DIGITALIZATION, INNOVATION AND PRODUCTIVITY IN SOUTH AFRICAN MICRO AND SMALL ENTERPRISES

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ABSTRACT

This paper aims to study the links between the use of digital communication technologies, innovation performance and productivity for a sample of micro and small enterprises (MSEs) in a middle-income country, South Africa. Based on the results of an original survey carried out in 2019, we investigate these links for a sample of 711 manufacturing MSEs located in Johannesburg. We estimate the relations sequentially, first estimating the relation between digitalization and innovation, and secondly the relation between innovation and productivity. Our results show that selected digital communication technologies including the use of social media and the use of a business mobile phone for browsing the internet have a positive effect on innovation, and that innovation conditional on the use of these technologies has a positive impact on labor productivity.

KEYWORDS

Digital communication technologies – Product innovation – Productivity – MSEs – Johannesburg.

JEL

O14, O31, O4.

Digitalization, innovation and productivity in South African Micro and Small Enterprises

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Abstract

This paper aims to study the links between the use of digital communication technologies, innovation performance and productivity for a sample of micro and small enterprises (MSEs) in a middle-income country, South Africa. Based on the results of an original survey carried out in 2019, we investigate these links for a sample of 711 manufacturing MSEs located in Johannesburg. We estimate the relations sequentially, first estimating the relation between digitalization and innovation, and secondly the relation between innovation and productivity. Our results show that selected digital communication technologies including the use of social media and the use of a business mobile phone for browsing the internet have a positive effect on innovation, and that innovation conditional on the use of these technologies has a positive impact on labor productivity.

Keywords: Digital communication technologies – Product innovation – Productivity – MSEs – Johannesburg.

JEL classification: O14, O31, O4.

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1. Introduction

Digital transformation is reshaping all economies, including the economies of Africa. The African Union's recent *"Digital Transformation Strategy for Africa 2020-2030"* argues that the digital transformation is a driving force for innovative, inclusive and sustainable growth. The African Union's strategic vision sees the current moment as offering a leapfrogging opportunity for the continent and observes that African countries with fewer legacy challenges are potentially able to adopt digitized solutions faster (African Union, 2020).

South Africa, an upper-middle income country, has made digital readiness and transformation a key component of its National Development Plan for eliminating poverty and reducing inequalities by 2030. The *2017-2030 National e-Strategy* aims to position South Africa as a significant player in the development of information and communication technologies (ICTs) throughout the value chain and the *2020 National Digital and Future Skills Strategy* sets out a roadmap for digital skills development and for stakeholder involvement in the adoption and use of new digital technologies (South African Department of Telecommunications, 2017 and 2020).

There is clear evidence of digital transformation in South Africa over the last decade or so linked to the wide adoption of mobile phones and improvements in the infrastructure for broadband internet access. Figure 1 below shows the share of the population in South Africa using the internet and compares this to the average for high-income countries between 1995 and 2017[4]. While internet use increased rapidly in high-income countries between 1995 and 2000, it remained low in South Africa. This was linked to the limited investments in the infrastructure for fixed-line telephone systems since at the time, internet access required dialing up a connection with a modem.

[4] The data for internet use and for mobile and fixed-line subscriptions are taken from the World Development Indicators series of the World Bank Group. For more information, see: https://datatopics.worldbank.org/world-development-indicators/.

Figure 1 – Individuals using internet (in % of population)

