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The Innovation Effects of ICT adoption in Ghana

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Abstract: Based on a sample of 523 manufacturing firms from Ghana, this study tries to uncover the direct and indirect innovation impacts of adopting ICT as a knowledge acquisition channel. The findings reveal that ICT as a source of innovation increases the likelihood of firms to become an innovator. For knowledge acquisition purpose, the adoption of ICT seeks the interaction with innovation inputs in response to the growth of new product sales. The results also suggest that Information acquired from internet is treated as a complemented source to in-house innovation to yield innovation sales new to the market while it replaces imitative innovation activities to enhance the innovation sales new to the firm.

Key word: ICT, Innovation in low-income countries, knowledge acquisition, instrumental effect

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1. Introduction

Innovation in the context of developing countries becomes a more complex system in which R&D is no longer considered as, for the majority of firms, the only core input among various innovation inputs. Due to the lack of internal resources and technological experiences, various external inputs emerge as equally, or more important, contributor to the innovativeness of firms in low-income countries. Although firms in low-income countries actively engaged in various innovation activities, the innovating process remains uncertain and the outcomes vary strongly due to the different levels of absorptive capacity and environmental settings.

The most recent empirical evidence confirms the positive effect of information and communication technologies (ICT) on firm performance not only in terms of economic growth (Bakhshi and Larsen, 2005; Lee et al., 2005; Brynjolfsson and Hitt 1995, 2000; Brynjolfsson and Yang 1998; Brynjolfsson, Hitt, and Yang 2002) and ICT nature itself (Corrocher et al., 2007; Shin & Park, 2007; Sorenson et al., 2006), but also innovation and diffusion patterns of a specific ICT (Chen, et. al., 2007; Vicente and Lopez, 2006; Greenan and Mairesse 2000). ICT has always been acknowledged as one of the main instrument in upgrading a firm's technological capability while many studies has uncovered its critical role in push the technology catch-up in developing countries. Yet evidence regarding the mechanism by which ICT contribute to innovation outcome are inconclusive. Moreover, many previous studies have been limited by focused only on the presence of ICT instead of further investigating the innovation effects of ICT by considering its interactions with knowledge input factors.

There is also considerable policy interest in the implications of different sources of innovation inputs in low-income countries (LDCs). Traditionally, in-house innovation would be targeted mainly at new and significantly improved product innovation (following the results of much earlier surveys, such as Mansfield 1968). In the context of developing countries, innovation would be transformed into different format of behaviours by which not only invention happens, but also imitative innovation also takes place. In addition, other sources of innovation inputs such as ICT investment, has frequently been found to be accompanied by innovations in processing and the organization of work within the firm. To our knowledge, studies that jointly

investigated the innovation effects of innovation activities and ICT adoption are scarce in the developing country context. There are few articles in the literature focused on developed economies and have produced conflicting results. For example, while Cerquera and Klein (2008) find that a more intense use of ICT brings about a reduction in R&D effort in German firms, Polder et al. (2009) find a complementarity effect of ICT with respect to innovation in the service sector only in the Netherlands, albeit one that is small in magnitude.

The current study attempts to highlight the critical role of ICT in the complex system of innovation in low-income countries. Various elements interact and complement each other in the system to reach the goal of becoming innovator. Several questions remain unanswered. Among different knowledge assets in an organization, whether ICT adoption plays a significant role to enhance innovation? How do the impacts vary for different types of innovation? And though which manner ICT is likely to yield the instrumental effects in facilitating innovation? We use an augmented knowledge production function in which ICT is treated in parallel with other innovation sourcing activities as an input to innovation performance. Not only uncover the role of ICT, such specification also takes into account the potential interactive effects between innovation-oriented ICT adoption and different types of knowledge sources.

The next section reviews the previous literatures in innovation in developing countries and the adoption of ICT in innovation. Section 3 introduces the model specification while the data used in the empirical analyses will be presented in section 4. Following section will discuss the empirical results and summarize the findings. Last section will conclude.

