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Industry and Innovation

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ciai20

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To cite this article: Xiaolan Fu, Giacomo Zanello, Carmen Contreras & Xuechen Ding (05 Mar 2024): Innovation under constraints: the role of open innovation in Ghana, Industry and Innovation, DOI: 10.1080/13662716.2024.2319798

To link to this article: https://doi.org/10.1080/13662716.2024.2319798

Published online: 05 Mar 2024.

INDUSTRY AND INNOVATION
https://doi.org/10.1080/13662716.2024.2319798

Routledge
Taylor & Francis Group

RESEARCH ARTICLE

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Innovation under constraints: the role of open innovation in Ghana

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ABSTRACT

This paper analyses Low-Income Country (LICs) firms' use of open innovation (OI) in overcoming various innovation constraints. We disaggregate local and foreign sources of innovation using a new measure of international openness. A survey of 501 manufacturing firms in Ghana reveals that OI is employed to address cost, knowledge, management, and market barriers. Knowledge and cost constraints lead to a broader and deeper search whereas cost barriers lead to a greater domestic search. Firms that faced market barriers significantly search more internationally while those facing infrastructure barriers tend to search less broadly and deeply for external knowledge. The substantial informal sector in Ghana hampers OI. Results also indicate an inverted-U-shaped relationship between the breadth of openness and innovation performance. This paper contributes to the literature by providing the first large firm-level survey-based evidence of OI in a LICs context, and by introducing a new measure of international innovation openness.

KEYWORDS

Open innovation; constraints; international openness; Africa; innovation performance; knowledge sourcing

JEL CLASSIFICATION

O14; O31; O33; O5

1. Introduction

Innovation is key for industrialisation and catch-up in developing countries. Building resilient infrastructure, in order to promote inclusive and sustainable industrialisation and foster innovation, is one of the important Sustainable Development Goals (SDGs) for all countries. The COVID-19 pandemic has proved the importance of technological innovation and resilient infrastructure in achieving SDGs. According to the SDG report 2022, global manufacturing rebounded from the pandemic in 2021, however, Least Developed Countries (LDCs) are still left behind. Although there has been a wealth of research on the determinants of innovation in developed countries in particular (Freeman and Soete 1997; Hoffman et al. 1998), the understanding of innovation in low-income countries (LICs) remains limited (Cirera and Maloney 2017) but it is critical for the achievement of the sustainable development goals. The innovation process is full of risks and high costs. LICs are usually characterised as having a relatively larger

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proportion of the economy functioning in the informal sector with low enforcement of the rule of law, low levels of confidence in the institutions and the government, and low levels of social capital matched with high levels of mistrust. These conditions may create barriers to innovation that are not present in high-income countries, increasing the risks and costs of innovation for firms in LICs.

Furthermore, there are additional constraints that may limit innovation. First, the availability and quality of financial and human resources in LICs are different from those in developed economies. This may limit how much a firm can invest in innovation. Second, the nature of demand is an important factor in shaping the direction of innovation (von Hippel 2006). A relatively low level of economic development and limited consumer demand may influence innovation motivations and activities. Third, in LICs with low levels of institutional development, firms are likely to operate in an underdeveloped national innovation system with weak linkages to other actors. These constraints suggest that the key to innovation success in LICs will be different from that observed in high-income countries.

Given these constraints, the World Bank (2010) suggests that LICs should 'garden innovation' by removing obstacles and supporting innovators through a proactive innovation policy. As a new innovation paradigm, open innovation (OI) has been proven to offer significant advantages to both large and small firms in developed countries (H. W. Chesbrough 2003; H. Chesbrough, Vanhaverbeke, and West 2014; Laursen and Salter 2006). In the setting of developing countries, some research found that external linkages with both public organisations (including universities) and private organisations can improve the innovation performance of firms (Freeman and Soete 1997); collaboration can improve the competitiveness of SMEs (Krause and Schutte 2015) and a firm's innovation performance is positively associated with the size of its networking portfolio. Despite these insights, our understanding of how firms in LICs can employ OI to enhance innovation performance is limited. Firms could choose to search locally or internationally, deeper or broader in OI decision-making based on their characteristics. However, there is limited work on the determinants of different OI choices for firms in LICs, and whether OI practices differ among different firms (formal and informal) in LICs.

This paper aims to fill this important gap in the literature through an investigation of the role of openness on the innovation performance of formal and informal firms in Ghana. Critically, we explore the differences between local and foreign openness regarding innovation outcomes, and also consider the breadth and depth of the openness under each dimension. To study these issues, we use a novel dataset of 501 firms from the manufacturing sector in Ghana. Research findings indicate that both knowledge constraints and cost constraints lead to a broader and deeper search of external knowledge, whereas cost barriers lead to greater domestic search in both depth and breadth but not to international search. Firms that face market barriers engage in significantly more international search. Firms that face infrastructure barriers tend to reduce search. Firms in the informal sector have a lower propensity to engage in broad search compared with firms in the formal sector.

The study contributes to the literature in the following ways. First, this study is one of the few studies investigating OI in LICs, enriching our understanding of OI in a specific context where OI is more difficult to achieve as there are more barriers. Second, it is unique in examining the impact of international OI on innovation in LICs, and the

different roles of openness to foreign and local knowledge. Third, building on the work of Laursen and Salter (2006), we develop a new method to measure a firm's breadth and depth of international openness in innovation, bringing a new view on how they have a different influence on innovation outcomes in LICs. Furthermore, breadth and depth of openness to foreign and local knowledge sources are measured separately, allowing us to examine how different barriers influence different types of OI practice.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature and identifies the key hypotheses. Sections 3 and 4 describe the data and methodology. Section 5 presents the main results. Finally, section 6 concludes.

2. Literature review and theoretical framework

2.1. OI in high-income countries

With the increasing global competition and rapid change in technologies, innovation has become an open and collaborative activity (H. W. Chesbrough 2003). An innovation process includes different subprocesses, which can be conducted inside the firm (intramural) or in collaboration with external partners (extramural). Furthermore, knowledge and ideas to develop innovation processes can come from either internal or external sources, or from both (H. W. Chesbrough 2003). Knowledge flows can be either Outside-In, where external knowledge is brought into the organisation, or Inside-Out, where the knowledge flows from the organisation to external bodies. The interaction between internal and external sources for innovation, which may include formal or informal collaborations, is frequently conceptualised as an 'OI' model.

The openness of a firm can improve innovation performance as linkages with external institutions increase a firm's knowledge base and innovation capacities (Freeman and Soete 1997; Goes and Park 1997; Hoffman et al. 1998; Powell, Koput, and Smith-Doerr 1996; Tsai 2001). External sources of information also help to expand a firm's knowledge base and reduce the risks and costs of developing new products and services (Fu 2012; Laursen and Salter 2006). Moreover, collaborations with different partners, particularly with clients, suppliers and even competitors, may lower the costs of launching a new product or service into the market (Darby, Zucker, and Wang 2004; Fu and Li 2016). Furthermore, it has been argued that the information search activities of the firm influence its innovation performance (Fu 2012; Katila 2002; Laursen and Salter 2006). For example, Laursen and Salter (2006) study the effects of the breadth and depth of external sources of information on the innovation of UK firms. They found that both search strategies are positively related to innovation outcomes, but for radical innovations (new to the market), the depth of information from external sources was the more crucial.

However, openness is costly. Maintaining external relations and the search for external knowledge may not be optimal for some firms. Researchers also report a decreasing return for openness (Fu 2012; Fu and Li 2016; Laursen and Salter 2006). Firms may engage in 'over-search' which incurs unnecessary costs. Thus, a firm needs to find a balance between internal and external knowledge that is appropriate to their objectives and there may be substitutability between internal and external knowledge (H. W. Chesbrough 2003; Laursen and Salter 2006).

Additionally, a firm engaged in external knowledge search needs the internal capacities to effectively absorb, use and exploit external knowledge. Internal absorptive capacities include: employing highly-skilled workers, having an internal R&D department, and investment in complementary internal R&D. It has been shown that there are complementarities between internal and external R&D strategies, with superior innovation performance in firms that conduct both of the R&D forms, compared with firms that use only one of them (Cassiman and Veugelers 2006; Lokshin, Belderbos, and Carree 2008; Piga and Vivarelli 2004).

The studies of OI have tended to focus on high-income countries but the innovation environment in LICs is very different, not only from high-income countries but also from emerging economies. It has been identified that there are specific external and internal barriers to innovation in firms in LICs.

2.2. Openness as a response to constraints to innovation in LICs

The literature on the diffusion of innovations in developing countries identifies several constraints that hamper the decisions and limit the choices of firms to innovate (Fu, Mohnen, and Zanello 2018). The factors that are important in middle-income countries include a lack of financial resources (cost barriers), technical knowledge and information (knowledge barriers), and market and institutions (market barriers) (Fu, Li, et al. 2014). These constraints may have a stronger impact on LICs, where there may be greater financial and knowledge constraints compared with industrialised and emerging countries. The limited financial resources of consumers in LICs may constrain the return to innovation and a lack of technical knowledge may prevent the adoption of innovations that are complex or that require complementary inputs.

The literature on innovation in LICs suggests that factors outside the firms may also constrain the creation and diffusion of innovation (Zanello et al. 2016). These include political factors, such as a weak political system and widespread corruption; economic characteristics, such as the openness of the economy and level of economic development; inadequate infrastructure; institutional factors, such as inadequate interactions between private (firms) and public sector (including research institutes and universities); and cultural and linguistic constraints. Many of these barriers are country-specific and shape the economic environment in which all firms operate. Other barriers, such as market and infrastructure barriers, affect specific firms or sectors.

2.2.1. Cost barriers

Technical innovations can be expensive, and often firms cannot afford to implement them. In some instances, financial and credit constraints are obstacles which are more critical to overcome compared to a lack of skills to adopt and use a new technology. Examples include the case of paper-manufacturing firms in Northern Vietnam (Kimura 2011) and manufacturing firms in Colombia (Kugler 2006), India (Vishwasrao and Bosshardt 2001) and China (Fu, Li, et al. 2014). In some cases, subsidies and grants can ameliorate these constraints (Darby, Zucker, and Wang 2004; Franco, Ray, and Ray 2011). Also, larger and older firms tend to have more capital to finance innovation (J. Chen, Chen, and Vanhaverbeke 2011; Fu, Li, et al. 2014; Robson, Haugh, and Obeng 2009). OI strategies can reduce the cost of innovation as they can enable access to external resources, reduce

uncertainties, diversify risks and improve learning from others (H. W. Chesbrough 2003; Fu 2012; Keupp and Gassmann 2009).

2.2.2. Knowledge barriers

Knowledge is critical to master a specific technology or to implement a marketing strategy or managerial change. Bell and Albu (1999) argue that the diffusion of innovation in LICs should be assisted by systems of knowledge accumulation. They highlight the critical role of external sources of knowledge, with a focus on cluster learning dynamics. Bagachwa (1992) studied the performance of small-scale and large-scale grain milling techniques in Tanzania to explain why some firms select inappropriate techniques and products. In addition to a lack of financial capital, he identified a lack of information about the appropriate technology as an important constraint. Other studies have shown that a lack of comprehensive information and experience in large-scale manufacturing is one of the largest impediments to the increase of Ghana's industrial capacity (McDade and MaLecki 1997) and in the manufacturing sector in India (Kumar and Saqib 1996). Chinese manufacturing firms that face high levels of knowledge and skill constraints have developed greater openness for innovation activities (Fu, Li, et al. 2014). Although the recent diffusion of information communication technologies (ICTs) in many developing countries provides improved access to information, knowledge accumulation is still low in LICs, and a lack of technical information is likely to hamper the diffusion and adoption of innovation.