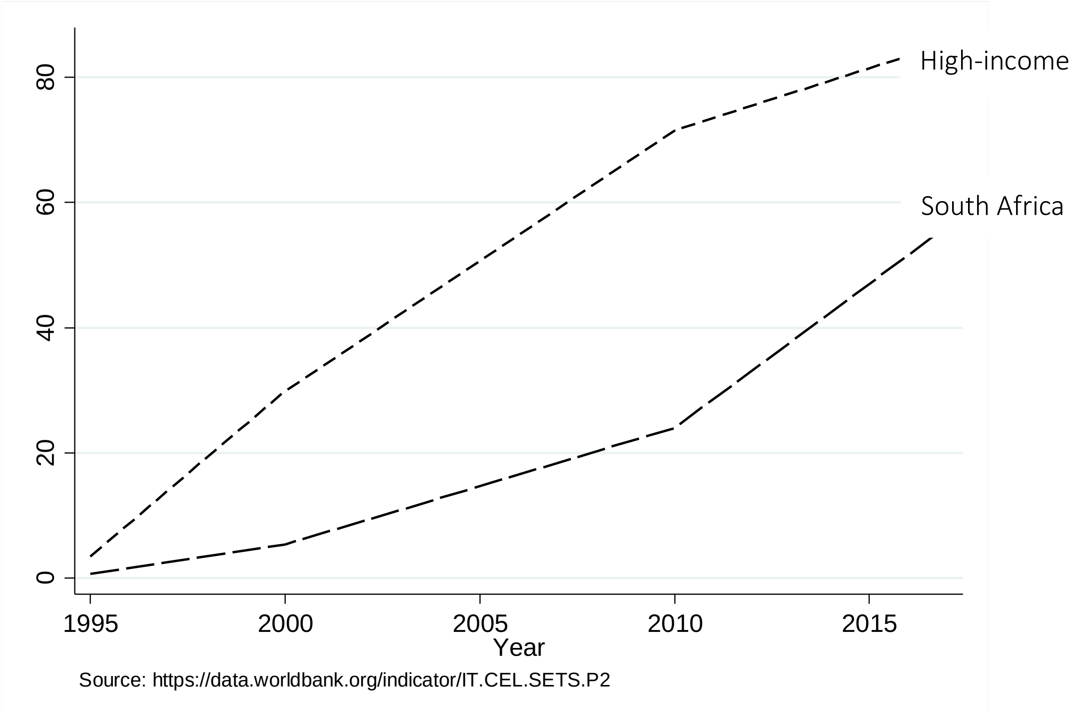
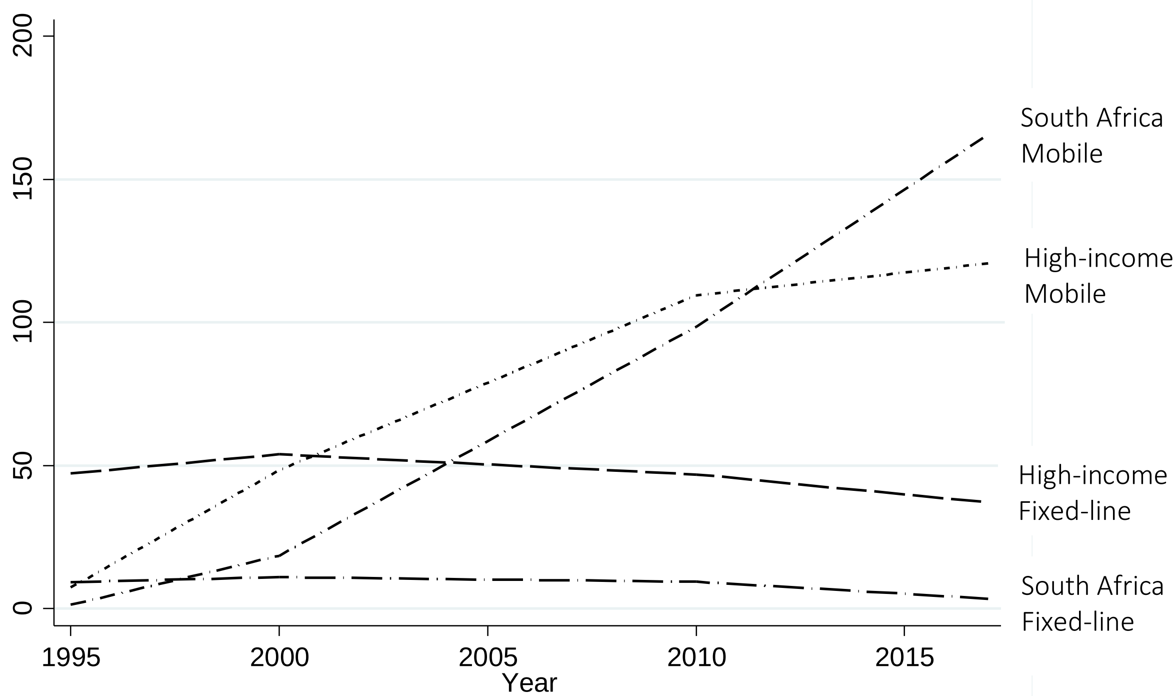


Figure 2 shows the number of fixed-line and mobile telephone subscriptions per 100 persons in South Africa compared to the average for high-income countries from 1995 to 2019. While the number of fixed-line telephone subscriptions in South Africa was under 10 per 100 persons in the mid-1990s, it was close to 50 per 100 persons on average in high-income countries. The evidence points to South Africa not benefiting substantially from the so-called ICT revolution of the 1990s that was taking hold in developed countries based on the use of personal computers and the copper wire fixed-line telecommunications infrastructure for internet access.