2. Innovation in LDCs and the adoption of ICT practices

2.1 Knowledge creation in LDCs

Innovation in least developing countries is gaining increasing mention in the literature as a mechanism to achieve economic development goals. Due to their specificities, firms in LDCs show a particular behaviour with regard to the creation, learning, development, sharing, and transmission of knowledge. Cooper (1989) explained the differences in characteristics between innovation in industrialised economies and

developing countries. At a low stage of development, firms normally face obstacles such as inadequate human capital and poor infrastructure. In-house innovative activities are severely constrained for a majority of firms. Freeman (1989) suggested that external knowledge and compatible innovation infrastructure supports have significant influences on the learning process. Aggarwal (2000) explained that external technological sourcing plays two important roles in developing economies: filling gaps in domestic technological capability and upgrading the existing technologies to international standards. By enhancing the technological capability, external technology sourcing benefits in-house activities.

However, acquiring external knowledge per se does not guarantee that a firm will achieve successful learning (Matusik, 2000). For external knowledge to be exploited effectively, it has to be combined with a compatible innovation infrastructure and complementary assets within the firm. Cooper (1989) mentioned that failure to learn is in fact quite common in developing countries because the firms there that receive technology via external sources are quite often unconcerned about how to develop and appropriate this internal technological supports. Cohen and Levinthal (1989) define "absorptive capacity" to describe the substantial role of a stock of prior knowledge in order to absorb external know-how. They argue that the in-house R&D process would at the same time accommodate firms to build up their own technological capability. This technological infrastructure and absorptive capability within firms is needed in order to understand the tacit components of the technology (Desai, 1989; Lall, 1989; Mowery and Oxley, 1995).

The paradigm of open innovation demonstrated that firms should make the best use of internal and external knowledge (Chesbrough, 2003). This perspective not only emphasises the significant value of external knowledge, it also indicates that firms organise their internal activities in part in order to absorb the wealth of available external information. Such a mutual interaction implies the possible complementary between own and external sources of knowledge.

2.2 The adoption of ICT in innovation

Firms can use ICT for different, but compatible, uses. These are related to acquiring information, facilitating communications and offering the automation of internal business processes. ICT (e.g. Internet) also plays as a knowledge acquisition channel

through which firms in developing countries can get access to advanced technological information and transfer back and share with inter-organizational stakeholders without the time and geographical boundaries. In this sense, ICTcan be used as a corporate channel for one-way information acquisition, dissemination and data access across organizational levels (Huzingh, 2000; Bafoutsou & Mentzas, 2002). The literature argues that the amount of information and knowledge in a modern organization that needs to be stored and shared, and the dynamic evolution of information making the use of technology support is not an option, but a necessity. Even in developing countries, No firm nowadays can afford to ignore new ICTs which radically reduce the time needed to create and communicate knowledge (Nonaka & Nishiguchi, 2001). Beside, ICT is also an effective way to leverage codified knowledge that acquired externally (Zack, 1999). Empirically, even if based on different indicators, the relationship between ICT and innovation and firm performance at the firm level is generally positive (Black and Lynch, 2001; Bresnahan, Brynjolfsson, and Hitt, 2002; Greenan, Topiol-Bensaid, and Mairesse, 2001; Castiglione, 2009).

In the knowledge creation process, ICT adoption also serves as an instrumental factor which contributes to innovation outcomes throughout both direct and indirect interactions with the innovation inputs activities (Adamides & Karacapilidis, 2006). Organization Learning theory suggest that ICT adoption is a process to accumulate an organization's capability, such as absorptive capability, integration, organization learning, and knowledge development (Wiseman & Anderson, 2012; Pavitt, 2003). Therefore, it has become an essential component to reinforce the innovation return of R&D investment (Hicks & Katz, 1996), suggesting that the adoption of ICT practices may increase the effectiveness of internal and external innovation activities, and hence upgrade innovation outputs. Sambamurthy and Subramani (2005) have also defended the critical role of ICTs in shaping organizational efforts for knowledge creation, acquisition, integration, valuation, and use. Ruiz-Mercader etc. (2006) find, from sample of ICT businesses, that these companies are likely to use ICT tools more frequently and they conclude that knowledge creation can be boosted through investing in ICT. Lee and Choi (2003) find that ICT support only has a significant influence on combination. In addition, ICT allows cost reduction communication in comparison to traditional communication tools. It effectively facilitates exchange of

information, collaboration and the possibility of establishing close relationships among various actors within a firm (Kalakota & Robinson, 2000). ICTs, and especially Web technologies, provide great opportunities for the automation of processes (Fischer, 2004).

