ISSN 2045-5119

University of Oxford

Department of International Development

TMCD Working Paper Series

No. 085

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Abstract

The employment effect of information and communication technologies has been a key concern of public policy. Our understanding of the ICT-employment growth relationship in both informal and formal sectors in developing countries, however, remains limited. Based on repeated cross-sectional data collected in 2013 and 2015 on 483 Ghanaian manufacturing, this paper shows that access to the internet leads to employment growth in enterprises, while the adoption of mobile phone technologies reduces the number of workers in enterprises. The positive effect of internet access on employment growth tends to be greater in enterprises with a higher degree of formality, while informal enterprises appear to remain small in terms of employment by using internet technology. The paper contributes to the literature by analysing the employment effects of ICT in low-income countries, especially in the informal versus the formal sectors, and their relevance for digital technology policy in developing countries.

Keywords: Information and Communication Technologies; Employment; Small Enterprises; Informality, Ghana; Africa.

JEL Codes: O17; O33; O55; Q55; J40

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1. Introduction

Information and communication technologies (ICTs) are at the heart of today's global digital technology revolution (Brynjolfsson et al., 2010; Heeks, 2010; Fu, 2020). As a result, there is a wealth of literature examining the effect of ICT on growth and development, particularly in developing countries. The emerging evidence suggests that ICTs drive economic growth and enhance various dimensions of development such as capabilities building and access to information, education, finance, and health services (Kaushik and Singh 2004; Chaudhuri, 2012; Fu, 2013; Garcia-Murillo, 2015; Fu and Akter, 2016; Palvia et al., 2018; Hjort and Poulsen, 2019).

In Africa, the evidence is mixed. ICTs are found to boost inclusive human development and poverty alleviation in the region (Asongu and Roux, 2017; You, et al., 2020). ICTs such as mobile phones, for instance, are also found to have an appealing complementary role for some business dimensions (Asongu, et al., 2018) and positive net effects on value added to the service sector (Asongu, et al., (2020). Gaglio et al. (2022) found similar results, indicating that selected digital communication technologies have a positive effect on innovation, and a subsequent positive effect on labour productivity in micro and small enterprises in South Africa. On the contrary, the evidence also suggests that the ICTs revolution is biased towards large enterprises, threatens the survival of local and informal SMEs, and it is yet to transform African SMEs (Murphy and Carmody, 2015; Foster et al., 2018). The enhancement of mobile phone and internet penetrations both, for instance, have net negative effects on value added in the agricultural and manufacturing sectors (Asongu, et al., (2020).

Despite the growing empirical evidence examining the effect of ICT on various measures of firm performance, the available literature remains biased towards productivity and innovation effects of ICTs (Biagi, 2013; Brynjolfsson and Yang, 1996; Gaglio, et al., 2022) or the role of ICTs in bridging the digital divide (Heeks, 2010; Fu, 2013; Fu and Akter, 2016; Koomson, et al., 2021). Given the nature of ICTs and its potential disruption to the labour market, understanding the employment effects of ICTs is critical for policy, specifically in Africa. Theoretically, this is important given that the effect of ICTs, a process innovation with direct cost-saving and efficiency effects on enterprises (Koellinger, 2008; Brynjolfsson and Hitt, 1996; Gaglio et al., 2022), may generate ambiguous effects on employment in Africa. Also, given that ICTs are skill-biased (Bresnahan et al., 2002), its adoption in firms may lead to lower growth in total employment in developing countries. Finally, given that the diffusion of ICTs is uneven (Hjort and Poulsen, 2019), particularly in Africa, there may be substantial differences in the adoption and use of ICTs within

and across formal and informal enterprises, leading to heterogenous effects on employment growth.

However, the literature on the effect of ICTs on employment growth, is under-researched in Africa (Khan et al., 2017). Majority of the available research is concentrated in the context of the developed countries (see, for instance, Fossen and Sogner, 2022; Aubert-Tarby, et al., 2018; Dengler and Matthes, 2018; Brougham and Harr, 2020). In exception, Hjort and Poulsen (2019), for instance, found that fast internet appears to have a positive impact on employment rates in twelve African countries. However, this evidence also ignores the 'dualist' structure of African economies – registered (formal) and unregistered (informal). Given that the informal economy is significant in Africa, and ICTs have been identified as key in transforming the performance of informal enterprises (Deen-Swarray et al., 2013; Garcia-Murillo and Velez-Ospina, 2017), it is crucial to examine enterprises' ICT adoption behaviours, and how they differ across formality status of firms.

This paper aims to contribute to this literature by investigating the effect of ICT on employment growth in Ghanaian manufacturing enterprises. Specifically, we examine the relationship between ICT adoption and employment growth in Ghanaian manufacturing by posing two main questions: (1) Does the adoption of ICT- access to the internet and mobile phone use - affect the manufacturing employment growth of both formal and informal enterprises in Ghana? (2) Does the formality status of enterprises influence ICTs' effect on manufacturing employment growth?

We employ balanced repeated cross-sectional data collected as part of the Diffusion of Innovation in Low-Income Countries (DILIC) project in Ghana, covering the period 2011-2015.[1] Estimating Feasible Generalised Least Squares (FGLS) panel regression, our results show that internet use enhances the growth of enterprises in terms of employment, while the use of mobile phones displaces workers. These effects are much stronger for firms that are closer to the formality end of the scale on the informality-formality continuum. Our results also show three key developments associated with enterprises' employment growth. Firstly, domestic market size, multiple ownership, and informal training influence the employment growth of informal firms. Secondly, male-ownership, subcontracting, and being part of a group of companies are important determinants of the employment performance of more formal enterprises. Given that the Government of Ghana is implementing considerable policy initiatives to promote and enhance

[1] The Diffusion of Innovation in Low-Income Countries (DILIC) project was an international project to study the innovation activities and diffusion of technologies in developing countries. DILIC was funded by the UK's Economic and Social Research Council and Department for International Development.

digital technologies in enterprises, these findings provide insights into the relationship between ICTs and labour market dynamics using data collected across all the major regions of Ghana.

This paper contributes to the literature in several ways. Firstly, it contributes to the literature on ICT and employment by providing rare quantitative evidence from low-income countries. As far as we are aware, this is one of the first firm level evidence on the employment effect of ICT in the African context. Secondly, the informal economy is a major sector in low-income countries. However, this sector is under-researched. Our understanding of the behaviour of firms in this sector and the impact of ICTs on this sector is very limited. This study contributes to the literature by providing the first comparative evidence of the employment effect of selected ICTs on the informal versus the formal sectors; and offers useful policy implications for technology policy in developing countries. Thirdly, the study uses two repeated cross-sectional data sets which allows us to examine the dynamic effects of ICTs on the employment growth of enterprises. The use of similar data is absent in the literature (see Siba, 2015, for a rare exception).

The rest of the paper is structured as follows. Section presents and discusses the literature on the effect of ICT on employment in developing countries. Sections 3 and 4 discuss the methodology and empirical findings from the econometric regressions respectively. Section 5 concludes the paper with some key policy directions emerging from the paper.

2. ICT and employment growth in developing countries

The emerging fourth industrial revolution (4IR) technologies promise to generate growth for economies and firms that successfully adopt and leverage the benefits of ICTs-based digital technologies. As a result, developing countries are implementing policies that aim to close the technological gap through the acceleration of ICTs-based digital learning and upgrade in firms.

At the firm level, ICTs are an important driver of value creation and success in firms. In particular, ICTs adoption is found to enhance organisational and production processes (Bresnahan et al., 2002), drives productivity (Brynjolfsson and Hitt, 2000), and the innovativeness of firms (Koellinger, 2008; Fu and Hou, 2020). The literature, therefore, shows a strong positive relationship between ICTs and the performance of firms, although largely focusing on the productivity and innovation effects of ICTs.

From a theoretical stance, however, the dominant positive effects of ICTs in the productivity and innovation literature may not be easily extrapolated to the ICTs-employment literature for three

reasons. Firstly, the effect of ICTs on employment may be ambiguous given that ICTs are a process innovation that may have direct cost-saving and efficiency effects on enterprises (Koellinger, 2008; Brynjolfsson and Hitt, 1996; Gaglio et al., 2022). The efficiency gains from process innovation may also lead to lower prices, thereby incentivising demand and leading to positive net employment growth (Avenyo et al., 2019). Secondly, according to skill-biased technical change theory, ICTs are skill-biased (Bresnahan et al., 2002) and as a result, may lead to lower growth in total employment in developing countries. Thirdly, given that the diffusion of ICTs is uneven (Hjort and Poulsen, 2019), there may be substantial differences in the adoption and use of ICTs, and subsequently, their effect on the employment performance of informal enterprises compared with their formal counterparts.