2.2.3. Management barriers

Managerial skills have received increased attention as one of the factors explaining differences in corporate performance in LICs (Bruhn, Karlan, and Schoar 2010). Cirera and Maloney (2017) argued that management practices in developing countries are lagging behind those in advanced countries in a wide range of capabilities and that 'firms that lack the capabilities required to respond to market conditions, identify new technological opportunities, develop a plan to exploit them, and then cultivate the necessary human resources, will find it difficult to innovate'. The scarcity of local knowledge in developing countries can lead managers to seek and value non-local sources of knowledge, increasing the openness of the firm (Menon and Pfeffer 2003). This scarcity may be extensive in LICs as local knowledge may be far from the technological frontier. However, innovation openness and external search activities require managerial capacities within the firm that can effectively manage the different interactions with external sources of knowledge.

Based on SMEs in the UK, Fu (2012) found that a lack of incentives for employees may hinder in-house innovation and may force managers to seek external sources of knowledge for innovation. Besides, if there are internal managerial rigidities that constrain innovation within the firm, the firm may search for external sources of innovation which will increase its openness (Fu 2012). Conversely, firms need to be able to effectively manage the OI process. Van de Vrande et al. (2009) found that Dutch SMEs face management challenges that include the management of external collaborations with other organisations and also the management of internal ideas from employees. When the volume of ideas from internal and external sources is high, and there are insufficient managerial capacities inside firms to deal with these ideas effectively, companies may fail

to recognise their value or implement any of the new ideas. Therefore, a lack of management capabilities in a firm can result in less openness. However, the relationship between management barriers and innovation openness is not clear in emerging economies and there may be contrasting outcomes. We argue here that managerial rigidities inside firms in LICs tend to act as disincentives to the exploitation of internal ideas and innovation, and a lack of incentives from internal employees will also hinder the internal innovation process. Thus, firms will seek external sources of knowledge and will increase their openness to innovation.

2.2.4. Market barriers

The market structure in which a firm operates will also influence its innovation activities. A lack of competition may provide a disincentive for leading firms to innovate. From a sample of 291 Indian manufacturing firms, Kumar and Saqib (1996) showed that the absence of competitive pressure in the market reduces the likelihood that firms would undertake R&D activities. Similarly, extensive competitive pressure may push firms to innovate to stay in the market (Blalock and Gertler 2008). Evidence from UK firms suggests that the relationship between innovation activities and competition follows an inverted-U shape as both a lack of competition and intense competition may discourage innovation (Aghion et al. 2005). Also, market constraints may positively affect firms' openness to innovate as shown in the case of China (Fu, Li, et al. 2014).

The evidence on the barriers to innovation in LICs suggests that firms in LICs face different or more restrictive constraints (Fu, Li, et al. 2014; Zanello et al. 2016). Consequently, we hypothesise that OI as reflected in search activity is a response by firms in LICs in order to overcome constraints to innovation. We follow Kugler's (2006) characterisation of Outside-In OI as the use of external sources of knowledge and disaggregate the openness into the breadth and depth of OI. Breadth refers to the number of different sources of external knowledge used, while the depth of OI refers to the intensity and importance of external sources of knowledge used. The degree of openness of a firm comprises both breadth and depth. We consider that firms will increase their breadth and depth of openness when faced with more severe barriers to innovation. More specifically, our first hypothesis is:

Hypothesis 1. Firms that face stronger cost, knowledge, management and market barriers to innovation will search more broadly and deeply for external knowledge for innovation.

2.2.5. Infrastructure barriers

An additional barrier that is particularly acute in many LICs is a lack of adequate infrastructure (Cirera and Maloney 2017). Unlike the other constraints identified above, a lack of infrastructure may hinder search activities. Zanello et al. (2016), in a review of the literature on innovation in developing countries, found that infrastructure is fundamental to realising the benefits of innovation creation, diffusion and openness. Adequate and efficient infrastructure – including an extensive road network and a continuous supply of energy – is essential for the diffusion of innovation. Well-developed infrastructure is critical to attract foreign capital and also to sustain the

development of firms. Kinda (2010) uses firm-level data from 77 LICs to show that inadequate physical infrastructure discourages FDI. Lack of reliable sources of electricity and water also reduces investment in capacity and this constraint is common in many LICs where the provision of utilities can be erratic (McCormick 1999; Wolde-Rufael 2006). Based on the last available Enterprise Survey data collected by the World Bank, Ghana faces more severe challenges in the production and distribution of electricity compared with other Sub-Saharan African countries (AfDB 2014). On average, power shortages occur on approximately 10 days per month, with an average of 12 hours of blackout. The estimated loss due to power shortage is up to 6 percent of the total sales of firms (World Bank 2011). For firms in LICs, maintaining normal operation is hard due to the inadequate infrastructure. For firms in the informal sector, where electricity generators are even less common because of the high costs, the frequent blackouts during the dry season further hamper production and, consequently, the commitment to invest in openness and innovation. Unlike the other constraints identified above, we assume that the infrastructure constraint will have a negative impact on the search activities as it will limit the ability to search or will raise the cost of search.

Hypothesis 2. Firms that face more infrastructure barriers will search less broadly and deeply for external knowledge for innovation.

2.2.6. Institutional voids: formal and informal firms

One of the additional characteristics of many LICs is the prevalence of institutional voids (Luo and Chung 2013). This may include weak institutions and regulations which limit the functioning of the economy through weak contract enforcement and corporate governance. Furthermore, there is a lack of market intermediaries including financial organisations and technology intermediaries (including universities that are engaged with their local economies) in LICs.

A lack of institutional oversight and a lack of property rights encourage the development of an informal economy. According to Webb et al. (2013), an informal economy is defined as economic activities in the production and trade of goods and services that are conducted by informal firms that may not be registered and which operate outside of government regulation and taxation systems. Informal firms play an increasingly significant role, and account for a larger proportion of the total number of firms in emerging economies (Pérez et al. 2019). In Ghana, the origin of the informal sector in its economy can be traced back to colonial capitalism (Osei-Boateng and Ampratwum 2011) and it has been estimated that it may comprise 80% of the total labour force (Hormeku 1998). One of the key elements that ensure the survival of firms in the informal sector is the lack of formal institutional oversights.

Compared with formal sectors, the mean education level in the informal sector is substantially lower (Funkhouser 1996). Informal firms are also characterised by being less productive (La Porta and Shleifer 2011), less skill intensive (Amaral and Quintin 2006), and producing low-quality versions of products produced by formal firms (Banerji and Jain 2007). The scarcity of these material, financial and human resources will effectively constrain the innovation behaviours and search choices of informal firms. In particular, engaging in search activities with external actors may put informal firms on

the radar of institutions, thus, they may face more institutional constraints in their operation. As informal firms serve the same market and exploit similar resources, formal firms usually regard informal firms as direct competitors with advantages in the cost and flexibility of products (Mendi and Costamagna 2017).

Competition from informal firms has become a critical concern for formal firms and may influence their innovation strategies. Research found that formal firms tend to increase their rate of innovation when faced with informal competition (Pérez et al. 2019). Informal firms supply low-cost and low-priced products and services to customers to gain competitive advantages. As a result, formal firms need to differentiate their products with more functionality and reasonable prices to meet the demands of customers (McCann and Bahl 2017). Innovation acts as a response to the competition from informal firms. As a result, we propose the following hypothesis:

Hypothesis 3. Firms in the informal sector will search less broadly and deeply for external knowledge for innovation compared to firms in the formal sector.

2.3. Openness to local and foreign knowledge for innovation in LICs

Openness is not only a response to innovation constraints but can itself be a source of innovation. In LICs, openness may be important as the knowledge gap between domestic firms and the technological frontier is large. Therefore, innovation diffusion, sourced from abroad and from within the LIC, may be an important source of productivity gains for local firms (Zanello et al. 2016). Previous work has found decreasing returns, in terms of innovation outputs, to openness (Laursen and Salter 2006), although others have found a linear relationship (Fu 2012). Given that the search for new information is costly (Fu 2012; Fu and Li 2016; Katila 2002; Laursen and Salter 2006), firms will find a balance between the number of external knowledge sources and the intensity of the use of each source in order to maximise the benefits from search efforts. The effects of openness on innovation outcomes can be different depending on the characteristics of the firm, the differences between internal and external knowledge bases, and the innovation stages conducted.

OI plays an important role in the innovation process in both technological and non-technological industries (H. Chesbrough and Crowther 2006). New technologies and innovations worldwide are highly concentrated in a few industrialised countries such as the US, Japan and Germany (Keller 2004). Thus, the adoption of technologies developed abroad is fundamental to increasing economic development in emerging economies (Fu, Pietrobelli, and Soete 2011). However, the adoption of new knowledge and technologies is not always possible and easy in developing countries given that foreign technology might be inappropriate for the local socio-economic conditions. Innovations that emerge in the context of industrialised countries optimise the use of factors and markets present in developed countries, whereas these conditions are significantly different in LICs (Acemoglu 2002; Fu, Pietrobelli, and Soete 2011). The appropriateness of foreign technologies depends on the characteristics of the host country and the sector (Fu and Gong 2011). For example, Fu and Gong (2011) study the role of indigenous and foreign

innovations in the process of technological upgrading in China and show that indigenous knowledge had a greater impact than foreign knowledge in low- and medium-technology sectors. The benefits of OI strategies on innovation outputs in LICs will depend on the features of the firm, the sector and the country, and the differences in knowledge bases between foreign and local knowledge. However, the gap between LICs and developed countries in knowledge base and market factors is even larger, increasing the difficulties and inappropriateness of knowledge absorption.

Cultural and geographical differences also influence the adoption and use of foreign knowledge (Auffray and Fu 2015; Galang 2014; Robson, Haugh, and Obeng 2009; Zanello et al. 2016). Larger distances in geographical, social and cultural proximity between the source of knowledge and the buyer or user of that knowledge increase transaction costs (Galang 2014). Robson, Haugh and Obeng (2009) studied innovative firms in Ghana, finding that more innovative firms are located in large towns and cities. Cities are the places where diversity of people, firms and knowledge converge, and new ideas are generated (Robson, Haugh, and Obeng 2009). It has been argued that ICTs can reduce these costs to some extent (Galang 2014; Overå 2006), however, the adoption of some technologies, such as machinery or equipment, requires physical transportation. Also, access to ICTs and the internet may be limited in LICs (Zanello et al. 2016). Overall, access to local knowledge may reduce barriers to innovation diffusion.

Geographical proximity is important for the transmission of tacit knowledge. Tacit knowledge usually diffuses by social connections and interactions (Galang 2014; Zanello et al. 2016). Trust is usually built from repetitive interaction and is enabled if agents share similar cultures. Gebreeyesus and Mohnen (2013) show that within shoemaking firms in Ethiopia, firms with more local ties and relationships tend to be more innovative. Cultural distances, such as differences in language or management styles, can affect the absorption of foreign knowledge (Galang 2014; Zanello et al. 2016). By analysing patent data, MacGarvie (2005) found that technology diffusion between countries was affected by language, and geographical and technological proximity. Also, trust between actors is relevant for the diffusion of knowledge among agents and in the firm's capacity for innovation (Meagher 2007; Murphy 2002; Zanello et al. 2016). Thus, we hypothesise that:

Hypothesis 4. Innovating firms in LICs will search more broadly and deeply for knowledge from local sources compared to foreign sources.

There are many types of innovation and each of them has different characteristics and requires different capabilities to conduct. As a result, it is important to recognise that the characteristics of openness and search activity may vary by the different types of innovation (product, process, managerial and marketing). In particular, local knowledge provides the advantage of proximity which may reduce costs and facilitate the exchange of tacit knowledge. Conversely, the pool of foreign knowledge will be more diversified than the pool of local knowledge and this will reflect greater possibilities. The search for knowledge at or near the technological frontier may require external sources, but here we present a more general hypothesis.

Hypothesis 5. Different forms of innovation will use different mixes of breadth and depth and local and foreign knowledge sources.

3. Data

We conducted an innovation survey of manufacturing firms in Ghana with the support of the Science and Technology Policy Research Institute (STEPRI). STEPRI is an internationally recognised public research institute specialising in science, technology and innovation policy research under the supervision of the Council for Science and Innovation Research in Ghana. Ghana provides an interesting context to investigate the research question as it has recently moved up from a low to a lower-middle-income country. Although the economy has traditionally been based on commodities' exports, its industrial development strategy is based on innovation, technological upgrading, and diversification. Furthermore, Ghana has a large and dynamic informal sector, including many firms that are co-located in clusters across the country.