However, ICTs used to support knowledge creation present some limitations, since they reduce the very richness of knowledge when it is codified and management and sharing of tacit knowledge through technologies is problematic (Flanagin, 2002). Some of the previous studies had pointed out that ICT alone is not enough to lead successful innovation and affect firm's productivity. Black and Lynch (2001) and Bresnahan, Brynjolfsson, and Hitt (2002) focus on the interaction between ICT and its complementary assets (human capital in this case) and discover their impact on organizational innovation. Meanwhile, the ability of using ICT to support knowledge creation in a meaningful manner depends on the types and natures of knowledge (Flanagin, 2002). Therefore, the technological-oriented information acquiring via Internet would not necessarily induce positive innovation effect.

In summary, the benefits derived from ICT implementation, which include efficient information and knowledge sharing as well as working with no distance limitations, are expected to be positively related to knowledge creation, which in turn may affect higher levels of innovation. However, ICT cannot improve innovation performance in LDCs if it is not used appropriately. We argue that the orientation in the implementation of ICTs can also have an impact on the different processes for creating knowledge. The innovation-oriented ICT as a source of innovation increases the likelihood of firms to become an innovator. For knowledge acquisition purpose, the adoption of these practices seeks the interaction with innovation inputs in response to the growth of new product sales.

2.3 Country background

Since the early 1990s, Ghana has considered the use of ICT as a means to leverage the country's development process. To this effect, a first five-year plan for accelerated development was launched in 1994. More recently, Ghana has developed its ICT for Accelerated Development (ICT4AD) policy statement, which was officially adopted in 2004. The ICT4AD took into consideration Ghana's Vision 2020 Socio- Economic Development Framework, the Ghana Poverty Reduction Strategy (2002–2004) and

the Coordinated Programme for Economic and Social Development of Ghana (2003–2012). The ICT4AD is a product of the National ICT Policy and Plan Development Committee set up by the Government to develop an ICT-led socio-economic development policy for the country. It aims to help Ghana to formulate a number of socio-economic development policy frameworks over years has identified a number of key developmental objectives to address the developmental problems facing the country. Of these policy frameworks, promote investment, innovation, R&D and diffusion of ICTs within the economy are one of the priorities. As a results, there has been a rapid growth of ICT adopt in local business and it has also been widely used to facilitate innovation activities.

In the developing country context, a stand of literature has discussed intensively regarding the ICT capability and its impact on firm performance (Bhagwat and Sharma, 2007; Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000; Dewett and Jones, 2001). Although ICT has been evolved to support new business strategies (Henderson and Venkatraman, 1999), the adoption of ICT in Ghana still plays its major role in traditional back office. Given the lack of internal technological capability and limited innovation resources, the adoption of ICT does not guarantee the knowledge creation within the firm.

3. Model specification

Innovation performance: dichotomous measures

As discussed in the previous sections, innovation in LDCs is more of an imitative behaviour rather than invention or knowledge creation process. Various sources could contribute to innovation performance besides investing in R&D. Given the limited strategic resources to invent new product or services, innovations are primarily developed in response to customer needs and they emerge and are developed in accordance to customer requirements. In such circumstances, firms in LDCs seek alternative sources such as through directly acquiring from Internet, collaborating with other actors, obtaining technology etc. Meanwhile, innovation performance will also be captured with different measures. First, we are interested in whether a firm is

an innovator or note. The dichotomous variable will be used to denote if a firm is innovator as given below

$$Y_I = \alpha + \beta_{inno} Inno_{activities_i} + \beta_{int} Internet_i + \beta_{md}\left(Inno_{activities_i} * Internet_i\right) + \beta_{int's} Int\_source_i + \beta_c Control_i + \varepsilon \quad (1)$$

$$\beta_{inno} Inno_{activities_i} = \beta_1 inhouse_i + \beta_2 Collaborate_i + \beta_3 Imitate_i \quad (2)$$