In the empirical literature, there is growing research on the effect of ICTs on employment. Bresnahan et al. (2002) highlight the critical importance of indirect mechanisms in explaining how ICTs affect the demand for labour in the United States of America. Aubert-Tarby, et al. (2018) found ICTs to be employment neutral in Europe (Biagi and Falk, 2017). In the context of developing economies, using industry level data from China, Wang et al. (2020) found that internet directly promotes employment within an industry, and indirectly through inter-industry spillovers on employment in other industries and positively affects employment within industry. In Latin America, Garcia-Murillo (2015) find conflicting results, with the use of mobile phones having a significantly negative influence on employment.

Presenting a rare example, Hjort and Poulsen (2019) analyse the impact of the internet on employment across twelve African countries. The authors find a significantly positive effect of fast internet speeds on the probability of employment. Further analysis by the authors shows that the positive employment impacts of ICTs are driven mainly by the growth in skilled employment, an increase in employment of less-educated workers, increase in entry by new firms, and the enhancement of productivity and the exporting activities of firms. In a related study in twelve SSA countries, Khan, et al. (2017) find mixed effects of ICTs on employment. The authors find internet use to have a negligible effect on the probability of employment, while mobile phone ownership tends to have a positive effect on the probability of employment only in certain countries. Similar results are found for Botswana by Tshukudu (2019).

The foregoing literature suggests that there is non-convergence in the empirical literature, in terms of the relationship between ICT and employment growth. More importantly, in Africa, the limited available evidence focuses only on the formal economy and the activities of formal enterprises.

The growing literature on formality and informality shows that the dualist view is not realistic (Avenyo et al., 2020; Maloney, 2004), and that all enterprises in developing countries, both registered (formal) and unregistered (informal), operate along a continuum where they have varying degrees of informality (Ulyssea, 2018; Williams et al, 2016; Bohme and Thiele, 2014, Kawooya, 2014). The empirical evidence from the informality literature shows that the level of employment and output of the informal sector is critical to the economies of most developing countries, and that ICTs are key in transforming the performance of informal enterprises (Deen-Swarray et al., 2013; Garcia-Murillo and Velez-Ospina, 2017). However, the ICTs-firm employment literature has largely ignored the effect of ICTs adoption behaviours of informal enterprises.

The transition to formality, as discussed in the ILO's 'Transition from the Informal to the Formal Economy Recommendation (No. 204)' offers opportunities for structural transformation in developing countries. Given that ICTs are general-purpose technologies, these technologies could influence the formalisation (transition) of informal enterprises, or otherwise, through reductions in transaction costs and general efficiency gains. For instance, Garcia-Murillo and Velez-Ospina (2017) examined the role of ICTs in transitioning informal activities to the formal sector. Using country-level data from 170 countries, the authors found that mobile phone use leads to the growth of the informal economy (transition to informality). Access to broadband internet reduces the size of the informal economy (transition to formality).

It follows that if the persistence of the informal sector is detrimental to the economic performance of countries, as argued in the empirical literature (see among others Ulyssea, 2018; La Porta and Shleifer, 2014, 2008), then the transition of enterprises from informality to formality or otherwise because of ICTs, may explain the employment growth in enterprises.

However, there may be differences in the ICTs adoption behaviours of informal enterprise compared with formal firms,[2] and in how ICTs adoption affects the employment performance of informal enterprises compared with their formal counterparts. Accordingly, we ask: How will the level of formality affect the impact of ICT adoption on jobs in the firms in Africa? Would the informal enterprises respond different to the opportunities offered by ICT? This paper provides evidence on these relationships.

3. Methodology

[2] Ilavarasan (2019), for instance, found that the use of ICTs is limited in informal enterprises in India.

3.1 Data

We use two repeated cross-sectional data sets collected as part of the Diffusion of Innovation in Low-Income Countries (DILIC) project in Ghana: cross-section 1 conducted at the end of 2013 (covering 2011-2013), and cross-section 2 conducted at the end of 2015 (covering 2013-2015). The data sets were collected by the University of Oxford's Technology Management Centre and Development (TMCD) and the Science and Technology Policy Research Institute (STEPRI-Ghana). This novel enterprise-level data cover formal and informal Ghanaian manufacturing enterprises across all major regions of Ashanti, Central, Eastern, Western, Greater Accra, and the then designated Northern Regions.

Informal enterprises do not appear in official databases, therefore the survey employed different sampling procedures for formal and for informal enterprises. For formal enterprises, the sampling frame (population of enterprises) was used on three main sources: the 2003 National Industrial Census; the Micro, Small, and Medium Enterprises database; and the register of the Association of Ghana Industries (AGI). The population of informal enterprises was based on a random sample of 25 enterprises in 10 clusters across purposively selected sub-sectors and regions. The sampling frame comprised 4,658 enterprises. Random sampling was conducted to select enterprises by stratifying enterprises into industry, size, and region. For cross-section 2, for instance, a total of 502 enterprises consisting of 321 informal enterprises and 181 formal enterprises were sampled and surveyed.[3]

Both cross-sections of the data contain detailed information on enterprises' characteristics, including sales, employment, etcetera in both the formal and informal economies. The data contain two main ICTs variables of interest: access to the internet, and access to mobile phones that we use in this paper to examine the effect of access to ICTs on employment growth.

A major advantage of using the DILIC data is that the survey collected information on enterprises by stratifying them into different status based on their registration and the nature of their main economic activities. In both cross-sections of the DILIC survey, the status of an enterprise is defined by registration with the Registrar General's Department. The law in Ghana considers all enterprises without a business registration certificate to be an informal enterprise, while all registered enterprises are formal enterprises. For the DILIC data collection all participants were asked to indicate based on their operations how they define the nature of their enterprise. This

[3] See Table 1 for the list of enterprises by manufacturing industries for cross-section 2.

enables us to classify formal and informal enterprises into different spectrums, and to examine the varying employment growth generated across these groups.

Table 2 below presents the descriptive statistics of all the variables we employ in the paper for the balanced repeated cross-sectional data.[4] The table shows that, over the period, the average employment growth is 3.4% in our data. The average proportion of enterprises with access to the internet is about 25%, while the average share of enterprises with access to mobile phones is about 92%. The descriptive statistics of our formality status variable suggest that enterprises operate in a continuum, with informal enterprises dominating in the data (about 50%).

3.2 The empirical model

The econometric model used in the paper attempts to explain employment growth in Ghanaian enterprises and the extent to which it is driven by ICTs. Based on this, we formulate a model as follows:

$$Employment\ growth_{it} = \alpha_{it} + \beta ICT_{it} + \gamma Status_{it} + \rho Z_{i,t} + \delta_i + \delta_j + \vartheta_t + \varepsilon_{it} \quad (1)$$

where $t = 1, \dots, T_i$, and $i = 1, \dots, N$. $Employment\ growth_{it}$ is the employment growth of enterprises across i and t. ICT_{it} refers to a vector of ICT indicators: access to the internet and access to mobile phones across i and t. $Status_{it}$ is a categorical variable indicating the registration status and the nature of operations of enterprises across i and t. $Z_{i,t}$ is a vector of all other explanatory variables. Finally, δ_i and δ_j are the enterprise and industry fixed effects, ϑ_t is the year effect, and ε_{it} is the idiosyncratic error term.

Equation (1) models the employment growth of enterprises as explained by our ICTs proxies, the dynamic transition status of enterprises, and other explanatory variables including time and industry dummies. Z_{it} includes the age of the enterprise and its square, both in logs, to capture the non-linearity in age. Besides age, we include the lagged size of the enterprise, and lagged domestic market share of the enterprise, both in logs and lagged, to take care of possible simultaneity bias between age, market share, and employment growth, as well as dummies capturing the level of education of the owner, and whether the enterprise undertakes formal and informal job training of workers. We also capture variables such as whether or not the enterprise is a sub-contractor, is part of a company group, in a network, have a foreign investor, is owned by a group of people, is

[4] Table 3 shows the list and definition of all variables.

male-owned, and the city of where the enterprise is located, as well as the industry in which the enterprise operates. These variables are further motivated in section 4.1. To estimate equation 1, we employ the FGLS regression to allow for cross-sectional correlation and heteroskedasticity across panels (Greene, 2018).