Before we conducted the innovation survey, we carried out a preliminary study on the innovation barriers firms may encounter in the innovation process, how firms respond to the constraints on innovation and how innovation policies can help overcome these barriers in different sectors in both formal and informal firms. Interview topics include innovation activities, the process of innovation, barriers to innovation transmission and space for innovation policies. The design of the survey was based on the in-depth interviews and was tailored to the Ghanaian environment. The types of questions used in innovation surveys are based on Laursen and Salter (2006) and described in the Organization for Economic Co-operation and Development's (OECD) Oslo Manual (OECD 2005). The data were collected between November 2013 and January 2014 and include detailed information on innovation activities undertaken by the 501 firms during a three-year period (2011–2013).[1] Data were electronically collected in the field during one-hour face-to-face interviews. The unique design of the survey provides unprecedented insights into the transmission mechanisms of innovation, capturing factors that go beyond the traditional input and output indicators. The survey gathered information from multiple sources of innovation, both at local and international levels.

The team of enumerators included ten data collectors and two supervisors. The enumerators were selected from amongst STEPRI staff or had been engaged in previous data collection in other projects coordinated by STEPRI. The team was designed to cover native speakers of the main local languages in Ghana. The process of data collection was preceded by a three-day training period, in which the facilitators reviewed the questionnaire with the enumerators and an extensive training of the electronic data collection tools was delivered. In September 2013, a pilot survey was conducted to ensure that the survey design and materials would capture the data necessary to meet the survey objectives. During the survey, enumerators were instructed to upload the questionnaires every week, so the data could be analysed for consistency checks.

[1]Ghana has been listed as a Lower-Middle-Income country (LMIC) by the World Bank since 2012. In our fieldwork and survey, we found that the distribution of formal and informal firms was still very typical of an LIC and the policy support from the government was still low, though Ghana had technologically been an LMIC. Our survey covers most of the time before Ghana was announced as an LMIC. Thus, we regard Ghana as an LIC in our paper.

The dataset includes firms across the whole spectrum of formality, allowing analysis of informal firms, whereas the literature on innovation in developing countries has concentrated on formally registered firms (Ayyagari, Demirgüç-Kunt, and Maksimovic 2011). Since informal firms are not recorded in official databases, we used a different sampling framework to avoid under-representation of the informal sector. Therefore, half of the firms were sampled from sources that were likely to mainly record informal firms and the other half from sources containing mainly formal firms. Informal firms were randomly sampled from 10 clusters spread across five regions (five clusters in Greater Accra, two in the Ashanti region, and one each in Central, Eastern, and Northern regions respectively). Clusters were engaged in food production and processing, garments and textiles, handicraft products, metalwork, sawmills and wood products. The choice of clusters and regions intended to obtain a sectoral and geographical representation of the Ghanaian informal economy. Various data sources were used to compile the population of formal firms. The sample was composed by randomly selecting firms based on three levels of stratification: industrial sector, firm size and regional location. A third of the firms originally sampled needed to be replaced as some could not be located by the enumerators (24 percent), others had closed down (8 percent), and a few firms were not willing to participate in the survey (1 percent). In these cases, a replacement protocol was in place, and substitute firms were randomly selected from among the firms working in the same sector and region of the same size as the missing firms.

The sample includes only manufacturing firms: half of the firms in the sample are equally distributed in the food processing and clothing and textile sectors. The sectoral distribution of the sample companies is shown in Table A4 in the Appendix.

4. Methodology

4.1. Measurement

4.1.1. Dependent variables

The notion of 'openness' is nuanced, and different measures have been deployed (such as sources of information, patterns of collaboration and the IPR regime) to measure a firm's openness to innovation. Such measures, however, are not very relevant for firms located in LICs. Therefore, in this study, we use a different approach, as used by Laursen and Salter (2006), where two measures of 'openness' are constructed as proxies for the breadth (range of external sources) and the depth (importance of sources) of OI practices. The former depends on the number of search channels a firm draws on in its innovative activities. The latter refers to the extent to which firms draw intensively on different search channels or sources of innovative ideas.

Laursen and Salter's (2006) work proposed four types of knowledge sources (Market, Institutional, Specialised and other) using 16 questions to study the openness in the context of the UK. Based on the questions raised by them and the research purpose of this paper, we also developed some similar questions to measure foreign sources of openness in each dimension while considering the underdeveloped context in Ghana. To increase the quality of the survey, we did a pre-test before the formal survey (Robinson and Leonard 2018). Then we tailored the overlapping dimensions

or dimensions that rarely exist in domestic or foreign contexts and tried not to include too many questions in the measurements (Dillman, Smyth, and Christian 2014) while keeping the original measurements as indicated in Laursen and Salter (2006). We merged some questions in the original questionnaire when measuring local knowledge sources and foreign knowledge sources, for example, we merged conferences, trade fairs, and exhibitions into one dimension 'conferences, trade fairs, and exhibitions' as they have similar functions and are hard to distinguish to some extent. We also merged technical standards, health and safety standards, and environmental standards into one dimension 'international standards' in measuring foreign sources. Finally, we measured the breadth of OI by calculating how many of the 17 major external knowledge sources (see Table A1 for details) are integrated into a firm's innovation processes (10 local and 7 foreign sources). We also measured the depth of OI by the number of these sources that were deeply integrated into a firm's innovation processes. This is self-reported by the respondents who identify the importance of different external knowledge sources for the innovation process. We computed an index of breadth and depth of OI but also divided the sources into those that were local and those that were foreign.

The questionnaire asks firms to state the degree of importance of each source, scaled from 1 to 5, where '1' means that this source was insignificant for the innovation activities and '5' was crucial. In order to calculate breadth (BREADTH), each item is measured as '0' when this item is marked as '1' (insignificant) in the questionnaire, or '1' otherwise (when the item takes the values '2', '3', '4' or '5'). BREADTH is then the sum of the 17 new values. Similarly, in order to calculate depth (DEPTH), each item is given the value of '0' when this item is marked as neither '4' nor '5' in the questionnaire (it can be '1' or '2' or '3'), or '1' otherwise (includes '4' very significant or '5' crucial). DEPTH is then the sum of the 17 new values. Thus, both BREADTH and DEPTH can take the range of values from 0 to 17. DEPTH_LOCAL, DEPTH_FOREIGN, BREADTH_LOCAL, and BREADTH_FOREIGN all use similar measures. According to our classification, both DEPTH_LOCAL and BREADTH_LOCAL can take the range of values from 0 to 10, and both DEPTH_FOREIGN and BREADTH_FOREIGN can take the range of values from 0 to 7.

Innovation performance is captured by the diversity of innovation output introduced by the firms. Following the guidelines from the Oslo Manual (OECD 2005) to collect innovation data, the questionnaire recorded whether a firm adopts a new product, process, management or marketing (where 'new' means new to the world or new to the country or the firm). Thus, the innovation performance index (BREADTH_INN) can range from '0' (no innovation) to '4' (innovations in all four types). This indicator reflects a firm's diversity of innovation outputs across different dimensions. It should be noted that there are other possible measures, for example, the percentage of firm turnover from new products (Garriga, von Krogh, and Spaeth 2013). The rationale for not using 'percentages of sales from new products' as a dependent variable was firstly due to the unreliability of the measure and that focusing on only one dimension of innovation (product) does not take into consideration other innovation activities (i.e. process, management, marketing). Compared to other types of innovation, product innovation, no matter whether new-to-the-company or new-to-the-market, usually involves more technology-related knowledge and higher R&D Investment (M. Chen et al. 2021). The level of product innovation is very limited in the LICs. A limitation of this approach is that it treats each innovation activity equally. Therefore, we also separately consider

innovation in the different dimensions which are measured by dummy variables that equal 1 if a firm had at least one product, process, management or marketing innovation, respectively. We first present the aggregate picture using the combined index, and then we test the performance impact of OI in the more disaggregated specifications.

4.1.2. Independent variables

The survey questionnaire contains 17 Likert-scale items that ask firms the extent to which specific impediments had significant negative consequences for their innovation activities. These include economic risks, cost, financing channels, talents, knowledge accumulation, technical information, market information and collaborators, as well as monopoly, competition, and uncertainty of market demand (see Table A2 for details). They are each scaled from '0' (irrelevant for the innovation activities) to '5' (crucial negative consequence). We use these items to construct scales to measure different kinds of constraints and risks to innovation. We classify those 17 items into five types of constraints to innovation: cost factors (COST_BARRIERS), knowledge factors (KNOWLEDGE_BARRIERS), management factors (MNGMT_BARRIERS), market factors (MKT_BARRIERS), and no need to innovate (NO_NEED). The construct and discriminant validity of these scales were also assessed using principal component analysis (with the varimax rotation method). All the items had strong loadings (above 0.70) on their respective constructs, implying discriminant validity. In terms of reliability, each measurement of a barrier showed adequate reliability with a Cronbach's alpha above 0.8. In the model, each constraint variable is measured as the average of the scores of all the relevant items. We also construct an index of infrastructure barriers (INFRA_BARRIERS), in which we sum the frequency of unreliable power and water supply. We emphasise that the constraints to accessing production resources (such as electricity and water) are motivated by the fact that these are essential inputs in the production process and can have a significant impact on firm performance. For instance, unreliable electricity and water supply can lead to reduced productivity, increased downtime, and higher production costs, which can ultimately affect the firm's ability to compete and engage in external search activities. The infrastructure index ranges from values of '0' to '4', '0' being reserved for firms that have good power and water supply. Details of components are included in Table A3.

The five barriers to innovation were tested for multicollinearity, and the variance inflation factor (VIF) reported values lower than 2. The nature of a firm may also influence that firm's openness to innovation. We therefore include a discrete variable (NATURE) capturing the nature of the business. In our sample, 393 are informal firms. Formal firms are distributed in most of the cities; 48% are located in the capital city and main industrial district (Accra or Tema), but are not predominantly from the more developed regions, which would not bring a systematic influence.

4.1.3. Control variables

Following the literature on determinants of OI, we include relevant variables as control variables. (1) Firm size (SIZE), measured by the logarithm of the number of employees. We identify four types of company size according to the number of employees (Micro, Small, Medium, and Large). Larger firms always have a greater range of market partners through which to look for opportunities for international collaboration. (2) Firm age (AGE) is

captured by the number of years since its establishment. As firm age increases, firms may have accumulated more experience and gained a larger knowledge base, which makes them more likely to engage with OI. Both firm size and firm age may also affect OI strategies and performance as larger or older firms may have larger technology portfolios. (3) Absorptive capacity (ABSORPTIVE CAPACITY) is an important factor for the ability to learn from outside, which is captured by the percentages of employees in a firm with a technical specialised degree. Employees' ability can be defined as their educational background, and it is a key aspect of a firm's absorptive capacity (Minbaeva et al. 2003). Employees with a technical specialised degree are more likely to learn, adapt and apply the new knowledge acquired from external activities. R&D expenditure or R&D personnel are the most canonical measures of absorptive capacity in many studies. We ran a series of exploratory in-depth interviews with entrepreneurs that were also used to inform the design of the survey, however, the vast majority of firms do not have formal R&D departments or R&D budgets, so their R&D workers or expenditure cannot be calculated accurately.

(4) Geographic location, which is proxied using a vector of regional dummies. Firms in different regions are normally influenced by the openness of the region's economy. The location of firms could be a critical factor in the choice and availability of innovation sources. Seven dummy variables capture whether the firm is located in a specific region (Accra, Tema, Kumasi, Tamale, Sekondi, Kasoa, or Osenase). Accra is the capital and Tema is the main industrial district. In our sample, 249 firms are located in Accra or Tema.