Yi is dichotomous variable takes value 1 if a firm is an innovator (product, process or management innovation). 'Internet' equals 1 if a firm has reported using Internet facilities within the firm. 'Int_source' is a binary variable taking value 1 if a firm report Internet has been adopted as an important channel to achieve innovation. 'Inno$_{activitiesi}$' captures a set of innovation inputs, including conducting in-house innovation activities, modifying existing products or process, collaborating with other actors, licensing and imitating existing technologies. The detailed definitions of each innovation inputs are given in Appendix A. 'Control' denotes a vector of control variables: age, scale, ownership, industry dummies etc. ε is the disturbance term. In equation (1), 'Int_source' enters as an explanatory variable which directly influence the propensity of a firm becoming an innovator. It is different from the ICT adoption '$Internet_i$' which is expected to take an instrumental role to complement other innovation inputs in the knowledge creation process. Such instrumental role is captured by the interaction term 'Innoactivities*i** Interneti' and equation (1) will be estimated with multivariate probit in which correlations between residuals from each type of innovation are taken into account.

Innovation performance: new product sales

Another indicator used to measure firms' innovation performance is new product sales. New product sales denote the ratio of sales of new product in total sales and it is recorded in a continuous manner. The ratio of new product sales is a function of knowledge inputs, ICT adoption and a set of firm characteristics with controlling for size, industry and location specificities. Given the censored nature of new product sales, Tobit estimation will be adopted in estimating the innovation function. Additionally, by including the interactions between ICT and knowledge inputs variable, it also systematically examines the potential complementarities existing among them.

$$PD_i^* = a + b_{inno} Inno_{activities_i} + b_{int} ICT\_source_i + b_{md}\left(Inno_{activities_i} * ICT\_source_i\right) + b_c Control_i + e \quad (3)$$

$$PD_i = \begin{cases} PD_i^*, & if\ PD_i > 0 \\ 0, & otherwise \end{cases}$$

where PD_i^* indicate ratio of new product sales in total sales. PD_i^* is a latent variable and observed only if PD is positive. '$Inno_{activitiesi}$' is defined as in equation (2) and it captures a set of innovation inputs. Two implications regarding the use of ICT in LDC firms will be given by estimating equation (3). First, the directly effects of 'ICT_source' in determine the level of innovation outcome will be captured by coefficients bint's. Second, with controlling for the potential interaction between the adoption of internet and innovation inputs, we will be able to uncover the intrinsic role of ICT in facilitating innovation by interacting with different types of knowledge sourcing activities.

4. Data and variables

The firm-level data –Diffusion of Innovation in Low-income countries (DILIC)[1] - conducted by Technology Management Centre for Development (TMCD) at Oxford University and the Ghanaian Science and Technology Policy Research Institute (STEPRI) covers a broad range of innovation related aspects across different stages of innovation process in Ghanaian manufacturing firms. The DILIC survey collects information of 525 firms[2] in Ghana and the data was collected through in-depth interviews. The interviews covered four main dimensions: innovation activities, process of innovation, barriers to innovation transmission and space for innovation policies. In order to have a comprehensive understanding of the nature and constraints to innovation, interviewees included a range of actors: senior managers, departmental managers (production, marketing, and human resources), R&D staff, technicians, and workers. For the firms in the informal sectors, the managers and workers were the main source of information since those firms did not have complex functional

[1] Funded by an ESRC-DFID grant, the DILIC project has had international breadth with investigators and advisors from Oxford University, the United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT), the Ghanaian Science and Technology Policy Research Institute (STEPRI), the University of Cape Town, Tshwane University of Technology, and the United Nations Conference on Trade and Development (UNCTAD).

[2] The 525 interviews were across 5 major regions in Ghana, including Great Accra, Ashanti, Central, Eastern and Northern region.

departments. Many covered information are particularly useful for the current study including whether the firm recently has new product or process innovation, innovation input activities, and in particular, information with respect to the adoption of ICT and the intensities of product innovation. Table 1 defines all variables used in the empirical analysis and shows the corresponding summary statistics.

