit deflators from United Nations System of Accounts with base year 2005.
Formal interaction	A binary variable taking the value of 1 if the enterprise has any form of relationship with registered enterprises over the last 3 fiscal years, and 0 if otherwise.
Compete	A binary variable taking the value of 1 if the enterprise has a competitive relationship with registered enterprises over the last 3 fiscal years, and 0 if otherwise.
Collaborate	A binary variable taking the value of 1 if the enterprise has a collaborative relationship with registered enterprises over the last 3 fiscal years, and 0 if otherwise.
Apprenticeship (log)	A continuous variable indicating the logarithm of the total number of apprentices the enterprise had in 2013 plus 1. The addition of 1 was to avoid the drop of enterprises that did not train any apprentice in 2013.
Crime	A binary variable that takes value of 1 if the enterprise considers crime as a major obstacle to their business, and 0 if otherwise.
Lack of access to finance	A binary variable that takes value of 1 if the enterprise's lack of finance is considered a major obstacle to their business, and 0 if otherwise.
Number of innovations	A continuous variable indicating the total number of product innovations introduced by the enterprise over the last 3 fiscal years.
Imitate of formal sector	A binary variable that takes value of 1 if the enterprise imitates goods and services of registered enterprises, and 0 if otherwise.
Firm marketing	A binary variable that takes value of 1 if the enterprise employs the services of a marketing agency, and 0 if otherwise.

Family business	A binary variable that takes value of 1 if the enterprise is owned and operated by a family, and 0 if otherwise.
Apprenticed owner	A binary variable that takes value of 1 if the owner of the enterprise is a former apprentice, and 0 if otherwise.
City of enterprise	A dummy variable that takes value 1 if the enterprise is located in Accra and 0 if the enterprise is located in Tema.
Sector of firm	A dummy variable that takes value 1 if the firm is engaged in manufacturing and 0 if firm is engaged in services. Services refers to retail services and non-retail services (other services).
Ownership	A dummy variable that takes value 1 if the firm is male-owned and 0 if the firm is owned by a female.
Firm size	A categorical variable that takes value 0 if the firm is micro (< 5 employees), 1 if the firm is small (5 and < 10), 2 if the firm is medium (10 and < 20).
Zones	A categorical variable indicating the 17 zones in which enterprises were interviewed.
Formal	A dummy variable that takes value 1 if the enterprise would like to formalize and 0 otherwise.
Corruption	A binary variable that takes value of 1 if the enterprise considers corruption as a major obstacle to their business and 0 if otherwise.
Equipment	A binary variable that takes value 1 if the enterprise purchased new equipments in the last 3 fiscal years and 0 if otherwise.
Lack of access to electricity and water	A binary variable that takes value of 1 if the enterprise considers lack of electricity and water as a major obstacle to their business and 0 if otherwise.
Total employment_2013 (log)	A continuous variable indicating the logarithm total number of employees of the enterprise in 2013.

Appendix B

Table 5: Estimation Outputs for Formal Interaction and Apprenticeship

Estimation method	**Full-information maximum likelihood (FIML)**
	Formal Interaction[a]
Formal	0.520***
	(0.121)
Lack of access to electricity and water	0.056
	(0.116)
Imitate formal sector	0.255
	(0.195)
Real total sales_2013 (log)	0.007
	(0.035)
Corruption	0.278
	(0.198)
Crime	-0.037
	(0.125)
Lack of access to finance	0.208*
	(0.122)
	Apprenticeship
Ownership	0.050*
	(0.030)
Lack of access to finance	0.013
	(0.032)
Equipment	0.132***
	(0.045)
Total employment_2013 (log)	0.079***
	(0.026)
Formal	0.113***
	(0.037)
Real total sales_2013 (log)	0.002
	(0.007)
Family business	0.001
	(0.030)
Corruption	-0.017
	(0.048)
Crime	-0.043
	(0.034)
Age (log)	0.011
	(0.020)
Apprenticed owner	0.175***
	(0.040)
N	**499**

Robust standard errors in parentheses. All regressions include 22 zones, city and sector dummies. [a]The reported estimates are probit regression coefficients. * p <0.10, ** p <0.05, *** p <0.01.