(5) Export orientation of the firms (EXPORTER), as exporters may be more likely to engage with external knowledge searching and OI due to the strong competitive pressure in the international market. A dichotomous variable was included, indicating whether the main market of the firm is abroad. (6) The degree of competition in the domestic market (COMPETITION). We captured the self-reported level of competition in the main market in which the firms operate. A discrete variable takes the value of '0' if the market is uncompetitive and '5' if it is extremely competitive. Finally, (7) sectoral-specific characteristics proxied by industry dummies are included to examine the sectoral heterogeneity. Firms in some sectors may be more likely to use OI due to the characteristics of the sectoral innovation system and the technologies used in the industry. The data were all from the manufacturing sector. We bring six dummies into the model as we classify all the manufacturing subsectors into seven categories according to their similarities.

The descriptions and summary statistics of variables are reported in Table 1.

4.2. Model setting

Given that the dependent variables are truncated, standard OLS estimates will be biased. We therefore use Tobit models for the estimation. Similar results were obtained when ordered probit models were used. Following previous literature (Fu, Li, et al. 2014; Garriga, von Krogh, and Spaeth 2013; Laursen and Salter 2006), we estimate a system of equations which are jointly expected to capture the determinants of the depth and breadth of OI and assess their impacts on innovation performances.

The equations modelling the depth (DEPTH) and breadth (BREADTH) of OI share the same specifications. Independent variables include a vector (**X**) of factors that are thought to hamper innovation activities (cost factors, knowledge factors, management factors, market factors, infrastructure barriers, and no need to innovate), and a vector (**Z**) of the firms'

Table 1. Description of variables (N = 501).

Variable	Description	Min	Max	Mean	S.D.
DEPTH	The number of very important and crucial sources of external knowledge	0	12	1.44	2.14
BREADTH	The number of sources of external knowledge used	0	17	5.58	4.12
DEPTH_LOCAL	The number of very important and crucial sources of external local knowledge	0	8	1.15	1.58
BREADTH_LOCAL	The number of sources of external local knowledge used	0	10	3.97	2.62
DEPTH_FOREIGN	The number of very important and crucial sources of external foreign knowledge	0	6	0.29	0.84
BREADTH_FOREIGN	The number of sources of external foreign knowledge used	0	7	1.61	1.99
BREADTH_INN	The number of different types of innovations done by a firm	0	4	1.56	1.21
PRODUCT_INN	Whether the firm engaged in product innovations-Dummy variable	0	1	0.43	0.50
PROCESS_INN	Whether the firm engaged in process innovations-Dummy variable	0	1	0.61	0.49
MNG_INN	Whether the firm engaged in management innovations-Dummy variable	0	1	0.24	0.43
MKT_INN	Whether the firm engaged in marketing innovations-Dummy variable	0	1	0.28	0.45
COST_BARRIERS	Average importance of barriers related to costs	0	5	2.93	1.15
KNOWLEDGE_BARRIERS	Average importance of barriers related to knowledge	0	5	1.88	1.09
MANAGEMENT_BARRIERS	Average importance of barriers related to management	0	5	1.25	0.97
MKT_BARRIERS	Average importance of barriers related to market	0	5	1.49	0.87
INFRA_BARRIERS	The severity of lack of power and water supply for production	0	4	2.17	1.35
NO_NEED	Average importance of factors related to no need to innovate	0	5	1.08	0.91
AGE	Number of years since the establishment	0	63	15.82	10.08
SIZE	Number of employees	0	3	0.42	0.81
NATURE	Nature of the business: informal (0) and formal (1)	0	1	0.22	0.41
ABSORPTIVE CAPACITY	Ratio of employees with a specialisation degree	0	0.89	0.06	0.16
EXPORTER	Whether the main market of the firm is abroad- Dummy variable	0	1	0.05	0.22
COMPETITION	Perception of competition for the firm. Equals 0 if the market is slightly competitive, 5 if it is extremely competitive	0	5	2.40	1.19

Note: S.D. stands for Standard Deviation.

characteristics as control variables. The innovation performance (BREADTH_INN) is modelled with the breadth and depth of OI and the vector ($\mathbf{Z}$) of the firm's characteristics. To examine whether too much openness will bring decreased returns to innovation performance, we include the quadratic terms of openness measurements in the models. As a result, we add depth (DEPTH2) and breadth (BREADTH2) to the equations. The system of equations is:

$$\begin{cases} DEPTH = \beta_0 + \mathbf{X}\beta_1 + \mathbf{Z}\beta_2 + \varepsilon_1 \\ BREADTH = \gamma_0 + \mathbf{X}\gamma_1 + \mathbf{Z}\gamma_2 + \varepsilon_2 \\ BREADTH\_INN = \delta_0 + \delta_1 DEPTH + \delta_2 DEPTH2 + \delta_3 BREADTH + \delta_4 BREADTH2 + \mathbf{Z}\delta_5 + \varepsilon_3 \end{cases} \quad (1)$$

The DEPTH and BREADTH regressions are estimated as a Tobit model and BREADTH_INN as an ordered probit model. Model 1 will only include the constraints to innovation and control variables. Departing from and developing Laursen and Salter (2006), we decomposed the sources of innovation into local sources (if originated from within Ghana) and foreign sources (which originated outside Ghana). Model 2, in which OI is decomposed into local and foreign, is presented below. Similarly, we added the quadratic terms of depth and breadth from different sources in the equations, namely, DEPTH_LOCAL2, DEPTH_FOREIGN2, BREADTH_LOCAL2, and BREADTH_FOREIGN2. In this case, the

first four equations are estimated with Tobit models and the BREADTH_INN is estimated with an ordered probit model.

$$\begin{cases} DEPTH\_LOCAL = \beta_0 + \boldsymbol{X}\beta_1 + \boldsymbol{Z}\beta_2 + \varepsilon_1 \\ BREADTH\_LOCAL = \gamma_0 + \boldsymbol{X}\gamma_1 + \boldsymbol{Z}\gamma_2 + \varepsilon_2 \\ DEPTH\_FOREIGN = \beta_3 + \boldsymbol{X}\beta_4 + \boldsymbol{Z}\beta_5 + \varepsilon_3 \\ BREADTH\_FOREIGN = \gamma_3 + \boldsymbol{X}\gamma_4 + \boldsymbol{Z}\gamma_5 + \varepsilon_4 \\ BREADTH\_INN = \delta_0 + \delta_1 DEPTH + LOCAL + \delta_2 DEPTH\_LOCAL2 + \delta_3 BREADTH\_LOCAL + \\ \quad + \delta_4 BREADTH\_LOCAL2 + \delta_5 DEPTH + FOREIGN + \\ \quad + \delta_6 DEPTH\_FOREIGN2 + \delta_7 BREADTH + FOREIGN + \\ \quad + \delta_8 BREADTH\_FOREIGN2 + Z\delta_9 + \varepsilon_5 \end{cases} \tag{2}$$

As a robustness check, we also reported the results of a second set of models in which the effect of breadth and depth of OI is captured in the probability that a firm has undertaken innovations in product (PROD_INN), process (PROC_INN), management (MNG_INN), or marketing (MKT_INN). The initial two regressions model the determinants of depth and breadth of OI which are simultaneously fed into the probability of undertaking single innovation activities.

$$\begin{cases} DEPTH = \beta_0 + \boldsymbol{X}\beta_1 + \boldsymbol{Z}\beta_2 + \varepsilon_1 \\ BREADTH = \gamma_0 + \boldsymbol{X}\gamma_1 + \boldsymbol{Z}\gamma_2 + \varepsilon_2 \\ PROD\_INN = \delta_{01} + \delta_{11} DEPTH + \delta_{21} DEPTH2 + \delta_{31} BREADTH + \delta_{41} BREADTH2 + Z\delta_{51} + \varepsilon_3 \\ PROC\_INN = \delta_{02} + \delta_{12} DEPTH + \delta_{22} DEPTH2 + \delta_{32} BREADTH + \delta_{42} BREADTH2 + Z\delta_{52} + \varepsilon_4 \\ MNG\_INN = \delta_{03} + \delta_{13} DEPTH + \delta_{23} DEPTH2 + \delta_{33} BREADTH + \delta_{43} BREADTH2 + Z\delta_{53} + \varepsilon_5 \\ MKT\_INN = \delta_{04} + \delta_{14} DEPTH + \delta_{24} DEPTH2 + \delta_{34} BREADTH + \delta_{44} BREADTH2 + Z\delta_{54} + \varepsilon_6 \end{cases} \tag{3}$$

The system of equations jointly estimated DEPTH and BREADTH regressions with a Tobit model, and PROD_INN, PROC_INN, MNG_INN and MKT_INN with probit models. Similar to Model 2, we estimated Model 3 by separating the depth and breadth of OI in the local and foreign OI (Model 4):

$$\begin{cases} DEPTH\_LOCAL = \beta_0 + \boldsymbol{X}\beta_1 + \boldsymbol{Z}\beta_2 + \varepsilon_1 \\ BREADTH\_LOCAL = \gamma_0 + \boldsymbol{X}\gamma_1 + \boldsymbol{Z}\gamma_2 + \varepsilon_2 \\ DEPTH\_FOREIGN = \beta_3 + \boldsymbol{X}\beta_4 + \boldsymbol{Z}\beta_5 + \varepsilon_3 \\ BREADTH\_FOREIGN = \gamma_3 + \boldsymbol{X}\gamma_4 + \boldsymbol{Z}\gamma_5 + \varepsilon_4 \\ PROD\_INN = \delta_{01} + \delta_{11} DEPTH\_LOCAL + \delta_{21} DEPTH\_LOCAL2 + \delta_{31} BREADTH\_LOCAL + \\ \quad + \delta_{41} BREADTH\_LOCAL2 + \delta_{51} DEPTH\_FOREIGN + \\ \quad + \delta_{61} DEPTH - FOREIGN2 + \delta_{71} BREADTH\_FOREIGN + \\ \quad + \delta_{81} BREADTH\_FOREIGN2 + Z\delta_{91} + \varepsilon_5 \\ PROC\_INN = \delta_{02} + \delta_{12} DEPTH\_LOCAL + \delta_{22} DEPTH\_LOCAL2 + \delta_{32} BREADTH - LOCAL + \\ \quad + \delta_{42} BREADTH\_LOCAL2 + \delta_{52} DEPTH\_FOREIGN + \\ \quad + \delta_{62} DEPTH - FOREIGN2 + \delta_{72} BREADTH\_FOREIGN + \\ \quad + \delta_{82} BREADTH\_FOREIGN2 + Z\delta_{92} + \varepsilon_6 \\ NG\_INN = \delta_{03} + \delta_{13} DEPTH\_LOCAL + \delta_{23} DEPTH\_LOCAL2 + \delta_{33} BREADTH\_LOCAL + \\ \quad + \delta_{43} BREADTH - LOCAL2 + \delta_{53} DEPTH\_FOREIGN + \\ \quad + \delta_{63} DEPTH\_FOREIGN2 + \delta_{73} BREADTH\_FOREIGN + \\ \quad + \delta_{83} BREADTH\_FOREIGN2 + Z\delta_{93} + \varepsilon_7 \\ MKT\_INN = \delta_{04} + \delta_{14} DEPTH - LOCAL + \delta_{24} DEPTH\_LOCAL2 + \delta_{34} BREADTH\_LOCAL + \\ \quad + \delta_{44} BREADTH\_LOCAL2 + \delta_{54} DEPTH\_FOREIGN + \\ \quad + \delta_{64} DEPTH\_FOREIGN2 + \delta_{74} BREADTH\_FOREIGN + \\ \quad + \delta_{84} BREADTH\_FOREIGN2 + Z\delta_{94} + \varepsilon_8 \end{cases} \tag{4}$$

Table 2. Determinants of depth and breadth of open innovation [stage 1 – Model 1].