3.3.1 Variable justification

We use employment growth for our dependent variable (Koellinger, 2008; McPherson, 1996; Davidsson, 1991). It is constructed as logarithm (log) differences between total employment at the end of each cross-section (2013 and 2015) and the total employment at the beginning of each cross-section (2011 and 2013).[5] In both cross-sections of the DILIC survey, enterprises were asked to state the total employment in the enterprise in the last fiscal year and in the fiscal year three years prior the survey. For instance, in cross-section 1, the data set contains information on the employment level of enterprises in 2011 and 2013, while for cross-section 2, the data contain employment information in 2013 and 2015. Employment growth is then generated as the logarithm difference between the appended employment levels in 2011 and 2013 and that of 2013 and 2015.

Our study gives insight into the link between employment growth and ICTs using access to the internet and access to mobile phones as proxies, following Khan et al. (2017), and Garcia-Murillo and Velez-Ospina (2017). Enterprises that use the internet are more innovative and sell more innovative products (Fu and Hou, 2020). Internet use enhances the effectiveness of relations by reducing the cost of establishing and maintaining social and business relations (Brynjolfsson and Hitt, 2010; Edwards, 2002; Hjort and Poulsen, 2019). This leads to radical changes to and in the distribution networks of goods and services, and how products are priced and exchanged (Brynjolfsson et al., 2010; Brynjolfsson and Hitt, 2010). Given the above and the evidence that the expansion of internet infrastructure is key to Africa's employment creation potential (Hjort and Poulsen, 2019), we expect access to the internet to have a positive employment growth effect due to its market expansion effects.

Access to business mobile phones may enhance communication within the enterprise and with other enterprises, customers, and suppliers (Heeks, 2010). This is found to lead to immediacy, thereby resulting in the reduction in transaction cost leading to competitiveness in medium and

[5] For robustness, we employ other constructions of employment growth. See Table 8 for estimation results.

small-scale enterprises (MSEs) (Essegbey and Frempong, 2011). This cost and time effective medium of communication may replace certain kinds of worker, specifically unskilled workers such as messengers employed to undertake routine tasks. In the DILIC data, access to the internet takes the value 1 if the enterprise uses the internet in its daily operations and 0 if otherwise. Access to mobile phones is also a dummy indicating whether the enterprise has a dedicated mobile phone for daily use and operations of the enterprise and 0 if otherwise. To resolve possible simultaneity bias with employment growth, we employ ICT variables at the beginning of each cross-section. This way, we allow enterprises to adopt ICTs before making employment decisions.

As noted, the literature on formality and informality shows that all enterprises in developing countries operate along a continuum where they have varying degrees of informality (Ulyssea, 2018; Williams et al, 2016; Bohme and Thiele, 2014, Kawooya, 2014). Examining the determinants of the varying levels of informality of informal enterprises in Lahore, Pakistan, using the survey data of 300 micro-enterprises and constructing an index of informality based on three proxies, Williams et al. (2016) find that informal enterprises operate at different levels of informality, which are determined by the characteristics of entrepreneurs and enterprises. Maloney (2004) also find similar results in Latin America arguing that the informal and formal sectors are intertwined, while Kawooya (2014) find 'symbiotic' linkages between informal and formal sectors in Kampala, Uganda. Bohme and Thiele (2014) in their study of informal enterprises in West Africa also found formal-informal linkages depend on the degree of informality.

Based on one-step transition probabilities obtained from the Markov chain analysis for the two repeated cross-sections, 2013 ($t-1$) and 2015 (t), the formality status of enterprises is defined as a categorical variable based on whether the enterprise is legally registered or not, and on the nature of the economic activity of the business, and defined as 0 if the enterprise is unregistered and operates entirely in the informal sector (informal), 1 if the enterprise is informal and operates in the formal sector (semi-informal), 2 if the enterprise is registered and operates in the informal sector (semi-formal), and 3 if the enterprise is registered and operates entirely in the formal sector (formal). The descriptive statistics suggest that about 68% and 53% of informal and formal enterprises remained in their initial status (see Table 4). For instance, the table shows that about 56%, 43%, and 28% of enterprises that were in 2013 semi-informal, semi-formal and formal

enterprises became informal in 2015, respectively. These figures suggest that enterprises experienced different levels of transition between statuses over the period under consideration.[6]

The empirical evidence suggests that informal enterprises transitioning to formality expend large financial and time resources on pre-formalisation costs. In other words, they face a 'transformation cost' (Amin and Islam, 2015). While the transformation cost is temporary, it may serve as a barrier to formality and could also lead to a substantial negative effect on the employment growth of semi-informal enterprises, for instance. Enterprises at the informal end of the continuum may employ informal workers with lower wages as they do not have formal contracts and social security benefits (Ulyssea, 2018). Also, the empirical literature suggests that mobile phone use drives informality while fixed broadband reduces informality (Garcia-Murillo and Velez-Ospina, 2017). In an extension to our basic model, we introduced interaction terms to capture these indirect mechanisms. We expect more 'formal' enterprises to increase employment with access to internet, and more 'informal' enterprises to decrease employment with access to the internet.

We use a host of other enterprise-level, location, and industry-level explanatory variables to explain an enterprise's employment growth. We explain employment growth by the age of the enterprise, its lagged size, its lagged domestic market share, the educational level of the owner, if the enterprise has a group of owners, the gender of the owner, if the enterprise undertakes formal and informal job training for workers, if the enterprise is a sub-contractor, being part of a company group, being part of a network, having a foreign investor, the city of location of the enterprise, and industry, and time dummies.[7] Several theoretical and empirical studies identify an inverse relationship between firm growth and the size and age of the firm (Gebreyeesus, 2011; Davidson, 1991; Janovic, 1982).

Contrary to Gilbrat's law, empirical studies have shown that employment growth and size are negatively related (Davidson, 1991). Gebreyeesus (2011) argues that smaller firms tend to lack the 'indivisibility of resources and availability of slack resources' and as a result, tend to grow faster than larger enterprises. Measuring size by the lag of the total number of employees, we expect a

[6]Tables 5 and 6 show the one-step transition probabilities obtained from the Markov chain analysis for the two repeated cross-sections for our ICT variables. Table 5 shows that, about 13% of enterprises that had no access to the internet in 2013 gained access in 2015. About 50% of enterprises that had access to the internet in 2013 lost access to the internet in 2015. In contrast, Table 6 shows that only about 5% of enterprises that had access to mobile phones in 2013 lacked access in 2015. On the contrary, about 60% of enterprises moved from no access in 2013 to access of mobile phones in 2015. These suggest across our data that enterprises tend to access and use mobile phones more easily over the period, while access to the internet is more difficult.

[7] The pairwise correlation of all explanatory variables is reported in Table 7.

negative relationship between size and employment growth. An enterprise's incentive to grow decreases with age as older enterprises tend to be conservative with routinised activities and they tend to prefer their older ways of doing things than otherwise (McPherson, 1996; Davidson, 1991). Younger enterprises learn and adapt quickly and can grow faster (Avenyo, et al, 2019; Gebreyeesus, 2011). Age is measured as the number of years from the establishment of the enterprise to the year of the survey (Avenyo, 2019; McPherson, 1996). In our estimation, age and size are log-transformed. Enterprises with a higher domestic market size grow faster (Avenyo, et al, 2019; Raymond et al, 2010; Koellinger, 2008). Koellinger's (2008) study of e-business enterprises in Europe finds domestic market share has a positive effect on employment growth.

Several other dummies that take the value 1 if the enterprise responded 'yes' and 0 if the enterprise responded 'no' are introduced as controls. Female-owned businesses tend to grow less than their male counterparts due to family ties and risk averseness (McPherson, 1996). Enterprises that invest in their human capital through activities such as training are expected to grow faster (Gebreyeesus, 2011; Frazer, 2006; McPherson, 1996), while enterprises with multiple owners may tend to have more financial resources leading to the expansion in employment (McPherson, 1996;). Financial constraint is a major obstacle most enterprises face in developing countries (Ayyagari et al., 2011). Enterprises that have foreign investors tend to have external sources of funding and are expected to perform and grow more than otherwise. La Porta and Shleifer (2008) find formal enterprises use external finance more than informal enterprises. Enterprises that sub-contract for others tend to perform better and grow as they are required to prove their technical know-how for specific subcontracts. However, Maloney (2004) finds limited subcontracting behaviour in informal enterprises. Networks lead to collective efficiency gains in small and micro enterprises (Barr, 1999; Dawson, 1992) that may result in lower employment growth. Finally, enterprises that are part of a bigger company group lack legal and financial autonomy (Raymond et al., 2010), and as a result, are less likely to hire more workers. We also control for location, industry, and year dummies in line with McPherson (1996).