Table 1 Summary of variables

Variable	Definition	Mean	S.D.	Min	Max
Dependent variables					
Product dum.	Value 1 if a firm reports having product innovation in the past three years	0.44	0.50	0	1
Process dum.	Value 1 if a firm reports having process innovation in the past three years	0.60	0.49	0	1
Management dum.	Value 1 if a firm reports having management innovation in the past three years	0.40	0.49	0	1
Product inno. sales in %	Percentages of sales due to new product innovation	21.35	29.41	0	100
Product inno. sales new to firm in %	Percentages of sales due to new product innovation, new to firm.	3.60	12.36	0	80
Process inno. sales new to market in %	Percentages of output due to process innovation new to market	17.75	25.02	0	100
Independent variables					
In-house	Value 1 if a firm reports conducing in-house innovation activities, dummy	0.64	0.48	0	30
Collaboration	Value 1 if a firm reports conducing collaborated innovation activities, dummy	0.44	0.50	0	1
Imitation	Value 1 if a firm reports conducing imitative innovation activities, dummy	0.44	0.50	0	1
ICT_source	Value 1 if a firm reports using Internet as a source to acquire innovation, dummy	0.12	0.32	0	1
Controlled variables					
No. Employee	Number of total employees, in logarithm	1.87	1.34	0	7.55
Ln.age	Logarithm of firm's age	2.65	0.65	0	4.16
Foreign, dum.	Value 1 if a firm is shared with foreign ownership	0.07	0.25	0	1
Competition, dum.	Value 1if a firm perceives the competition in the local market is fierce	0.49	0.50	0	1
Technician ratio	Ratio of employees which completed technical trainings	0.07	0.18	0	1

Innovation performance is measured with two indicators: a dichotomous and a continuous term. As given in equation (1) and equation (3), innovation is a function of

innovation inputs and a set of controlled variables. Although taking various forms in LDCs, knowledge sources are still the main contributor to innovation performance. Without engaging in effective knowledge acquiring or creation activities, firms may fail to achieve innovation goals given the unavoidable uncertainties and risks of innovation. Therefore, it is essential to distinguish different types knowledge sources and evaluate their innovation effects.

The dependent variable in the innovation equation (3) is product innovation and it is a continuous variable, in logarithm. The explanatory variables are the set of innovation inputs. Firms are asked to report if they have engaged in any of the indicated innovation activates during the survey period. The knowledge input variable will be given value 1 if a firm reported engaging in the corresponding activity. As a innovation-oriented ICT practice, 'ICT_source' a binary measure specifies that a firm has adopted Internet as a channel to acquire innovation-related information. The descriptive statistics below show that innovators, regardless the types of innovation, are in general more likely to engage in innovation activities and they also tend to use Internet more frequently than non-innovators.

The survey contains information on a set of firm and industry specifics. We control for several variables that capture the firms' competitiveness and technological capability. The natural log of number of employees serves as an indicator of the capital intensity. Firm size is measured by the natural log of the mean of number of employees. We also control for industry and year specificities by using industry and year dummies. In accordance with the Schumpeterian, firm size has been included as control variable. The first Schumpeter hypothesis claims that innovation activity increases more proportionately than firm size, larger firms are expected to have more resources to allocate to innovation, which leads to better innovation performance. Scale in logarithm is measured by the total number of employees by the end of 2013 and it is used to capture the scale effect of innovation. Company ownership can be a crucial variable in innovation performance in the case of Ghana, as it affects the motivation to innovate and the continuity of business strategy. Foreign-owned firms are characterized by higher capital intensity, high quality of human capital and efficient management. Many previous studies suggest that foreign-owned firms are more innovative (Kimura & Kiyota, 2007). Many previous studies suggest that

foreign-owned firms are more innovative and productive compared to domestic ownership firms (Globerman et al., 1994; Doms and Jensen, 1998; Kimura and Kiyota, 2007). 'Foreign' indicate if a firm is shared with foreign ownership. AGE is calculated as the number of years evolved since the enterprise started production, up to 2013. Young firms are expected to be more dynamic and innovative, all other things equal (Katrak, 1997), and therefore a negative effect is expected.. 'Competition' is measured by the scale of competition in the domestic market perceived by interviewed firms. We also control for industry and year specifics by using industry and year dummies.