	DEPTH (I)		BREADTH (II)	
COST_BARRIERS	0.780***	(0.161)	0.676***	(0.202)
KNOWLEDGE_BARRIERS	0.643***	(0.175)	0.605***	(0.233)
MANAGEMENT_BARRIERS	−0.049	(0.164)	0.614***	(0.217)
MKT_BARRIERS	0.636***	(0.207)	0.442	(0.277)
INFRA_BARRIERS	−0.344***	(0.126)	−0.305*	(0.161)
NO_NEED	−0.256	(0.182)	−0.950***	(0.234)
AGE	0.007	(0.014)	0.027	(0.018)
SIZE	0.350	(0.232)	0.215	(0.303)
NATURE	0.167	(0.431)	1.435**	(0.569)
ABSORPTIVE CAPACITY	2.654***	(0.872)	4.094***	(1.189)
EXPORTER	1.354**	(0.584)	3.227***	(0.783)
COMPETITION	−0.544	(0.425)	1.348**	(0.554)
COMPETITION2	0.227**	(0.094)	−0.193	(0.123)
Constant	−2.905**	(1.304)	−0.575	(1.742)
Industry dummies	Yes		Yes	
Location dummies	Yes		Yes	
LR chi-squared	273.13***		238.59***	
Pseudo R-squared	0.158		0.088	

Notes: Significance at the 10 per cent, 5 per cent or 1 per cent levels are indicated by one, two or three asterisks respectively. Robust standard errors in parenthesis. Industry dummies include six binary variables: (1) Manufacture of Food and Beverages; (2) Manufacture of Textiles and Apparel; (3) Manufacture of products of wood, paper and furniture; (4) Manufacturing of printing and reproduction of recorded media; (5) Manufacture of chemicals, basic pharmaceutical products, and rubber and plastic products; (6) Manufacture of metal products, electrical products, machinery and equipment and repair of machinery and equipment. Location dummies include seven binary variables for: Accra, Tema, Kumasi, Tamale, Sekondi, Kasoa, Osenase.

5. Results and discussion

The results from the first model are shown in Table 2. Before evaluating the main hypotheses, it is important to highlight some general results. First, firms that consider they do not need to innovate are less likely to use external sources of knowledge, in particular, they will search less broadly ($\beta = -0.950$, $p < 0.01$). Second, older firms tend to show no difference in broad and deep searching compared to younger firms. Third, absorptive capacity plays an important part in search activity. It is expected that firms with higher absorptive capacity are better suited to search and absorb external knowledge. The results show that firms with a higher proportion of employees with a technical specialised degree are more open to external knowledge measured by the breadth and depth of OI. Fourth, variable EXPORTER is statistically significant and positive for DEPTH ($\beta = 1.354$, $p < 0.05$) and for BREADTH ($\beta = 3.227$, $p < 0.01$), indicating that firms with higher export orientation tend to have a higher propensity to search deeply and broadly compared to firms with less export orientation.

5.1. Test of hypothesis 1 (H1)

The results in Table 2 show that both depth and breadth of OI are mostly positively associated with constraints, partially supporting H1. Analysing the specific types of constraints, we observe some differences between types of constraints and the openness behaviour of firms.

Cost barriers are positively and significantly associated with the depth of openness (β = 0.780, $p < 0.01$) and with the breadth of openness (β = 0.676, $p < 0.01$). In the Chinese case, financial constraints on innovation are also positive and significant with both the breadth and the depth of openness (Fu, Li, et al. 2014). This indicates that the cost of gathering and managing knowledge are both highly relevant to openness for firms in LICs and emerging economies such as China. A lack of knowledge as an innovation barrier is positively associated with the depth and breadth of OI (β = 0.643, $p < 0.01$; β = 0.605, $p < 0.01$). These results are consistent with results from McDade and Malecki (1997) in Ghana and Fu et al. (2014a) in China. The evidence suggests that a lack of internal knowledge including a lack of internal capital and information on technology is consistent with both increased breadth and depth of search. Market barriers to innovation are positively and significantly associated with the depth of openness (β = 0.636, $p < 0.01$) but are not highly associated with the breadth of openness (β = 0.442, $p > 0.10$). This is consistent with the need for deep market-specific expertise to enter or maintain presence in markets. Management barriers are only significant and positive for the breadth of OI activities (β = 0.614, $p < 0.01$). This means that organisational rigidities or a lack of internal incentives will drive broader collaborations to overcome the management constraints instead of deeper connections with external sources.

5.2. Test of hypothesis 2 (H2)

H2 proposed that the infrastructure constraint will have a negative impact on the search as it will limit the ability to search or will raise the cost of search. The evidence in Table 2 supports H2 as infrastructure barriers significantly reduce the degree of openness of firms both on the depth dimensions (β= −0.344, $p < 0.01$) and the breadth of openness (β= −0.305, $p < 0.10$). Infrastructure barriers are external to the firm, and it is difficult to coordinate and cooperate with other partners as they may be faced with similar constraints. Infrastructure barriers not only reduce the probability of innovation (Zanello et al. 2016) but also reduce the level of local openness. If firms do not have enough water or energy supply for production, it is extremely difficult for them to obtain knowledge and information from external sources; as their basic needs are not sufficient to maintain normal operation, it is even more difficult for them to connect deeply and broadly with external sources as this requires more resource investment. It is, therefore, important to emphasise that infrastructure constraints may reduce the connective capacity of firms in LICs. In addition, firms may need to adopt novel strategies to overcome infrastructure barriers, if public policies cannot address these issues directly.

5.3. Test of hypothesis 3 (H3)

The evidence in Table 2 partially supports H3 that formal firms have a higher propensity to engage in broad search compared with informal firms (β = 1.435, $p < 0.05$), but there is no support for differences in the depth of search (β = 0.167, $p > 0.10$). This provides some support for the notion that firms operating outside the regulatory and institutional framework may be reluctant to engage in broad collaborative behaviour as on the one hand, this may expose their activities to the regulators and other public institutions, but formal firms do not have these concerns. On the other hand, informal firms do not have enough resource endowments and

motivation to carry out broader and deeper exploitation as they spend time producing low-quality and low-price products for their customers. Even for formal firms that might have more resources and capabilities, there is no significant signal that they are likely to search deeply to innovate as they always face the threat of being imitated by informal firms in products or services. Thus, the development of connective and exploitative capacity may be constrained by the extensive size of the informal sector in Ghana.

5.4. Test of hypothesis 4 (H4)

The results of disaggregating the sources of external knowledge between local and foreign sources are shown in Table 3. Cost barriers are significantly and positively associated with the local depth and breadth of OI strategies ($\beta = 0.734$, $p < 0.01$; $\beta = 0.702$, $p < 0.01$), but not with the foreign depth and breadth openness ($\beta = -0.124$, $p > 0.10$; $\beta = -0.211$, $p > 0.10$). This result shows that when the cost barriers to innovation are high, firms tend to search within local partners for innovation activities and knowledge. Local connections may lower transaction and coordination costs, and allow the sharing of innovation costs

Table 3. Determinants of local depth and breadth and foreign depth and breadth of open innovation [stage 1 – Model 2].

	DEPTH_ LOCAL (I)	BREADTH_ LOCAL (II)	DEPTH_ FOREIGN (III)	BREADTH_ FOREIGN (IV)
COST_BARRIERS	0.734***	0.702***	−0.124	−0.211
	(0.132)	(0.138)	(0.215)	(0.156)
KNOWLEDGE_BARRIERS	0.393***	0.287*	0.734***	0.640***
	(0.143)	(0.159)	(0.214)	(0.174)
MANAGEMENT_BARRIERS	−0.112	0.079	0.188	0.814***
	(0.133)	(0.148)	(0.197)	(0.158)
MKT_BARRIERS	0.385**	0.136	0.801***	0.461**
	(0.170)	(0.188)	(0.259)	(0.206)
INFRA_BARRIERS	−0.190*	−0.164	−0.369**	−0.236**
	(0.102)	(0.109)	(0.167)	(0.119)
NO_NEED	−0.240	−0.670***	−0.068	−0.492***
	(0.147)	(0.159)	(0.214)	(0.173)
AGE	0.006	0.005	0.006	0.037***
	(0.011)	(0.012)	(0.018)	(0.013)
SIZE	0.106	0.084	0.626**	0.247
	(0.191)	(0.206)	(0.302)	(0.219)
NATURE	0.115	0.637*	0.401	1.107***
	(0.350)	(0.386)	(0.591)	(0.413)
ABSORPTIVE CAPACITY	2.335***	2.989***	0.131	1.966**
	(0.711)	(0.812)	(1.049)	(0.831)
EXPORTER	1.102**	1.679***	0.757	2.246***
	(0.476)	(0.537)	(0.636)	(0.547)
COMPETITION	−0.332	0.992***	−1.287**	0.490
	(0.348)	(0.380)	(0.519)	(0.401)
COMPETITION2	0.159**	−0.145*	0.305***	−0.088
	(0.076)	(0.084)	(0.118)	(0.091)
Constant	−2.135**	0.116	−3.890**	−1.920
	(1.055)	(1.186)	(1.550)	(1.264)
Industry dummies	Yes	Yes	Yes	Yes
Location dummies	Yes	Yes	Yes	Yes
LR chi-squared	250.33***	221.70***	172.09***	243.12***
Pseudo R-squared	0.160	0.096	0.260	0.137

Notes: Significance at the 10 per cent, 5 per cent or 1 per cent levels are indicated by one, two or three asterisks respectively. Robust standard errors in parenthesis. Industry dummies and location dummies are the same as in Table 2.

with local partners (H. W. Chesbrough 2003; Fu 2012; Goes and Park 1997; Tsai 2001). Local connections and knowledge may also reduce innovation costs if firms can apply for public grants for innovation in association with local partners, such as other companies or local universities (Karo and Kattel 2011).

A lack of knowledge is positively associated with the depth and breadth of OI and this result holds both at the local levels ($\beta = 0.393$, $p < 0.01$; $\beta = 0.287$, $p < 0.01$) and foreign levels ($\beta = 0.734$, $p < 0.01$; $\beta = 0.640$, $p < 0.01$) of analysis. Firms that consider the lack of knowledge to be a relevant barrier to introducing an innovation are willing to search for external sources of knowledge in national and international markets. These results are consistent with results from McDade and Malecki (1997) in Ghana and Fu et al. (2014a) in China.

Management barriers are significant and positive for the breadth of OI activities for foreign sources ($\beta = 0.814$, $p < 0.01$) but not for the local and foreign depth of sources ($\beta = -0.112$, $p > 0.10$; $\beta = 0.188$, $p > 0.10$). Thus, there is partial support for a positive relationship between managerial barriers and the innovation openness of firms. These results are to some extent in line with findings for the UK, where lower internal incentives for employees and managers to innovate are related to higher levels of openness (Fu 2012). Managerial barriers to innovation inside the firm will tend to motivate greater external search, particularly for knowledge from a broader variety of sources.

Market barriers are positive and significantly correlated with the depth and breadth of foreign openness ($\beta = 0.801$, $p < 0.01$; $\beta = 0.461$, $p < 0.05$), but there is a positive and significant correlation only with the depth of local openness ($\beta = 0.385$, $p < 0.05$). This result is slightly different to that found in the case of manufacturing firms in China (Fu, Li, et al. 2014), where market and institutional barriers were relevant for both breadth and depth of openness. A plausible explanation is that the cost of conducting a wider knowledge search with different local sources and partners is more costly or difficult in LICs than in emerging countries.

Overall, the results provide some support for H4, that local sources are used more extensively compared to foreign sources. However, it should be emphasised that the evidence is nuanced and complex as there are various barriers in LICs. Foreign sources are important to overcome knowledge and market barriers. In many cases, local and foreign sources may be complementary. Furthermore, the use of local sources may improve the capacity to collaborate and use foreign sources.

The evidence in Table 3 also sheds further light on H2 and H3. First, regarding H2, the evidence suggests that infrastructure barriers are negatively and significantly correlated with the depth of local search, plus the depth and the breadth of foreign search ($\beta = -0.190$, $p < 0.10$; $\beta = -0.369$, $p < 0.05$; $\beta = -0.236$, $p < 0.05$). When infrastructure barriers exist, the most probable choice for firms in LICs is to search broadly in the local area. Second, regarding H3, formal firms in Ghana have a relatively high propensity to be engaged in breadth of local and foreign collaboration compared to informal firms ($\beta = 0.637$, $p < 0.10$; $\beta = 1.107$, $p < 0.01$). The significance level and value of the coefficient are higher in BREADTH_FOREIGN. This suggests that 'formality' is particularly important for international collaborations and potential international sources may be reluctant to collaborate with informal firms where there may be a lack of legal or institutional processes or safeguards.