4 Results and discussion

4.1 The effect of ICTs on employment growth in manufacturing enterprises

As noted in earlier sections, this paper aims to provide insight into the relationship between employment growth and ICTs in Ghana, using two repeated cross-sections of the DILIC data.

Table 8 reports the results of the random effects Generalised Least Squares and the FGLS panel regressions. Our preferred FGLS estimates are reported in Table 8 columns 3 and 4.

The results across different specifications are consistent and show that access to the internet has a significantly positive effect on employment growth, while we observe that access to mobile phones has a significantly negative effect on the employment growth of enterprises. The compensation effect of access to the internet on the employment growth of enterprises is also observed in the wider literature that analyses the effect of the internet on the employment growth performance of the enterprise (Hjort and Poulsen, 2019; Koellinger, 2008). Koellinger (2008) finds internet-based technologies drive employment growth in European e-business enterprises. This result may be explained by the reasoning that access to the internet exposes enterprises to new knowledge and production processes thereby enhancing their efficiency, leading to relative price reductions. The relative drop in price may be driving an increase in demand and the compensation effect on employment. Also, internet access could lead to marketing innovation in enterprises that may drive increases in demand and employment growth.

Conversely, the displacement effect due to the use of mobile phones may be explained by the reduction in transaction costs leading to the replacement of 'unskilled' workers such as messengers. On the one hand, this result partly disagrees with findings in the empirical study by Khan, et al. (2017) who find mobile phone ownership tends to have a positive effect on the probability of employment only in certain countries. On the other hand, our results agree with Khan, et al. (2017) who find a negative effect for mobile phone use in other countries.

In general, our status variable indicates that informal enterprises grow more and the growth in employment declines the more as one moves along the spectrum towards complete formality. This may be due to the differences along the continuum of the type of labour employed with its associated costs. There is evidence that the more an enterprise operates closer to the informality continuum, the more it employs 'off the book' (Ulyssea, 2018). The cost difference between informal employment and formal employment may explain this result.

The extended specifications also report the effect of other enterprise characteristics on employment growth. Lagged total employees (in log) is our size variable and the result suggests that larger enterprises grow less in line with the extant literature (Gebreyeesus, 2011; Davidson, 2011; Janovic, 1982). The coefficients of age and its square term are insignificant but suggest a U-shaped relationship between age and employment growth in line with the empirical literature (Avenyo, et al., 2019; Gebreyeesus, 2011). The gender and company group coefficients are

insignificant suggesting that there is no statistical difference between male and female-owned enterprises and enterprises that are part of a group. A positive relationship is observed with employment growth for domestic market share, ownership, and for enterprises that are sub-contractors, or engage in informal job training, in networking, and have foreign investors. More specifically, enterprises with a larger domestic market share employ more workers and this may be due to the reasoning that new market entries aimed at expanding domestic dominance may require enterprises to employ more workers (Avenyo, et al, 2019; Raymond et al, 2010). Multiple ownership tends to lead to higher growth in employees than enterprises owned by single individuals. The coefficient of informal training is statistically significant indicating the importance of on-the-job training and learning-by-doing in supporting employment growth. Enterprises that are in networks such as local associations and chambers of commerce show more employment growth than enterprises that are not demonstrating a positive effect of social capital. Finally, enterprises that have foreign investors may not be affected by constraints such as lack of finance and as a result, may tend to show more employment growth than enterprises that do not have foreign investors.

4.2 The effect of ICTs on the employment growth: Role of formality status

Table 9 reports the estimation results when we extend our model in equation (1) by interacting access to the internet and formality status dummies to analyse any possible indirect mechanisms using the data.

Columns (1) – (5) add interaction terms between access to the internet and our enterprise status dummies. The results in columns (1) – (5) indicate that enterprises that operate informally with access to the internet tend to grow less on average (column 1) than otherwise. On the contrary, enterprises with formal status on average show more employment growth with access to the internet than all other enterprises. These findings suggest that, compared with other enterprises, internet use enables informal enterprises to remain small to avoid drawing attention to their activities. This allows them to keep labour costs low and enjoy some flexibility from being informal. This result may also be explained by the higher cost associated with the use of the internet or the complementarity between labour and internet use, leading enterprises to reduce employment. All other explanatory variables remain qualitatively similar to our earlier results in terms of sign and significance.[8]

[8] We failed to observe similar indirect mechanisms for mobile phone use (results are not reported but are available upon request).

The estimates in Table 10 allow us to go a step further to assess the determinants of employment growth at the informal and formal margins. The informal margin comprises of enterprises that operate in informal and semi-formal spectrums, while the formal margin comprises of enterprises that operate in the formal and semi-informal spectrums. Our main result is in line with Ulyssea (2019), suggesting that enterprises that are more informal tend to avoid been caught by remaining small. Our results reported in column (2) show that enterprises that operate at the informal margin tend to 'hide' by growing less in employment with access to the internet, buttressing our earlier findings and the empirical literature. Also, following the evidence from other studies, this result may be due to the reasoning that enterprises that operate at the formal margin tend to have the capacity to better adapt knowledge sourced from the internet, and as a result, can perform and grow more than otherwise. A similar indirect effect of ICT is also found by Bresnahan et al. (2002).

In columns (3) and (4), the estimates show access to the internet as a significant determinant of employment growth for enterprises operating at both the formal and informal margins, while access to mobile phones has no significant effect in both models. Large enterprises operating at both margins show little employment growth. In line with Williams et al (2015), we find a U-shaped relationship between the age and employment growth of enterprises, suggesting that older enterprises' employment growth is greater at the formal margin. Domestic market size and multiple ownership matter significantly for enterprises operating at the informal margin. Male-owned and subcontracting enterprises at the formal margin tend to show significantly more employment growth. Subcontracting is insignificant for enterprises at the informal margin, corroborating with the findings of Maloney (2004). Informal on-the-job-training leads to employment growth in enterprises at the informal margin while it leads to displacement effects in enterprises at the formal margin: this suggests the importance of apprenticeship in enterprises. On the contrary, enterprises at the informal margin that are part of a company group lack autonomy that characterises informality, and as result employment grows less, while the reverse holds for enterprises at the formal margin who may be taking advantage of the financial resources the bigger group offers. Network effects matter positively for both groups of enterprises, despite the drop in statistical significance in column 4.

5 Conclusion

The creation of new and quality avenues of employment has become an important policy concern in most developing countries. The discussion recognises that the ICT revolution lies at the heart of today's global digital transformation and the fourth industrial revolution and could play a critical

role in creating new job opportunities, and transitioning informal enterprises to the formal economy. As a result, understanding the relationship between ICTs and employment growth in Africa has become a key national employment policy. This paper contributes to the ICTs-employment literature by exploring the role of ICTs on employment growth in Ghanaian manufacturing. We examine the question: (1) does the adoption of ICTs affect the manufacturing employment growth of enterprises in Ghana?; (2) Does the formality status of enterprises influence ICTs' effect on manufacturing employment growth?

We estimate feasible generalised least squares (FGLS) regression using data collected in 2013 and 2015. Our results show that access to the internet has a positive effect on employment while access to mobile phones leads to a negative effect on employment. Our results show that the more informal an enterprise is, the less it grows with access to the internet. In other words, the employment gains from internet access mainly occur for formal enterprises and enterprises that are more formal. Enterprises with mobile phone access are more likely to pursue smallness in labour employment to benefit from the flexibility and efficiency gains. The key determinants of employment growth are also identified to vary depending on the specific formality status of the enterprise. The results strongly indicate that other factors such as domestic market size, multiple ownership, and informal training matter for the employment growth of enterprises at the informal margin (informal and semi-formal), while male-ownership, subcontracting, and being part of a group of companies positively determine the employment performance of enterprises at the formal margin (formal and semi-informal).