Table 2 Descriptive statistics: sourcing strategies across innovativeness

	In house	Collaboration	Imitate	ICT_source	Size	Age	Foreign	Compete	Uni.
Product									
No	0.427	0.308	0.319	0.054	1.646	2.606	0.054	0.437	0.041
Yes	0.917	0.605	0.588	0.202	2.149	2.716	0.088	0.548	0.119
Process									
No	0.378	0.239	0.191	0.048	1.682	2.592	0.091	0.344	0.040
Yes	0.815	0.570	0.599	0.166	1.987	2.696	0.054	0.580	0.098
Management									
No	0.468	0.334	0.341	0.057	1.703	2.588	0.057	0.411	0.049
Yes	0.900	0.593	0.579	0.211	2.108	2.753	0.086	0.598	0.113
Total	0.641	0.438	0.436	0.119	1.865	2.654	0.069	0.486	0.075

Int_source: Internet was reported as an important source of innovation.

To get some preliminary implications regarding the relationships between different types of knowledge inputs, Table 3 below presents the pairwise correlation matrix results. Two issues are worth mentioning here. First, innovation is not a single path process. Multiple activities can be conducted simultaneously to achieve innovation. The positive correlation between in-house activities and other types of sources suggest that knowledge-acquiring behaviours are potential associated especially in-house creation, modifying existing technologies and collaboration with other actors. Such associations between various innovation inputs imply the potential interdependent relationships among them. Second, not all the innovation inputs and ICT practices conducted in a firm will be treated as complements elements. Some of they may enter the innovation process as substitutive inputs. This is particularly true while firms making innovation investment decisions in LDCs, where financial, technicians and other strategic resources are limited. Increasing the investment of

these substitutive inputs would result in the decrease in the investment of other inputs such as in-house R&D. In such circumstances, positive correlation will not be appeared. As one of the major channels to acquire knowledge externally, innovation through imitative activities does not appear to have strong associations with other types of knowledge inputs. This may be caused by the hard budget constraints of the firm. Without enough investment to allocate to multiple knowledge inputs, optimize the inputs regarding the innovation performance become difficult. The negative association between 'ICT_source' and 'Imitate' may reflect this point.

Table 3 correlation matrix: innovation sources

	Product Inno.	Process Inno.	Management Inno.	In-House	Collaboration	Imitation	ICT_source
Product Inno.	1						
Process Inno.	0.32	1					
Management Inno.	0.22	0.22	1				
In House	0.51	0.45	0.44	1			
Collaboration	0.30	0.33	0.26	0.53	1		
Imitation	0.29	0.46	0.26	0.21	0.09	1	
IT_inno. source	0.23	0.18	0.23	0.23	0.17	0.02	1

5. Empirical evidence

Table 4 presents the Multivariate Probit results. The left panel are the estimates in which interaction terms (complementary effects of ICT) are included. Having relatively more capital, human and strategic resources, large firms tend to be more innovative compared to small sized firms. Such effect is reflected by the positive estimates of log employees, although the innovation effects only appear in product and process innovation. Given the simple structure and smaller size of employees, Small sized firm, management innovation may takes place easier among small sized firms in Ghana. The foreign ownership variable included in the process innovation exerts a significant negative impact on the likelihood of process innovation. Such finding suggests that firms with foreign ownership tend not to be innovative. This may because that most of innovation activities are conducted back in their home countries (OECD, 2003). More vigorous competition exerts discipline on firms. It therefore tends to strengthen their efficiency and push firm to be more innovative in

order to survive, and the estimated coefficient of competition shows a positive innovation effect in process and management innovation.

Regarding the knowledge acquisition activities, in-house innovation activities is found to have significant positive effects on the likelihood to become innovator, regardless the types of innovation. 'Imitation' competitor is a significant innovation input strategies to all three types of innovation whereas process innovators are more likely to adopt collaboration as their innovation inputs. Among three types of innovations, in-house innovation activity has the highest coefficient for process innovation, which reflects its significant role in increasing the likelihood of becoming a process innovator. The direct innovation effects of acquiring knowledge via Internet are exhibited in the results, suggesting ICT as a source of innovation increases the likelihood of firms to become an innovator.