Table 4. Depth and breadth of openness (I), local and foreign openness (II) on product, process, management, marketing innovations, and breadth of innovation performance [stage 2 – models 3 and 4].

	Product		Process		Management		Marketing		Innovation performance	
	(I)	(II)	(I)	(II)	(I)	(II)	(I)	(II)	(I)	(II)
DEPTH	−0.015 (0.094)		0.097 (0.103)		0.096 (0.100)		0.136 (0.092)		0.115 (0.082)	
DEPTH2	0.008 (0.010)		−0.009 (0.012)		−0.009 (0.010)		−0.018* (0.009)		−0.014 (0.009)	
BREADTH	0.423*** (0.065)		0.395*** (0.066)		0.133 (0.082)		0.141** (0.066)		0.440*** (0.056)	
BREADTH2	−0.023*** (0.004)		−0.018*** (0.004)		0.001 (0.005)		−0.003 (0.004)		−0.018*** (0.003)	
DEPTH_ LOCAL		−0.014 (0.131)		0.175 (0.143)		0.184 (0.152)		0.091 (0.129)		0.501*** (0.123)
DEPTH_ LOCAL2		0.026 (0.023)		−0.028 (0.025)		−0.002 (0.027)		0.001 (0.021)		−0.023 (0.015)
DEPTH_ FOREIGN		−0.491** (0.230)		−0.004 (0.285)		−0.545** (0.268)		−0.011 (0.234)		−0.072 (0.245)
DEPTH_ FOREIGN2		0.104** (0.051)		0.012 (0.076)		0.078 (0.062)		−0.077 (0.057)		−0.003 (0.047)
BREADTH_ LOCAL		0.602*** (0.106)		0.656*** (0.105)		−0.046 (0.139)		0.256** (0.107)		0.330** (0.151)
BREADTH_LOCAL2		−0.047*** (0.010)		−0.044*** (0.011)		0.034** (0.014)		−0.011 (0.010)		−0.031*** (0.008)
BREADTH_FOREIGN		0.286** (0.118)		−0.249* (0.134)		0.168 (0.138)		−0.021 (0.125)		−0.038 (0.119)
BREADTH_FOREIGN2		−0.055*** (0.018)		0.043* (0.022)		−0.026 (0.022)		0.007 (0.019)		−0.011 (0.014)
AGE	−0.005 (0.007)	−0.004 (0.007)	0.002 (0.007)	0.005 (0.007)	0.016** (0.007)	0.016** (0.008)	0.018*** (0.007)	0.020*** (0.007)	0.017*** (0.006)	0.012** (0.006)
SIZE	0.317*** (0.113)	0.365*** (0.116)	0.170 (0.123)	0.198 (0.129)	0.201 (0.123)	0.272** (0.129)	0.043 (0.112)	0.063 (0.114)	0.242** (0.102)	0.272*** (0.098)
NATURE	−0.134 (0.216)	0.020 (0.221)	0.025 (0.233)	0.123 (0.243)	−0.383 (0.236)	−0.207 (0.246)	−0.115 (0.227)	0.009 (0.230)	−0.344* (0.187)	0.247 (0.199)
ABSORPTIVE CAPACITY	0.788* (0.468)	0.661 (0.470)	0.542 (0.518)	0.779 (0.531)	0.493 (0.482)	0.304 (0.521)	0.582 (0.434)	0.512 (0.451)	0.831* (0.427)	1.067*** (0.403)
EXPORTER	0.278 (0.294)	0.304 (0.303)	0.482 (0.360)	0.556 (0.365)	−0.240 (0.345)	−0.087 (0.378)	0.532* (0.297)	0.506 (0.308)	0.147 (0.281)	0.725** (0.288)
COMPETITION	0.596*** (0.229)	0.554** (0.234)	0.119 (0.217)	0.074 (0.227)	−0.153 (0.257)	−0.084 (0.278)	0.286 (0.233)	0.239 (0.241)	0.327* (0.186)	0.595*** (0.171)
COMPETITION2	−0.111** (0.049)	−0.108** (0.051)	0.012 (0.049)	0.006 (0.052)	0.058 (0.056)	0.047 (0.060)	−0.037 (0.051)	−0.030 (0.052)	−0.027 (0.041)	−0.098*** (0.036)
Constant	−0.469 (0.685)	−0.689 (0.713)	−0.738 (0.665)	−0.966 (0.696)	−1.431** (0.690)	−1.438* (0.754)	−2.145*** (0.656)	−2.385*** (0.680)		
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LR chi-squared	172.27***	190.07***	195.16***	218.46***	188.52***	222.39***	112.18***	126.62***	342.5***	393.03***
Pseudo R-squared	0.259	0.286	0.291	0.326	0.349	0.412	0.197	0.222	0.324	0.372

Notes: Significance at the 10 per cent, 5 per cent or 1 per cent levels are indicated by one, two or three asterisks respectively. Robust standard errors in parenthesis. Industry dummies and location dummies are the same as in Table 2.

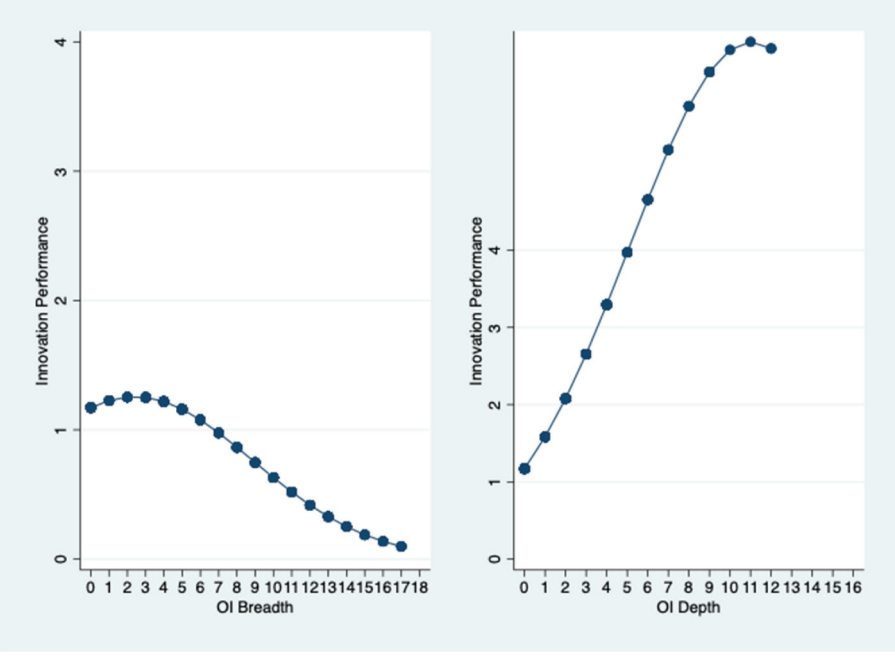

Figure 1. Breadth (BREADTH) and depth (DEPTH) of OI against innovation performance (BREADTH_INN) (Model 1).

5.5. Test of hypothesis 5 (H5)

The preceding section has considered the varying importance of different geographical sources of knowledge. In this section, we extend the analysis to consider how the mix of foreign and local knowledge separately influences product, process, management and marketing innovations, and how they influence the breadth of innovation performance (Table 4).

A further extension is to analyse whether there is an inverted-U relationship between firms' openness and innovation performance as identified in previous studies (Fu 2012; Laursen and Salter 2006). Figure 1 shows that firms with approximately 11 highly

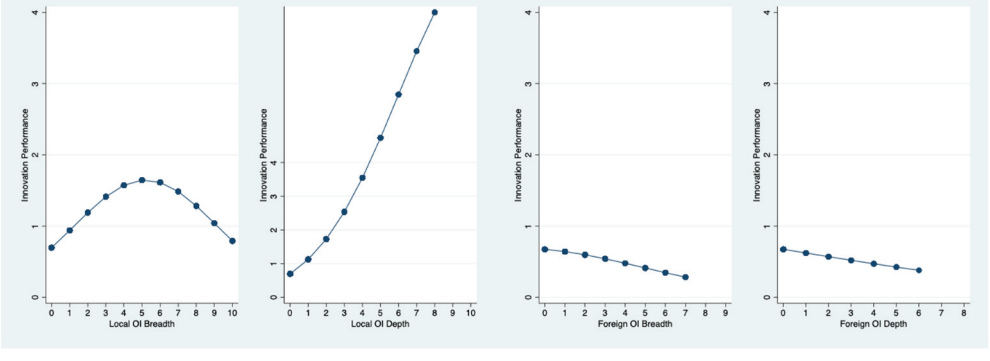

Figure 2. Local and foreign breadth (BREADTH) and depth (DEPTH) of OI against innovation performance (BREADTH_INN) (Model 2).

relevant sources of knowledge tend to have the highest levels of innovation performance, and firms with 3 different sources of knowledge have the highest levels of innovation performance. As shown in Figure 2, there is a slightly different result when considering local depth and local breadth; the inverted-U shape still exists between OI breadth and innovation performance, but the value which predicts the highest level of innovation performance is different. The results are less clear when we consider the foreign openness variables. The possible explanation for this result is the relatively small variety of foreign knowledge sources.

The results shown in Table 4 show a mix of sources used in the four different types of innovation. In the case of product innovations, *local depth* of openness has an insignificant influence on product innovation. This finding is different from the findings of Laursen and Salter (2006) for the UK, where the depth of openness greatly affects innovations new to the world, in comparison to innovations new to the firm or improvement of products. In the Ghanaian case, product innovation could be thought of as innovations requiring more investment and knowledge than other types of innovations. Though the foreign depth of openness offers access to knowledge closer to the international technological frontier and it may be more useful than local knowledge for technological innovations, however, maintaining deep connections with external partners requires high motivation to conduct radical innovation and resource commitment. Conversely, both *local breadth* of openness and *foreign breadth* of openness have an inverted-U-shape relationship with product innovation.

The picture of process innovation contrasts with that of product innovation: local breadth also has an inverted-U relationship with process innovations. For foreign depth and local depth, the results are insignificant. This result suggests that highly relevant local and foreign sources of knowledge have no impact on process innovation. Foreign breadth has a U-relationship with process innovation, but the significance level is relatively low. This is almost consistent with the notion that some foreign technologies may not be appropriate for process innovation in Africa (Acemoglu 2002). The local breadth of openness is significant for process innovation and has the expected inverse-U shape. Overall, local knowledge seems to be more relevant for process innovation than for other sources of knowledge as local knowledge has more similar characteristics and a development background which is easier to absorb and put into use. However, with the increase of the local knowledge breadth, the positive effect on process innovation will decrease, indicating that the cost of broad searching may exceed the advantage it brings to process innovation.

In the case of management innovation, both depth and breadth of openness are insignificantly correlated with the probability of innovation. When distinguishing local and foreign openness, we find that local breadth has a significant positive influence on management innovation and foreign depth of openness has a negative effect on management innovation. The results suggest that though the management process includes much tacit knowledge, foreign depth of openness is not highly relevant as different countries have various contexts in management practice. Instead, relevant and appropriate sources of knowledge about management are mostly present in the local environment. Finally, in terms of marketing innovation, the coefficient of the squared form of depth is significant, showing the expected signs and an inverted-U shape. The coefficient of the breadth is positive while the squared form is insignificant. Local breadth also has a significant and positive influence on marketing innovation. This result is consistent with the perspective that broad information is needed

when conducting marketing innovation as firms need to know much about the market. In addition, local marketing strategies are highly context-dependent and therefore local knowledge may be most appropriate for firms to conduct innovation.

In general, the evidence in Table 4 shows that the breadth of openness, especially the local breadth of openness, is more relevant than the foreign breadth of openness for product, process, and management innovations. Both depth and breadth of openness are relevant for marketing innovations whereas local breadth of openness is more important for marketing innovations. In terms of the breadth of innovation performance, the breadth of openness has an inverted-U relationship with innovation performance, and the local breadth of openness plays a significant role in this mechanism. Overall, these results support H5 that different types of innovation use different mixes of knowledge sources. It also provides further support for H4, i.e. that local sources of knowledge are more relevant and effective than foreign sources of knowledge for innovation outcomes in the context of LICs.