These findings contribute to the literature and develop the debate on both the ICTs and formality at the firm level. Overall, the findings suggest a view that informal enterprises with access to the internet actively pursue smallness by substituting internet for labour. Conversely, the use of mobile phones reduces the number of workers, most of which transition into the informal sector. Our findings confirm the growing evidence that indicates most enterprises in developing countries are interconnected and operate at varying degrees on the informality-formality continuum, and the ICT technology revolution has brought new changes into the transition dynamics.

The emerging findings from this paper have significant policy and practical implications in developing countries. Firstly, the insights will help policy makers to successfully incentivise and harness the employment creation potentials of all enterprises. For example, the ILO's 'Transition from the Informal to the Formal Economy Recommendation (No. 204)' aims to formalise enterprise. The ILO may develop even more effective policies with understanding of some of the subtle nuances of how enterprises operate and how ICTs are transforming the operations and

business models of enterprises in developing countries, especially among small and micro enterprises at the borderline of formality and informality.

Secondly, our findings have useful implications for the digital transformation of businesses in African economies. Our findings indicate that the use of ICTs decreases transaction costs and entry barriers. To achieve optimal digital transformation enterprises still need technologies and capabilities that can facilitate transformation in production processes, marketing strategies, and supply chain management systems. The rise of the platform economy in recent years may change the digital technology-formality-employment nexus.

There are limitations to our research. Despite the paper's innovation and contribution to the wider literature, our analysis employs ICT proxies that are dummies, thereby, for example, not examining differences in investment in ICTs, and intensive and extensive margins of ICTs. Our analysis does not consider the skill level and status of jobs and workers. These are mainly due to data limitations. Our cross-sectional data would benefit from an extensive longitudinal study: it comprises only two relatively short periods. The use of other better-measured ICTs and employment variables, and panel data over a longer period would be natural extensions of the debate. Lastly, while we employ lagged variables to address endogeneity concerns, a more formal method could be used in future studies.

Compliance with Ethical Standards

Funding: This work was supported by the ESRC/DFID Grants (ES/J008699/1 and ES/S001336/1).

Conflict of interest: This is to declare that we have no competing interests to declare.

Ethical Statement: This manuscript is the authors' own original work, which is not currently being considered for publication elsewhere and has not been previously published elsewhere.

Data Availability Statement: The dataset generated during the current study is not publicly available as it contains sensitive information. Further information on how to obtain it and reproduce the analysis is available on request from the corresponding author.

Acknowledgement: We would like to thank Marc Ventresca, Pierre Mohnen, George Essegbey, Anne Miroux and Pervez Ghauri for helpful comments and suggestions. We are also grateful for comments from participants at the SBS-TMCD joint workshop at the Oxford University, 2015 Globelics Conference, 1st Africa Innovation Summit, Innovation in Low Income Countries Conference (London), and Innovation and African Industry Upgrading Workshop (Ghana).

References

Aker, J. C. (2011). Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics, 42*(6), 631–647.

Amin, M., & Islam, A. (2015). Are large informal firms more productive than the small informal firms? Evidence from firm-level surveys in Africa. *World Development*, *74*, 374–385.

Asongu, Simplice A., Jacinta C. Nwachukwu, Stella-Maris I. Orim, 2018. Mobile phones, institutional quality and entrepreneurship in Sub-Saharan Africa, *Technological Forecasting and Social Change*, Vol. 131, 183-203, https://doi.org/10.1016/j.techfore.2017.08.007.

Asongu, Simplice A., Mushfiqur Rahman, Joseph Nnanna, Mohamed Haffar, 2020. Enhancing information technology for value added across economic sectors in Sub-Saharan Africa, *Technological Forecasting and Social Change*, Vol. 161, https://doi.org/10.1016/j.techfore.2020.120301.

Asongu, Simplice A., Sara Le Roux, 2017. Enhancing ICT for inclusive human development in Sub-Saharan Africa, *Technological Forecasting and Social Change*, Vol. 118, 44-54.

Aubert-Tarby, Clémence; Octavio R. Escobar, Thierry Rayna, 2018. The impact of technological change on employment: The case of press digitisation, *Technological Forecasting and Social Change*, Volume 128, Pages 36-45, https://doi.org/10.1016/j.techfore.2017.10.015.

Avenyo, E.K., Konte, M., & Mohnen, P. (2019). The employment impact of product innovations in sub-Saharan Africa: Firm-level evidence. *Research Policy, 48(9),* 103806.

Avenyo, E.K., Konte, M., & Mohnen, P. (2020). Product innovation and informal market competition in sub-Saharan Africa. *Journal of Evolutionary Economics*, 1-33. https://doi.org/10.1007/s00191-020-00688-2.

Ayyagari, M., Demirgüç-Kunt, A., & Maksimovic, V. (2011). Firm innovation in emerging markets: The role of finance, governance, and competition. *Journal of Financial and Quantitative Analysis, 46(6)*, 1545–1580.

Barr, A. (1999). Do SMEs network for growth? In K. King & S. McGrath (Eds.), *Enterprise in Africa – Between poverty and growth* (pp. 121–131). Rugby, UK: Practical Action.

Baker, A., & Velasco-Guachalla, V.X. (2018). Is the informal sector politically Different? (Null) answers from Latin America. *World Development*, 102, 170-182.

Biagi, F., & Falk, M. (2017). The impact of ICT and e-commerce on employment in Europe. *Journal of Policy Modeling*, *39*(1), 1-18.

Biagi, F. (2013). ICT and productivity: A review of the literature. Institute for Prospective Technological Studies Digital Economy Working Paper 2013/09: Spain, Seville.

Böhme, M.H., & Thiele, R. (2012). Is the informal sector constrained from the demand side? Evidence for six West African capitals. *World Development, 40 (7)*, 1369-1381.

Böhme, M.H., & Thiele, R. (2014). Informal–formal linkages and informal enterprise performance in urban West Africa. *The European Journal of Development Research, 26 (4)*, 473-489.

Brougham, David and Haar, Jarrod. 2020. Technological disruption and employment: The influence on job insecurity and turnover intentions: A multi-country study, *Technological Forecasting and Social Change*, Volume 161, https://doi.org/10.1016/j.techfore.2020.120276.

Bresnahan, T., Brynjolfsson, E., & Hitt, L.M. (2002). Information technology, workplace organization and the demand for skilled labor: Firm-level evidence. *Quarterly Journal of Economics, 117 (1)*, 339-376.

Brynjolfsson, E., & Hitt, L.M. (2000). Beyond computation: information technology, organizational transformation and business performance. *Journal of Economic Perspectives, 14 (4)*, 23-48.

Brynjolfsson, E., Hu, Y., & Smith, M.D. (2010). Long tails vs. superstars: The effect of information technology on product variety and sales concentration patterns. *Information Systems Research, 21 (4)*, 736–747.

Chaudhuri, A. (2012). ICT for Development: solutions seeking problems? *Journal of Information Technology*, *27*(4), 326-338.

Cosh, A., Fu, X., & Hughes, A. (2012). Organisation structure and innovation performance in different environments. *Small Business Economics*, *39*(2), 301-317.

Cunningham, W., & Maloney, W. F. (2001). Heterogeneity in the Mexican micro-enterprise sector: an application of factor and cluster analysis. *Economic Development and Cultural Change, 50 (1),* 131-156.

Davidsson, P. (1991). Continued entrepreneurship: Ability, need, and opportunity as determinants of small firm growth. *Journal of Business Venturing, 6*(6), 405–429.

Dawson, J. (1992). The relevance of the flexible specialisation paradigm for small-scale industrial restructuring in Ghana. *IDS Bulletin, 23*(3), 34–38.

Deen-Swarray, M., Moyo, M., & Stork, C. (2013). ICT access and usage among informal businesses in Africa. *Digital Policy, Regulation and Governance*, *15* (5), 52-68.

Dengler, Katharina; Britta Matthes, 2018. The impacts of digital transformation on the labour market: Substitution potentials of occupations in Germany, 2018. *Technological Forecasting and Social Change,* Volume 137, Pages 304-316, https://doi.org/10.1016/j.techfore.2018.09.024.

Distinguin, I., Rugemintwari, C., & Tacneng, R. (2016). Can informal firms hurt registered SMEs' access to credit? *World Development*, *84*, 18-40.

Edwards, S. (2002). Information technology and economic growth in developing countries. *Challenge, 45 (3),* 19-43.

Essegbey, G.O., & Frempong, G.K. (2011). Creating space for innovation - The case of mobile telephony in MSEs in Ghana. *Technovation, 31* (12), 679-688.