Table 4 Probit results: the role of ICT in determining the likelihood of becoming innovators, without and with Internet interactions

VARIABLES	Product inno. (1)	Process inno. (2)	Management inno. (3)
In-house	1.364***	0.851***	1.274***
	(0.182)	(0.169)	(0.191)
Collaboration	0.078	0.533***	0.209
	(0.149)	(0.159)	(0.150)
Imitation	0.616***	1.039***	0.610***
	(0.146)	(0.152)	(0.146)
ICT_source	0.473*	0.374	0.211
	(0.252)	(0.283)	(0.233)
No. employees	0.196***	0.166**	-0.004
	(0.067)	(0.072)	(0.067)
Ln.age	-0.010	0.051	0.161
	(0.114)	(0.117)	(0.112)
Foreign	-0.074	-0.958**	-0.152
	(0.342)	(0.375)	(0.346)
Competition	0.243*	0.440***	0.416***
	(0.141)	(0.146)	(0.141)
Technician ratio	0.640	1.280**	0.687
	(0.423)	(0.498)	(0.431)
Constant	-1.952***	-2.866***	-2.965***
	(0.748)	(0.788)	(0.786)
Observations	523	523	523

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; industry dummies are included

We now turn to the results of the econometric analysis regarding how ICT affect the intensity of innovation. We estimate ICT's interactive effects in affecting innovation

performance and estimated coefficients are presented in Table 5 for product innovation and process innovation, with standard errors given in parentheses. Acknowledged as one of the most crucial sources of innovation, in-house activities drive innovation of Ghanaian firms via directly improving the innovation performance regardless of product or process innovation. The estimated coefficients for 'in-house' are all positive and significant at 99 per cent level. The same innovation effect has also been observed for imitative activities despite the magnitudes are much lower. Although both internal creation and external imitation are of essential to product innovation, it is confirmed in our results that in-house R&D investment plays a more important role to increase innovation sales compared to buying technology externally. The scale effects have also been observed for innovation intensity, as shown in Table 5. Larger size firms are expected to have more resources to support innovation. In terms of new product sales, firms having large number of employees have performed significantly better than those with fewer employees. Competition effects are also shown to enhance intensity of innovation. Neither 'ln.age', nor 'foreign' coefficients are significant.

The estimated coefficients of ICT suggest that, without taking into account the potential interactive effects, ICT significantly contribute to innovation performance and the adoption of ICT increases the ratio of sales due to both product and process innovation. Turning to the models with interaction terms, the variables of 'ICT_source*inhouse' is significant in the model 5, suggesting that there is a moderate effect of innovation-oriented ICT adoption to in-house innovation. Hence, Information acquired from internet is treated as a complemented source to in-house innovation to yield innovation sales new to the market. In contrast to innovation new to the market, different patterns are exhibited for innovation new to the firms. There is a replacement effect exhibited between 'ICT_source' and 'imitate', as shown by the corresponding coefficient (Model 6). This finding suggests that Information acquired from internet replace imitative innovation activities to enhance the innovation sales new to the firm.

Table 5 Tobit estimation results: the role of ICT in fostering innovation intensity