6. Conclusions

This paper examines how different constraints influence the choice of innovation openness and the role of OI on innovation outcomes of firms in LICs, based on the empirical analysis of a sample of 501 Ghanaian firms, capturing the differences between breadth and depth of openness, local and international openness, in the process of innovation. Five key findings have emerged. First, OI in terms of using external sources of knowledge is used by innovating firms that face cost, knowledge, managerial and market constraints. This result is highly relevant for LICs and even some developing economies, where the barriers are often higher than in industrialised economies. Second, firms that face infrastructure barriers search less deeply and broadly for external knowledge. Inadequate infrastructure has been identified as a major limitation on economic development, the evidence here suggests that such limitations in infrastructure constraints may reduce the connective and exploitative capacity of firms in LICs. Third, firms in the informal sector have a lower propensity to engage in broad search compared with formal firms. Firms that operate outside the regulatory and institutional framework may be reluctant and not have enough resources and incentives to engage in collaborative behaviour as they produce low-quality products or services; encouraging formalisation may also enhance collaborative and search activity. Fourth, local sources of knowledge are used more extensively compared to foreign sources. However, it should be emphasised that both sources are important for different types of innovation and that the use of local sources may improve collaborative capacity and increase the use of foreign sources. Fifth, different types of innovation use different mixes of sources of knowledge. Initiatives to encourage collaboration should consider the variety of sources that are used in different types of innovation.

This study highlights the relevance of external sources of knowledge for innovation, especially in the specific contexts of LICs, contributing to the literature on how to realise the sustainable development of the world through promoting innovation in LICs. The world is now closely interconnected by flows of people, information, goods, and capital which link the development of nations across the world. OI is an effective strategy to realise innovation development in LICs. However, due to the different aspects of the barriers, firms in LICs do use openness to overcome the barriers, but not all of them can search both broadly and deeply, sometimes they can only search locally but not internationally. According to the Global

Sustainable Development Report Global Sustainable Development Report (2019), there are still gaps between the goals and real progress. The interactions among diverse actors are still insufficient.

Our findings have important policy implications. First, policy should strengthen and support OI activities and the collaborative capacity of both formal and informal firms. For example, as proposed by Fu et al. (2014b), the development of dedicated online platforms for technological and managerial knowledge transfer can help firms in Africa in their innovation knowledge search. Moreover, firms with low innovation capabilities could benefit from being engaged in inter-firm networks and university-business networks to gain more local knowledge. Second, policies to solve the most basic infrastructure barriers faced by firms will facilitate collaboration and innovation. This includes increasing the coverage of 4 G networks and digital devices to connect with the world. By reducing the infrastructure barriers, firms would have more motivation and courage to chase higher development goals in innovation through a lower searching cost. Third, policies promoting international collaborations could focus on the promotion of product innovations. Product innovation usually involves more technology-related knowledge and higher R&D investment and requires the participation of R&D experts (M. Chen et al. 2021), which firms in LICs lack. Tacit knowledge is also embedded in the communication process. Collaborations on these dimensions will bring more knowledge to firms. For example, Eureka now has provided a large network for international cooperation in R&D and innovation for over 45 countries, enhancing the fund raising, market expansion, and international partnership. Fourth, it is important that policy considers diversity and promotes different collaborations and searches of knowledge for different types of innovation outcomes. Fifth, firms in LICs need high-tech from developed economies. According to the data from UN Statistics Division in 2019, the share of medium- and high-tech manufacturing in total manufacturing in Europe and Northern America is 47.7 percent compared with 21.4 percent in sub-Saharan Africa and 10.5 percent in LDCs. Policies should aim to encourage the diffusion of technologies that are more suitable to LICs so that they can absorb this effectively for their innovation activities.

There are some limitations of our research which further studies should address. First, the cross-sectional nature of our data does not allow us to control the dynamics of openness and innovation processes. Panel data collected at regular time intervals would be able to capture the development of innovation behaviours. Second, the study focuses on one of the LICs in Africa. While Ghana provides a useful case, more general conclusions could be reached by conducting cross-country studies to analyse the role of OI in different institutional environments.

Acknowledgements

We would like to thank Marc Ventresca, Pierre Mohnen and George Essegbey for helpful comments and suggestions. We are also grateful for comments from participants at the Seminar at the Oxford University and 2016 World Open Innovation Conference, 2015 Globelics Conference, 1st Africa Innovation Summit, Innovation in Low Income Countries Conference (London), and Innovation and African Industry Upgrading Workshop (Ghana). This work was supported by the ESRC/DFID Grant 'The Diffusion of Innovation in Low Income Countries' (ES/J008699/1).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the ESRC-DFID.

References

Acemoglu, D. 2002. "Directed Technical Change." *The Review of Economic Studies* 69 (4): 781–809. https://doi.org/10.1111/1467-937X.00226.

AfDB, O. E. C. D. 2014 "UNDP. 2014." *African Economic Outlook*.

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt. 2005. "Competition and Innovation: An Inverted-U Relationship." *The Quarterly Journal of Economics* 120 (2): 701–728. https://doi.org/10.1093/qje/120.2.701.

Amaral, P. S., and E. Quintin. 2006. "A Competitive Model of the Informal Sector." *Journal of Monetary Economics* 53 (7): 1541–1553. https://doi.org/10.1016/j.jmoneco.2005.07.016.

Auffray, C., and X. Fu. 2015. "Chinese MNEs and Managerial Knowledge Transfer in Africa: The Case of the Construction Sector in Ghana." *Journal of Chinese Economic & Business Studies* 13 (4): 285–310. https://doi.org/10.1080/14765284.2015.1092415.

Ayyagari, M., A. Demirgüç-Kunt, and V. Maksimovic. 2011. "Firm Innovation in Emerging Markets: The Role of Finance, Governance, and Competition." *Journal of Financial and Quantitative Analysis* 46 (6): 1545–1580. https://doi.org/10.1017/S0022109011000378.

Bagachwa, M. S. D. 1992. "Choice of Technology in Small and Large Firms: Grain Milling in Tanzania." *World Development* 20 (1): 97–107. https://doi.org/10.1016/0305-750X(92)90139-M.

Banerji, A., and S. Jain. 2007. "Quality Dualism." *Journal of Development Economics* 84 (1): 234–250. https://doi.org/10.1016/j.jdeveco.2005.09.010.

Bell, M., and M. Albu. 1999. "Knowledge Systems and Technological Dynamism in Industrial Clusters in Developing Countries." *World Development* 27 (9): 1715–1734. https://doi.org/10.1016/S0305-750X(99)00073-X.

Blalock, G., and P. J. Gertler. 2008. "Welfare Gains from Foreign Direct Investment Through Technology Transfer to Local Suppliers." *Journal of International Economics* 74 (2): 402–421. https://doi.org/10.1016/j.jinteco.2007.05.011.

Bruhn, M., D. Karlan, and A. Schoar. 2010. "What Capital is Missing in Developing Countries?" *The American Economic Review* 100:629–633. https://doi.org/10.1257/aer.100.2.629.

Cassiman, B., and R. Veugelers. 2006. "In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition." *Management Science* 52 (1): 68–82. https://doi.org/10.1287/mnsc.1050.0470.

Chen, J., Y. Chen, and W. Vanhaverbeke. 2011. "The Influence of Scope, Depth, and Orientation of External Technology Sources on the Innovative Performance of Chinese Firms." *Technovation* 31 (8): 362–373. https://doi.org/10.1016/j.technovation.2011.03.002.

Chen, M., T. (Ya)., Tang, S. Wu, and F. Wang. 2021. "The Double-Edged Sword of Coopetition: Differential Effects of Cross-Functional Coopetition on Product and Service Innovations." *Journal of Business & Industrial Marketing* 36 (2): 191–202. https://doi.org/10.1108/JBIM-06-2019-0313.

Chesbrough, H. W. 2003. "The Era of Open Innovation." *MIT Sloan Management Review* 44 (3): 35–42.

Chesbrough, H., and A. K. Crowther. 2006. "Beyond High Tech: Early Adopters of Open Innovation in Other Industries." *R&D Management* 36 (3): 229–236. https://doi.org/10.1111/j.1467-9310.2006.00428.x.

Chesbrough, H., W. Vanhaverbeke, and J. West, eds., 2014. *New Frontiers in Open Innovation*. London: Oxford University Press.

Cirera, X., and W. F. Maloney. 2017. *The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up*. Washington, D.C: World Bank Publications.
Darby, M. R., L. G. Zucker, and A. Wang. 2004. "Joint Ventures, Universities, and Success in the Advanced Technology Program." *Contemporary Economic Policy* 22 (2): 145–161. https://doi.org/10.1093/cep/byh011.
Dillman, D. A., J. D. Smyth, and L. M. Christian. 2014. *Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method*. Hoboken, NJ: John Wiley & Sons.
Franco, E., S. Ray, and P. K. Ray. 2011. "Patterns of Innovation Practices of Multinational-Affiliates in Emerging Economies: Evidences from Brazil and India." *World Development* 39 (7): 1249–1260. https://doi.org/10.1016/j.worlddev.2011.03.003.
Freeman, C., and L. Soete. 1997. *The Economics of Industrial Innovation* -. *3rd* ed. Cambridge, Mass: MIT Press.
Fu, X. 2012. "How Does Openness Affect the Importance of Incentives for Innovation?" *Research Policy* 41:512–523. https://doi.org/10.1016/j.respol.2011.12.011.
Fu, X., and Y. Gong. 2011. "Indigenous and Foreign Innovation Efforts and Drivers of Technological Upgrading: Evidence from China." *World Development* 39 (7): 1213–1225. https://doi.org/10.1016/j.worlddev.2010.05.010.
Fu, X., and J. Li. 2016. "Collaboration with Foreign Universities for Innovation: Evidence from Chinese Manufacturing Firms." *International Journal of Technology Management* 70 (2–3): 193–217. https://doi.org/10.1504/IJTM.2016.075162.
Fu, X., J. Li, H. Xiong, and H. Chesbrough. 2014. "Open Innovation as a Response to Constraints and Risks: Evidence from China." *Asian Economic Papers* 13 (3): 30–58. https://doi.org/10.1162/ASEP_a_00289.
Fu, X., P. Mohnen, and G. Zanello. 2018. "Innovation and Productivity in Formal and Informal Firms in Ghana." *Technological Forecasting and Social Change* 131:315–325. https://doi.org/10.1016/j.techfore.2017.08.009.
Funkhouser, E. 1996. "The Urban Informal Sector in Central America: Household Survey Evidence." *World Development* 24 (11): 1737–1751. https://doi.org/10.1016/0305-750X(96)00074-5.
Fu, X., C. Pietrobelli, and L. Soete. 2011. "The Role of Foreign Technology and Indigenous Innovation in the Emerging Economies: Technological Change and Catching-Up." *World Development* 39 (7): 1204–1212. https://doi.org/10.1016/j.worlddev.2010.05.009.
Fu, X., G. Zanello, G. O. Essegbey, J. Hou, and P. Mohnen. 2014. "*Innovation in Low Income Countries: A Survey Report*." Oxford
Galang, R. M. N. 2014. "Divergent Diffusion: Understanding the Interaction Between Institutions, Firms, Networks and Knowledge in the International Adoption of Technology." *Journal of World Business* 49 (4): 512–521. https://doi.org/10.1016/j.jwb.2013.12.005.
Garriga, H., G. von Krogh, and S. Spaeth. 2013. "How Constraints and Knowledge Impact Open Innovation: Research Notes and Commentaries." *Strategic Management Journal* 34 (9): 1134–1144. https://doi.org/10.1002/smj.2049.
Gebreeyesus, M., and P. Mohnen. 2013. "Innovation Performance and Embeddedness in Networks: Evidence from the Ethiopian Footwear Cluster." *World Development* 41:302–316. https://doi.org/10.1016/j.worlddev.2012.05.029.
Global Sustainable Development Report. 2019. "The Future is Now: Science for Achieving Sustainable Development - World | ReliefWeb. September 11, 2019. https://reliefweb.int/report/world/global-sustainable-development-report-2019-future-now-science-achieving-sustainable.
Goes, J., and S. Park. 1997. "Interorganizational Links and Innovation: The Case of Hospital Services." *Academy of Management Journal* 40 (3): 673–696. https://doi.org/10.2307/257058.
Hoffman, K., M. Parejo, J. Bessant, and L. Perren. 1998. "Small Firms, R & D, Technology and Innovation in the UK: A Literature Review." *Technovation* 18 (1): 39–55. https://doi.org/10.1016/S0166-4972(97)00102-8.
Hormeku, T. 1998. "The Transformation and Development of the Informal Sector and the Role of Trade Unions". In *Proceedings of the OATUU/ILO/ETUF Seminar on "Trade Unions and the Informal Sector"*, Cairo, Egypt (pp. 4–6).