Fields, G.S. (2005). A guide to multisector labor market models. Social protection discussion paper 0505. World Bank, Washington, DC.

Fossen, Frank M. and Sorgner, Alina. 2022. New digital technologies and heterogeneous wage and employment dynamics in the United States: Evidence from individual-level data, *Technological Forecasting and Social Change*, Volume 175, https://doi.org/10.1016/j.techfore.2021.121381.

Foster, C., Graham, M., Mann, L., Waema, T., & Friederici, N. (2018). Digital control in value chains: Challenges of connectivity for East African firms. *Economic Geography*, *94*(1), 68-86.

Frazer, G. (2006). Learning the master's trade: Apprenticeship and human capital in Ghana. *Journal of Development Economics, 81(2),* 259–298.

Fu, X. (2013). Computerisation and efficiency of rural credit cooperatives: evidence from India. *Journal of International Development, 25* (3), 412–437.

Fu, X. and Akter, S. (2016). The impact of ICT on agriculture extension services delivery: evidence from the rural e-services project in India. *Journal of Development Studies*, 52(11):1561-1576.

Fu, X., Zanello, G., Owusu Essegbey, G., Hou, J., & Mohnen, P. (2014). Innovation in low income countries: A survey report. Oxford, UK: TMDC. Retrieved from http://eprints.lincoln.ac.uk/id/eprint/26671/1/__network.uni_staff_S2_jhou_RDS_Desktop_DILIC_Report_2.pdf

Fu, M. X., Bao. Q., Xie, H.J. & Fu, X. 2021. Diffusion of Industrial Robots and Inclusive Growth: Labour Market Evidence from Cross-Country Data. *Journal of Business Research*, vol. 122, 670-684. https://doi.org/10.1016/j.jbusres.2020.05.051.

Gaglio, C., Kraemer-Mbula, E. & Lorenz, E. 2022. The effects of digital transformation on innovation and productivity: Firm-level evidence of South African manufacturing micro and small enterprises, *Technological Forecasting and Social Change*, Volume 182, https://doi.org/10.1016/j.techfore.2022.121785.

Garcia-Murillo, M. (2015). The impact of ICTs on employment in Latin America: A call for comprehensive regulation. 26th European Regional Conference of the International Telecommunications Society (ITS): "What Next for European Telecommunications?", Madrid, Spain, 24th-27th June, 2015.

Garcia-Murillo, M., & Velez-Ospina, J. A. (2017). ICTs and the informal economy: mobile and broadband roles. *Digital Policy, Regulation and Governance*, *19* (1), 58-76.

Gebreeyesus, M. (2011). Innovation and microenterprise growth in Ethiopia. In Szirmai, A., Naud´e, W., and Goedhuys, M., editors, Entrepreneurship, innovation, and economic development, pages 122–146. Oxford University Press, Oxford, UK.

Greene, W. H. (2018). Econometric Analysis. 8th Ed. New York: Pearson.

Günther, I., & Launov, A. (2012). Informal employment in developing countries: opportunity or last resort? *Journal of Development Economics, 97 (1)*, 88-98.

Hjort, J., & Poulsen, J. (2019). The arrival of fast internet and employment in Africa. *American Economic Review*, *109*(3), 1032-79.

Heeks, R. (2010). Do information and communication technologies (ICTs) contribute to development? *Journal of International Development*, *22*(5), 625-640.

Heeks R. (2002). i-development not e-development: special issue on ICTs and development. *Journal of International Development, 14*(1): 1–11.

Ilavarasan, P. V. (2019). Present and future of the use and impact of information and communication technology in informal microenterprises: Insights from India. *The Electronic Journal of Information Systems in Developing Countries*, *85*(3), e12091.

ILO (2018). Women and Men in the Informal Economy: A Statistical Picture Third Edition. International Labour Organization, Geneva. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_626831.pdf

Kawooya, D. (2014). Informal–formal sector interactions in automotive engineering, Kampala. In J. De Beer, C. Armstrong, C. Oguamanam & T. Schonwetter (Eds.), *Innovation & intellectual property: Collaborative dynamics in Africa* (pp. 59–76). Cape Town, South Africa: UCT Press.

Khan, S., Lilenstein, K., Oosthuizen, M., & Rooney, C. (2017). *Correlates of ICTS and employment in Sub-Saharan Africa*. Development Policy Research Unit, University of Cape Town.

Koellinger, P. (2008). The relationship between technology, innovation, and firm performance: Empirical evidence from e-business in Europe. *Research Policy*, 37 (8), 1317-1328.

Koomson, Isaac., Chei Bukari, Renato A Villano, 2021. Mobile money adoption and response to idiosyncratic shocks: Empirics from five selected countries in sub-Saharan Africa, *Technological Forecasting and Social Change*, Volume 167, https://doi.org/10.1016/j.techfore.2021.120728.

Maloney, W.F. (2004). Informality revisited. *World Development, 32 (7)*, 1159-1178.

McPherson, M. A. (1996). Growth of micro and small enterprises in southern Africa. *Journal of Development Economics, 48 (2)*, 253-277.

Murphy, J. T., & Carmody, P. (2015). *Africa's information revolution: technical regimes and production networks in South Africa and Tanzania*. John Wiley & Sons.

La Porta, R., & Shleifer, A. (2008). The unofficial economy and economic development. *Brookings Papers on Economic Activity, 39(2 Fall),* 275–352.

La Porta, R., & Shleifer, A. (2014). Informality and development. *Journal of Economic Perspectives, 28 (3)*, 109-126.

Palvia, P., Baqir, N., & Nemati, H. (2018). ICT for socio-economic development: A citizens' perspective. *Information & Management*, *55*(2), 160-176.

Pérez Pérez, J. (2020). The minimum wage in formal and informal sectors: Evidence from an inflation shock. *World Development*, *133,* 104999.

Raymond, W., Mohnen, P., Palm, F., & van der Loeff, S. S. (2010). Persistence of innovation in Dutch Manufacturing: Is It Spurious? *The Review of Economics and Statistics, 92(3)*, 495-504.

Rothenberg, A.D., Gaduh, A., Burger, N.E., Chazali, C., Tjandraningsih, I., Radikun, R., Sutera, C., Weilant, S., 2016. Rethinking Indonesia's informal sector. *World Development*. 80, 96–113.

Shao, B., & Lin, W. T. (2016). Assessing output performance of information technology service industries: Productivity, innovation and catch-up. *International Journal of Production Economics*, *172*, 43-53.

Siba, E. (2015). Returns to physical capital in Ethiopia: Comparative analysis of formal and informal firms. *World Development*, 68, 215–229.

Tshukudu, M. K. (2019). Impacts of Access to ICTs on Employment Status in Botswana. Botswana Institute for Development Policy Analysis Working Paper 68. Accessed on 31 March 2021 at https://www.africaportal.org/publications/impacts-access-icts-employment-status-botswana/

Ulyssea, G. (2018). Firms, informality, and development: Theory and evidence from Brazil. *American Economic Review*, 108 (8): 2015-47.

Wang, Huijuan; Lin Ding, Rong Guan, Yan Xia, 2020. Effects of advancing internet technology on Chinese employment: a spatial study of inter-industry spillovers, *Technological Forecasting and Social Change*, Volume 161, https://doi.org/10.1016/j.techfore.2020.120259.

Williams, C. C., Shahid, M. S., & Martínez, A. (2016). Determinants of the Level of Informality of Informal Micro-enterprises: Some Evidence from the City of Lahore, Pakistan. *World Development*, 84, 312–325.

Yahmed, S. B. (2018). Formal but less equal. Gender wage gaps in formal and informal jobs in urban Brazil. *World Development*, 101, 73–87.

You, Kefei; Silvia Dal Bianco, Joseph Amankwah-Amoah, 2020. Closing Technological Gaps to Alleviate Poverty: Evidence from 17 Sub-Saharan African Countries, *Technological Forecasting and Social Change*, Volume 157, https://doi.org/10.1016/j.techfore.2020.120055.

Zanello, G., Srinivasan, C. S., & Shankar, B. (2014). Transaction costs, information technologies, and the choice of marketplace among farmers in Northern Ghana. *The Journal of Development Studies, 50*(9), 1226–1239.