VARIABLES	Product inno. Total (Model 1)	Product inno. New to market (Model 2)	Product inno. New to firm (Model 3)	Product inno. Total (Model 4)	Product inno. New to market (Model 5)	Product inno. New to firm (Model 6)
In-house	0.574***	0.694***	0.488***	0.542***	0.548**	0.469***
	(0.071)	(0.226)	(0.062)	(0.074)	(0.224)	(0.065)
Collaboration	0.059	0.045	0.036	0.053	0.081	0.043
	(0.051)	(0.104)	(0.045)	(0.059)	(0.131)	(0.051)
Imitation	0.231***	0.084	0.216***	0.273***	0.149	0.255***
	(0.052)	(0.106)	(0.045)	(0.057)	(0.127)	(0.050)
ICT_source	0.205***	0.286**	0.167**	0.164	0.072	0.200**
	(0.078)	(0.134)	(0.069)	(0.103)	(0.178)	(0.092)
ICT_source *inhouse				0.198	0.532*	0.106
				(0.144)	(0.280)	(0.127)
ICT_source* collab				-0.001	-0.124	-0.041
				(0.121)	(0.211)	(0.107)
ICT_source* imitate				-0.216*	-0.214	-0.198**
				(0.114)	(0.221)	(0.100)
No. employees	0.065***	0.012	0.062***	0.058**	-0.009	0.061***
	(0.023)	(0.045)	(0.020)	(0.023)	(0.045)	(0.021)
Ln.age	-0.005	-0.039	-0.004	-0.006	-0.045	-0.004
	(0.040)	(0.079)	(0.035)	(0.040)	(0.079)	(0.035)
Foreign	0.006	0.196	-0.036	-0.052	0.099	-0.074
	(0.110)	(0.184)	(0.099)	(0.115)	(0.189)	(0.103)
Competition	0.082*	0.177*	0.055	0.080	0.165	0.051
	(0.049)	(0.102)	(0.043)	(0.049)	(0.102)	(0.043)
Technician ratio	0.067	-0.098	0.121	0.074	-0.090	0.132
	(0.133)	(0.249)	(0.117)	(0.133)	(0.247)	(0.117)
Constant	-0.660***	-0.909**	-0.737***	-0.677***	-0.916**	-0.736***
	(0.246)	(0.448)	(0.222)	(0.252)	(0.455)	(0.225)
Sigma	0.428***	0.538***	0.375***	0.426***	0.530***	0.372***
	(0.022)	(0.065)	(0.020)	(0.022)	(0.064)	(0.019)
Observations	523	523	523	523	523	523

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1; industry dummies are included

6. Final remarks

The lack of advanced technological competencies in LDCs requires innovation to occur through the absorption of existing knowledge and the adoption of existing technologies. Due to the inadequate experiences and limited resources allocating to the technology development, innovation in developing countries normally face greater risks and uncertainties compared to developed countries. A well-designed and optimal investment level for innovation is therefore needed in order to achieve technological

catching-up. In the low-income countries, the low levels of technological infrastructure and lack of competence R&D personnel severely inhibits firms in their efforts to build up their own knowledge stock. Meanwhile, the presence of hard budget constraints requires firms in these countries to seek a balance point between internal and external innovation inputs to optimize their investment, which result in the failure of benefiting from the potential complementarity. Hence, firms in countries where income-level is low and technology capability is weak are more likely to rely instead on alternative knowledge acquisitions such as imitative behaviours and ICT technologies. The returns of the technological acquisition via Internet verify the substantial contribution of ICT for innovation performance in Ghanaian manufacturing firms.

The empirical findings reveal that the adoption of ICT not contribute to innovation directly by influence the innovation output, it also seeks the interaction with innovation inputs in response to the growth of new product sales. It is important to emphasis the role of the Internet as a vector of innovation information. Among the sample firms that have access to the Internet, the Internet is considered a significant source of information. This is relevant, considering the potential which the Internet holds to overcome the lack of information in low income countries and allow users to find specific knowledge sources. Besides getting access to strategic information, ICT serves as an instrumental factor and its' function of facilitating in-house innovation is acknowledged by Ghanaian manufacturing firms. The adoption of ICT offers a unique and integrated opportunity for interacting with innovation activities. In this regard, ICTs facilitate the in-house innovation (as potential innovation infrastructure) and become part of the integrated innovation resources to affect innovation performance. By differentiating the innovation sales new to the market and new to the firm, we found that the presence of knowledge acquisition Internet has helped firm to utilize the use of in-house innovation activities and eventually yield high innovation sales which are new to the market. Ghanaian manufacturing firms, in particular those achieve innovation mainly replying on imitating competitors adopt Internet as a replacement for their imitative activities.

Obtaining information via the Internet and pairing international standards with local production were acknowledged as the important channel by the Ghanaian manufacturing firms. Therefore, it is important for host-country governments to

differentiate between the policy needs of firms which target in different types of knowledge sources and also different types of innovation. ICTs are tools that allow knowledge flow and information exchange. The adoption of ICT can break the geographic boundaries and help firm gain access to the global knowledge pool. To ensure the success of international technology transfer, a fundamental challenge for developing countries is to improve the local innovation environment and climate to encourage domestic firms to open up various channels (e.g. Internet knowledge sourcing) that allow them to access the international stock of knowledge, and strengthen the interactions between ICT practices and innovation activities that foster knowledge creation.

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