Karo, E., and R. Kattel. 2011. "Should Open innovation" Change Innovation Policy Thinking in Catching-Up Economies? Considerations for Policy Analyses." *Innovation: The European Journal of Social Science Research* 24 (1–2): 173–198. https://doi.org/10.1080/13511610.2011.586496.

Katila, R. 2002. "New Product Search Over Time: Past Ideas in Their Prime?" *Academy of Management Journal* 45:995–1010. https://doi.org/10.5465/3069326.

Keller, W. 2004. "International Technology Diffusion." *Journal of Economic Literature* 42 (3): 752–782. https://doi.org/10.1257/0022051042177685.

Keupp, M. M., and O. Gassmann. 2009. "The Past and the Future of International Entrepreneurship: A Review and Suggestions for Developing the Field." *Journal of Management* 35 (3): 600–633. https://doi.org/10.1177/0149206308330558.

Kimura, Y. 2011. "Knowledge Diffusion and Modernization of Rural Industrial Clusters: A Paper-Manufacturing Village in Northern Vietnam." *World Development* 39 (12): 2105–2118. https://doi.org/10.1016/j.worlddev.2011.04.017.

Kinda, T. 2010. "Investment Climate and FDI in Developing Countries: Firm-Level Evidence." *World Development* 38 (4): 498–513. https://doi.org/10.1016/j.worlddev.2009.12.001.

Krause, W., and C. S. L. Schutte. 2015. "A Perspective on Open Innovation in Small- and Medium-Sized Enterprises in South Africa, and Design Requirements for an Open Innovation Approach." *The South African Journal of Industrial Engineering* 26 (1): 163–178. https://doi.org/10.7166/26-1-997.

Kugler, M. 2006. "Spillovers from Foreign Direct Investment: Within or Between Industries?." *Journal of Development Economics* 80:444–477. https://doi.org/10.1016/j.jdeveco.2005.03.002.

Kumar, N., and M. Saqib. 1996. "Firm Size, Opportunities for Adaptation and In-House R&D Activity in Developing Countries: The Case of Indian Manufacturing." *Research Policy* 25:713–722. https://doi.org/10.1016/0048-7333(95)00854-3.

La Porta, R., and A. Shleifer. 2011. "The Unofficial Economy in Africa." Working Paper 16821. National Bureau of Economic Research.

Laursen, K., and A. Salter. 2006. "Open for Innovation: The Role of Openness in Explaining Innovation Performance Among U.K. Manufacturing Firms." *Strategic Management Journal* 27:131–150. https://doi.org/10.1002/smj.507.

Lokshin, B., R. Belderbos, and M. Carree. 2008. "The Productivity Effects of Internal and External R&D: Evidence from a Dynamic Panel Data Model." *Oxford Bulletin of Economics and Statistics* 70 (3): 399–413. https://doi.org/10.1111/j.1468-0084.2008.00503.x.

Luo, X. R., and C. N. Chung. 2013. "Filling or Abusing the Institutional Void? Ownership and Management Control of Public Family Businesses in an Emerging Market." *Organization Science* 24 (2): 591–613. https://doi.org/10.1287/orsc.1120.0751.

MacGarvie, M. 2005. "The Determinants of International Knowledge Diffusion as Measured by Patent Citations." *Economics Letters* 87 (1): 121–126. https://doi.org/10.1016/j.econlet.2004.09.011.

McCann, B. T., and M. Bahl. 2017. "The Influence of Competition from Informal Firms on New Product Development." *Strategic Management Journal* 38 (7): 1518–1535. https://doi.org/10.1002/smj.2585.

McCormick, D. 1999. "African Enterprise Clusters and Industrialization: Theory and Reality." *World Development* 27 (9): 1531–1551. https://doi.org/10.1016/S0305-750X(99)00074-1.

McDade, B. E., and E. J. MaLecki. 1997. "Entrepreneurial Networking: Industrial Estates in Ghana." *Tijdschrift voor Economische en Sociale Geografie* 88 (3): 262–272. https://doi.org/10.1111/j.1467-9663.1997.tb01603.x.

Meagher, K. 2007. "Manufacturing Disorder: Liberalization, Informal Enterprise and Economic "Ungovernance" in African Small Firm Clusters." *Development & Change* 38:473–503. https://doi.org/10.1111/j.1467-7660.2007.00420.x.

Mendi, P., and R. Costamagna. 2017. "Managing Innovation Under Competitive Pressure from Informal Producers." *Technological Forecasting & Social Change* 114:192–202. https://doi.org/10.1016/j.techfore.2016.08.013.

Menon, T., and J. Pfeffer. 2003. "Valuing Internal Vs. External Knowledge: Explaining the Preference for Outsiders." *Management Science* 49:497–513. https://doi.org/10.1287/mnsc.49.4.497.14422.

Minbaeva, D., T. Pedersen, I. Björkman, C. F. Fey, and H. J. Park. 2003. "MNC Knowledge Transfer, Subsidiary Absorptive Capacity, and HRM." *Journal of International Business Studies* 34 (6): 586–599. https://doi.org/10.1057/palgrave.jibs.8400056.

Murphy, J. 2002. "Networks, Trust, and Innovation in Tanzania's Manufacturing Sector." *World Development* 30 (4): 591–619. https://doi.org/10.1016/S0305-750X(01)00131-0.

OECD. 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. 3rd ed.* Paris: Organisation for Economic Co-operation and Development.

Osei-Boateng, C., and E. Ampratwum. 2011. *The Informal Sector in Ghana*. Accra: Friedrich-Ebert -Stiftung, Ghana Office.

Overå, R. 2006. "Networks, Distance, and Trust: Telecommunications Development and Changing Trading Practices in Ghana." *World Development* 34 (7): 1301–1315. https://doi.org/10.1016/j.worlddev.2005.11.015.

Pérez, J. A. H., X. Yang, O. Bai, A. Flores, and W. Heredia. 2019. "How Does Competition by Informal Firms Affect the Innovation in Formal Firms?." *International Studies of Management and Organization* 49:(2): 173–190. https://doi.org/10.1080/00208825.2019.1608402.

Piga, C., and M. Vivarelli. 2004. "Internal and External R&D: A Sample Selection Approach." *Oxford Bulletin of Economics and Statistics* 66 (4): 457–482. https://doi.org/10.1111/j.1468-0084.2004.00089.x.

Powell, W. W., K. W. Koput, and L. Smith-Doerr. 1996. "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology." *Administrative Science Quarterly* 41 (1): 116. https://doi.org/10.2307/2393988.

Robinson, S. B., and K. F. Leonard. 2018. *Designing Quality Survey Questions*. New York: Sage publications.

Robson, P., H. Haugh, and B. Obeng. 2009. "Entrepreneurship and Innovation in Ghana: Enterprising Africa." *Small Business Economics* 32 (3): 331–350. https://doi.org/10.1007/s11187-008-9121-2.

Tsai, W. 2001. "Knowledge Transfer in Intraorganizational Networks: Effects of Network Position and Absorptive Capacity on Business Unit Innovation and Performance." *Academy of Management Journal* 44 (5): 996–1004. https://doi.org/10.2307/3069443.

van de Vrande, V., J. P. J. de Jong, W. Vanhaverbeke, and M. de Rochemont. 2009. "Open innovation in SMEs: Trends, motives and management challenges." *Technovation* 29 (6–7): 423–437. https://doi.org/10.1016/j.technovation.2008.10.001.

Vishwasrao, S., and W. Bosshardt. 2001. "Foreign Ownership and Technology Adoption: Evidence from Indian Firms." *Journal of Development Economics* 65 (2): 367–387. https://doi.org/10.1016/S0304-3878(01)00141-9.

von Hippel, E. 2006. *Democratizing Innovation*. Cambridge, MA: The MIT Press.

Webb, J. W., G. D. Bruton, L. Tihanyi, and R. D. Ireland. 2013. "Research on Entrepreneurship in the Informal Economy: Framing a Research Agenda." *Journal of Business Venturing* 28 (5): 598–614. https://doi.org/10.1016/j.jbusvent.2012.05.003.

Wolde-Rufael, Y. 2006. "Electricity Consumption and Economic Growth: A Time Series Experience for 17 African Countries." *Energy Policy* 34 (10): 1106–1114. https://doi.org/10.1016/j.enpol.2004.10.008.

World Bank. 2010. "*Innovation Policy: A Guide for Developing Countries*." World Bank

World Bank. 2011 "*Enterprise Surveys: Ghana Country Profile 2007*."

Zanello, G., X. Fu, P. Mohnen, and M. Ventresca. 2016. "The Creation and Diffusion of Innovation in Developing Countries: A Systematic Literature Review." *Journal of Economic Surveys* 30 (5): 884–912. https://doi.org/10.1111/joes.12126.

Appendix

Table A1. Sources of innovation.

During the three years 2011 to 2013, how important to your enterprise's innovation activities were each of the following local and foreign information sources?	
Local knowledge sources	Suppliers of equipment, materials, components or software Clients or customers Competitors or other enterprises in your sector Consultants, commercial labs or private R&D institutes National universities or other higher education institutions Government or public research institutes Member of cluster Member of associations Conferences, trade fairs, exhibitions Scientific journals and trade/technical publications
Foreign knowledge sources	Foreign research institutions & universities Foreign competitors Foreign suppliers Foreign customers Foreign technology acquired through licensing International conferences, trade fairs, exhibitions International standards

Note: The importance of each source was assessed based on five degrees: insignificant (1), marginally significant (2), significant (3), very significant (4), and crucial (5).

Table A2. Factors hampering innovation.

During the three years 2011 to 2013, how important were the following factors in hampering your innovation activities or projects or influencing a decision not to innovate?	
Cost factors	Lack of funds within your enterprise or group Lack of finance from sources outside your enterprise Innovation costs too high Excessive perceived economic risks
Knowledge factors	Lack of qualified personnel Lack of information on technology Lack of information on markets Difficulty in finding co-operation partners for innovation
Market factors	Market dominated by established enterprises Uncertain demand for innovative goods or services Innovation is easy to imitate Little competition in the market and hence no need to innovate Too much competition in the market and too low perceived return of innovation investment
Management factors	Organisational rigidities within the enterprise Little reward for innovation in the firm. Workers do not have the incentive to innovate.
No need to innovate	No need due to prior innovations No need because of no demand for innovations

Note: The degree of importance of each factor was assessed based on six degrees: Irrelevant (0), insignificant (1), marginally significant (2), significant (3), very significant (4), and crucial (5).

Table A3. Infrastructure index.

During the past year, did the establishment experience the following
Insufficient power for production?
Insufficient water supply for production?

Note: The frequency of unreliability of power and water supply: Never (0), seldom (1), sometimes (2), often (3), very often (4).

Table A4. Sectoral distribution of the firms in the sample.

Sector	Frequency	Percent
Manufacture of Food and Beverages	125	24.95
Manufacture of Textiles and Apparel	125	24.95
Manufacture of Products of wood, paper and furniture;	135	26.95
Manufacture of Printing and reproduction of recorded media	9	1.8
Manufacture of chemicals, basic pharmaceutical products, and rubber and plastic products	10	2
Manufacture of metal products, electrical products, machinery and equipment and repair of machinery and equipment	89	17.76
Other sectors	8	1.6
Sum	501	100