Table 1: List of enterprises in the sample by industry

Industries	**Full sample**	**Informal**	**Formal**
Manufacture of food products	124	90	34
Manufacture of beverages	2	0	2
Manufacture of textiles	23	15	8
Manufacture of wearing apparel	102	52	50
Manufacture of leather and related products	1	1	0
Manufacture of wood and of products of wood and cork	51	36	15
Manufacture of paper and paper products	10	0	10
Printing and reproduction of recorded materials	9	4	5
Manufacture of chemicals and chemical products	1	1	0
Manufacture of basic pharmaceutical products	1	0	1
Manufacture of rubber and plastics products	8	0	8
Manufacture of fabricated metal products	65	45	20
Manufacture of electrical equipment	2	2	0
Manufacture of machinery and equipment	1	0	1
Manufacture of furniture	74	51	23
Other manufacturing	5	4	1
Repair and installation of machinery	21	20	1
Construction of buildings	2	0	2

Table 2: Descriptive statistics

	Mean	S.D. Overall	S.D. Between	S.D. Within
Variables				
Dependent variable				
Growth of employment (log)	0.034	0.530	0. 414	0. 341
Explanatory variables				
Access to internet (Yes=1)	0.248			
Access to mobile phone (Yes=1)	0.917			
Formality status of enterprises				
Informal	0.491			
Semi-informal	0.056			
Semi-formal	0.145			
Formal	0. 308			
Age of enterprise	18.04	11.076	10.179	4.426
Domestic market share[a]	0.168	0.257	0.211	0.173
Ownership (Multiple owners=1)	0.141			
Gender (Male=1)	0. 661			
Formal job training (Yes=1)	0.176			
Informal job training (Yes=1)	0.478			
Sub-contractor (Yes=1)	0.164			
Part of a company group (Yes=1)	0.139			
Part of a network (Yes=1)	0.120			
Foreign investor (Yes=1)	0.062			

Note: [a] ln (total sales/total sales in the industry).

Table 3: Variables' description and definition

Variable	Description
Growth of employment	This is generated as the logarithm (log) difference between the appended employment levels in 2011 and 2013 and that of 2013 and 2015 respectively.
Firm status	Categorical variable indicating if the firm is informal (54.36%), semi-informal (5.97%), semi-formal (2.63%) or formal (27.03%). These are further classified as formal margin and informal margin.
Informal margin	Enterprises that operate in the informal and semi-formal spectrum of the informality-formality continuum.
Formal margin	Enterprises that operate in the formal and semi-informal spectrums of the informality-formality continuum.
Access to mobile phone	This refers to whether the enterprise has access to mobile phones, with 1 indicating yes and 0 indicating no at the beginning of the period (2011 and 2013).
Access to internet connectivity	Refers to whether the enterprise during the last three years has access to internet connectivity, with 1 indicating yes and 0 indicating no at the beginning of the period (2011 and 2013).
Lagged total employees	Refers to the total number of employees at the beginning of the period.
Age enterprise and Age of enterprise square	This refers to how old the enterprise is from the year it was established, and its square term.
Lagged domestic market share	Refers to the domestic market share of enterprises, constructed as the total sales divided by the total sales of the industry.
Ownership	This refers to whether the enterprise has multiple owners (=1) or owned by an individual (=0).
Gender (Male)	Refers to the gender of the owner of the enterprise, with 1 representing male-owned enterprises and 0 representing female-owned enterprises.
Formal job training	Indicates whether the enterprise undertakes formal training for its employees, with 1 indicating yes and 0 indicating no.
Informal job training	Indicates whether the enterprise undertakes informal training for its employees, with 1 indicating yes and 0 indicating no.
Sub-contractor	Indicates whether the enterprise subcontracts for other enterprises, with 1 indicating yes and 0 indicating no.
Company group	This indicates whether the enterprise is part of a group of companies, with 1 indicating yes and 0 indicating no.
Network	This indicates whether the enterprise belongs to a network, with 1 indicating yes and 0 indicating no.
Foreign investor	This indicates whether the enterprise has foreign investors, with 1 indicating yes and 0 indicating no.
Education	Refers to five education of owner dummies: No education, Primary school, Secondary School, Vocational Training, Graduate degree
Industry	Refers to the eighteen manufacturing industry dummies based on ISIC Revision 3.1.
City	Refers to ten city dummies: Accra, Tema, Kumasi, Sekondi-Takoradi, Sunyani, Cape Coast, Koforidua, Techiman, Bolgatanga, and Others.
Year	Years of data collection.

Table 4: Transition probabilities – Persistence in formality status

Period $t-1$ (2013)	Period t (2015)			
Formality status	Informal	Semi-informal	Semi-formal	Formal
Informal	0.678	0.051	0.096	0.175
Semi-informal	0.564	0.077	0.128	0.231
Semi-formal	0.434	0.105	0.250	0.211
Formal	0.277	0.071	0.124	0.529
Pearson chi² (9)	101.0056 (0.000)			
Likelihood-ratio chi² (9)	96.8238 (0.000)			

Note: Markov chain analysis - one-step transition.

Table 5: Transition probabilities – Persistence in access to the internet

Period $t-1$ (2013)	Period t (2015)	
Access to the internet	Yes	No
Yes	0.496	0.504
No	0.133	0.867
Pearson chi² (9)	78.968 (0.000)	
Likelihood-ratio chi² (9)	68.836 (0.000)	

Note: Markov chain analysis - one-step transition.

Table 6: Transition probabilities – Persistence in access to mobile phone

Period $t-1$ (2013)	Period t (2015)	
Access to mobile phone	Yes	No
Yes	0.953	0.047
No	0.595	0.405
Pearson chi² (9)	75.155 (0.000)	
Likelihood-ratio chi² (9)	42.555 (0.000)	

Note: Markov chain analysis - one-step transition.

Table 7: Pairwise correlation matrix of all explanatory variables.

Access to internet	1														
Access to mobile phone	0.110*	1													
Status	0.459*	0.191*	1												
Age (log)	0.215*	0.156*	0.371*	1											
Age squared	0.217*	0.158*	0.373*	0.99*	1										
Total employees	0.625*	0.224*	0.552*	0.418*	0.420*	1									
Domestic mkt size	0.345*	0.134*	0.349*	0.195*	0.196*	0.426*	1								
Ownership	0.439*	0.084*	0.299*	0.194*	0.196*	0.475*	0.113*	1							
Gender	0.198*	0.262*	0.249*	0.255*	0.256*	0.316*	0.119*	0.231*	1						
Education	0.548*	0.289*	0.410*	0.269*	0.272*	0.565*	0.366*	0.304*	0.262*	1					
Formal job training	0.567*	0.077	0.328*	0.140*	0.142*	0.546*	0.301*	0.415*	0.168*	0.460*	1				
Informal job training	0.016	-0.003	0.203*	0.081*	0.082*	0.120*	0.159*	0.056	0.108*	0.145*	0.004	1			
Sub-contractor	-0.006	-0.448*	-0.038	-0.167*	-0.168*	-0.075	-0.063	-0.027	-0.196*	-0.166*	0.003	0.085*	1		
Company group	0.163*	-0.386*	0.020	-0.131*	-0.131*	0.073	-0.022	0.185*	-0.187*	-0.072	0.136*	-0.0182	0.452*	1	
Network	0.142*	0.094*	0.057	0.095*	0.096*	0.208*	0.067	0.28*	0.173*	0.103*	0.209*	0.077	-0.047	-0.018	1
Foreign investor	0.434*	0.067	0.323*	0.057	0.059	0.457*	0.137*	0.469*	0.137*	0.329*	0.317*	0.0414	0.044	0.326*	0.112*	1

Note: * $p < 0.05$.

Table 8: Employment growth, ICTs and formality status of enterprises

	Random-effects GLS Panel regression		FGLS Panel regression	
	(1)	(2)	(3)	(4)
Dependent variable	Log of employment growth			
ICTs				
Access to internet	0.287***	0.160**	0.228***	0.130***
	(3.88)	(2.16)	(9.43)	(4.26)
Access to mobile phone	-0.605***	-0.207	-0.583***	-0.196***
	(-5.78)	(-1.50)	(-10.43)	(-3.25)
Formality status				
Semi-informal	-0.142**	-0.051	-0.146***	-0.035
	(-2.00)	(-0.67)	(-5.37)	(-0.97)
Semi-formal	-0.148***	-0.097	-0.141***	-0.051*
	(-2.90)	(-1.55)	(-9.37)	(-1.90)
Formal	-0.064	-0.151	-0.0575***	-0.077**
	(-1.21)	(-1.63)	(-4.81)	(-2.03)
Lagged total employees (in log)	-0.117***	-0.145***	-0.075***	-0.120***
	(-4.89)	(-4.31)	(-9.74)	(-9.67)
Age of enterprise (in log)		-1.493		-1.102
		(-0.88)		(-1.41)
Age of enterprise squared (in log)		0.764		0.570
		(0.89)		(1.44)
Lagged domestic market share (in log)[a]		0.0476		0.037**
		(1.07)		(2.22)
Ownership		0.205***		0.140***
		(3.09)		(4.13)
Gender (Male)		-0.0245		-0.024
		(-0.43)		(-1.06)
Formal job training		0.026		0.015
		(0.41)		(0.49)
Informal job training		0.182***		0.132***
		(3.58)		(6.86)
Sub-contractor		0.286***		0.262***
		(3.36)		(7.01)
Company group		-0.060		-0.014
		(-0.57)		(-0.33)
Network		0.121**		0.125***
		(2.12)		(4.46)
Foreign investor		0.341***		0.272***
		(3.30)		(5.32)
Constant	0.781***	0.343*	0.686***	0.200**
	(7.90)	(1.88)	(12.26)	(2.29)
Wald chi^2	100.21	202.21	395.50	1320.47
Prob > chi^2	0.000	0.000	0.000	0.000
N	598	483	598	483

t statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Note: Two time dummies, eighteen industry dummies, ten city and five level of education of owner dummies are included in all extended regressions. [a] log (total sales/total sales of industry). Formality status is defined as: informal is unregistered enterprises who hire informal labour and operate solely in the informal sector; semi-informal is unregistered enterprises who hire informal workers but operate in both the formal and informal sectors; semi-formal are registered enterprises who hire informal workers or engage with other informal enterprises, and formal are registered enterprises and operate solely in the formal sector.

Table 9: Employment growth, ICTs and formality status of enterprises with interaction terms

	FGLS Panel regression				
	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Log of employment growth				
ICTs					
Access to internet	0.218***	0.112***	0.103***	0.094***	0.069**
	(5.76)	(3.72)	(3.07)	(2.61)	(2.12)
Access to mobile phone	-0.213***	-0.211***	-0.201***	-0.208***	-0.183***
	(-3.07)	(-3.59)	(-3.17)	(-3.32)	(-3.15)
Status					
Informal	0.102***				
	(4.18)				
Access to internet*Informal	-0.309***				
	(-5.92)				
Semi informal		-0.016			
		(-0.40)			
Access to internet*Semi informal		0.046			
		(0.46)			
Semi-formal			-0.049*		
			(-1.82)		
Access to internet*Semi formal			0.068		
			(1.09)		
Semi informal and formal				-0.050**	
				(-2.10)	
Access to internet* Semi informal and formal				0.086	
				(1.50)	
Formal					-0.159***
					(-3.29)
Access to internet*Formal					0.254***
					(3.95)
Lagged total employees (in log)	-0.123***	-0.128***	-0.125***	-0.125***	-0.129***
	(-9.22)	(-10.45)	(-9.74)	(-9.92)	(-10.37)
Age enterprise (in log)	-0.911	-1.072	-0.892	-0.921	-1.114
	(-1.35)	(-1.41)	(-1.17)	(-1.22)	(-1.48)
Age of enterprise squared (in log)	0.468	0.552	0.460	0.475	0.574

	(1.36)	(1.43)	(1.19)	(1.24)	(1.50)
Lagged domestic market share (in log)[a]	0.027*	0.030**	0.028*	0.031**	0.023
	(1.67)	(2.01)	(1.77)	(2.02)	(1.48)
Ownership	0.108***	0.149***	0.146***	0.142***	0.130***
	(3.19)	(4.24)	(4.04)	(4.04)	(3.54)
Gender (Male)	-0.028	-0.026	-0.024	-0.022	-0.039*
	(-1.26)	(-1.14)	(-1.08)	(-1.00)	(-1.73)
Formal job training	0.001	0.001	-0.008	-0.001	-0.008
	(0.01)	(0.01)	(-0.26)	(-0.02)	(-0.24)
Informal job training	0.124***	0.119***	0.121***	0.123***	0.126***
	(5.99)	(6.08)	(6.22)	(6.35)	(6.43)
Sub-contractor	0.240***	0.268***	0.270***	0.264***	0.249***
	(6.59)	(6.25)	(6.24)	(6.33)	(6.43)
Company group	-0.024	0.004	-0.003	0.006	-0.039
	(-0.55)	(0.09)	(-0.06)	(0.12)	(-0.90)
Network	0.107***	0.124***	0.127***	0.122***	0.122***
	(3.90)	(4.60)	(4.76)	(4.65)	(4.35)
Foreign investor	0.241***	0.249***	0.253***	0.256***	0.243***
	(4.77)	(5.03)	(4.90)	(4.95)	(4.80)
Constant	0.198**	0.255***	0.260***	0.268***	0.216**
	(2.01)	(2.86)	(2.85)	(2.96)	(2.46)
Wald chi^2	1184.62	836.09	567.63	1161.96	589.47
Prob > chi^2	0.000	0.000	0.000	0.000	0.000
N	483	483	483	483	483

Note: *t* statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Two time dummies, eighteen industry dummies, and ten city and five level of education of owner dummies are included in all regressions. [a] log (total sales/total sales of industry). Formality status is defined as: informal is unregistered enterprises who hire informal labour and operate solely in the informal sector; semi-informal is unregistered enterprises who hire informal workers but operate in both the formal and informal sectors; semi-formal are registered enterprises who hire informal workers or engage with other informal enterprises, and; formal are registered enterprises and operate solely in the formal sector.

Table 10: Employment growth, ICTs and informality margin

	FGLS Panel regression			
	(1)	(2)	(3)	(4)
	Full sample		Informal margin	Formal margin
Dependent variable:	Log of employment growth			
ICTs				
Access to internet	0.130***	0.246***	0.106***	0.135***
	(4.40)	(5.29)	(3.10)	(2.93)
Access to mobile phone	-0.217***	-0.220***	-0.001	-0.034
	(-3.90)	(-3.92)	(-0.01)	(-0.15)
Informal margin	0.0315	0.087***		
	(1.22)	(2.66)		
Access to internet*Informal margin		-0.198***		
		(-3.59)		
Lagged total employees (in log)	-0.125***	-0.125***	-0.205***	-0.076***
	(-10.27)	(-10.03)	(-12.82)	(-4.85)
Age enterprise (in log)	-1.179	-1.080	-0.912	-5.142*
	(-1.56)	(-1.43)	(-1.40)	(-1.78)
Age of enterprise squared (in log)	0.606	0.557	0.472	2.586*
	(1.58)	(1.45)	(1.40)	(1.77)
Lagged domestic market share (in log)[a]	0.033**	0.021	0.083**	-0.008
	(2.21)	(1.40)	(2.52)	(-0.48)
Ownership	0.139***	0.119***	0.200***	0.0716
	(4.10)	(3.33)	(4.27)	(1.59)
Gender (Male)	-0.029	-0.036	0.026	0.120***
	(-1.26)	(-1.60)	(0.92)	(3.96)
Formal job training	0.012	-0.002	-0.074	-0.002
	(0.38)	(-0.05)	(-1.62)	(-0.06)
Informal job training	0.124***	0.122***	0.234***	-0.125***
	(6.39)	(6.17)	(9.68)	(-3.71)
Sub-contractor	0.262***	0.255***	-0.021	0.165***
	(6.64)	(6.58)	(-0.22)	(3.42)
Company group	-0.007	-0.019	-0.949***	0.0747*
	(-0.16)	(-0.45)	(-6.11)	(1.84)
Network	0.127***	0.116***	0.123***	0.102*
	(4.65)	(4.21)	(4.28)	(1.74)
Foreign investor	0.264***	0.226***	-	0.057
	(5.31)	(4.54)	-	(0.88)
Constant	0.214**	0.165*	0.097	-0.246
	(2.35)	(1.67)	(0.91)	(-0.95)
Wald chi^2	1362.33	5726.02	914.40	3118.33
Prob > chi^2	0.000	0.000	0.000	0.000
N	483	483	307	176

Note: *t* statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Two time dummies, eighteen industry dummies, and ten city and five-level of education of owner dummies are included in all regressions. [a] log (total sales/total sales of industry). Informal margin refers to enterprises that operate in the informal and semi-formal spectrum; Formal margin refers to enterprises that operate in the formal and semi-informal spectrums.