The number of mobile cellular subscriptions increased rapidly in South Africa after the year 2000, overtaking the number of fixed-line subscriptions. The increase in mobile subscriptions occurred at a slightly faster rate than in high-income countries while starting from a lower level. In 2000 there were about 18 mobile subscriptions per 100 persons in South Africa compared to 48 per 100 on average in high-income countries. By 2011 South Africa had fully caught up and subsequently it surpassed the average rate of penetration in high-income countries. The wide diffusion of mobile phones in combination with better and cheaper access to broadband connectivity provided the basis for a rapid increase in internet use in South Africa after 2009 as shown in Figure 1. The key institutional and infrastructural developments were an end to Telkom's monopoly on international internet access combined with the landing on the African continent of several new undersea cables resulting in an open and competitive international connectivity market contributing to significant reductions in bandwidth prices (World Bank, 2019)[5].

Figure 2 – Number of fixed-line and mobile cellular subscriptions per 100 persons



Source: https://data.worldbank.org/indicator/IT.CEL.SETS.P2

[5] At present the three largest mobile network operators in terms of market share are MTN, Vodacom and Cell C. Telekom is number four. A World Bank Report (2019) notes that while prices in South Africa compare well to other Sub-Saharan African nations in terms of the cost of broadband as a share of per capita income, the absolute price of 1GB mobile broadband data is higher than in Kenya, Nigeria or Mauritius.

The evidence points to a profound digital transformation in South Africa over the last 10 to 15 years based on the wide adoption of mobile phones and increasing internet access. However, little is known about how this digital transformation is impacting on firm performance in terms of innovation and productivity. This is especially the case for micro and small firms (MSEs) including those in the informal economy, despite the recognized role that MSEs play in alleviating poverty through employment generation (Booyens, 2011; SEDA, 2016). Moreover, while there is evidence that micro and small firms in the informal economy are creative and can contribute to the generation of new products (Wunsch-Vincent and Kraemer-Mbula, 2016; Kraemer-Mbula et *al.*, 2019), there have been few quantitative studies focusing on the determinants and impact of innovation for MSEs in South Africa. This reflects in part the lack of data as the national innovation surveys carried out in South Africa and other African countries are for the most part limited to registered firms with a minimum of 5 employees.

The paper aims to contribute to filling this gap in our knowledge through a study of the relationship between digitalization, innovation and productivity at the enterprise level for a sample of 711 manufacturing MSEs in South Africa, including informal sector businesses. We do this by making use of a recent and unique survey conducted by researchers at the University of Johannesburg, covering the innovative activities of a sample of micro and small firms in the Johannesburg conurbation and their use of new technologies associated with the recent process of digitalization including social media and access to the internet. Our main findings point first to a positive relation between the use of selected digital communication technologies and product innovation, and secondly to a positive relation between innovation performance and labor productivity conditional on the use of these technologies.

The remainder of the paper is structured as follows. Section 2 discusses the recent literature on digitalization, innovation and productivity in developing countries. Section 3 presents the model and explains the two-step estimation approach we adopt, estimating firstly the relation between the use of digital communication technologies and innovation and secondly the relation between innovation and productivity. Section 4 describes the data and presents the sample. Section 5 discusses the results. Section 6 concludes.

2. The link between digitalization and innovation

Innovation as a driver of firm performance in terms of productivity is well established in the literature. There have been several quantitative studies establishing these links based on the use of innovation survey data for both developed and developing countries. Many of these studies use the so-called Crepon-Duguet-Mairesse (CDM) sequential modeling approach, which we draw inspiration from in this paper[6]. In a 2009 overview of eight developing countries studies using the CDM framework, Fagerberg et *al.* (2010) observed that statistically significant effects on labor productivity of at least one of the innovation measures used was confirmed. Crespi and Zuñiga (2010) in a study of six Latin American countries also found that innovation has a significant impact on productivity while noting that the determinants of firm-level investments in innovation are much more heterogeneous in the Latin American countries studied than in OECD countries. In a later study of service firms in Chile, Colombia and Uruguay, Crespi et *al.* (2014) confirm the positive effect of innovation in productivity in services, although the firm size appears to be a less relevant determinant of innovation in services as compared to manufacturing. Fu et *al.* (2018), in one of the rare studies including informal or non-registered businesses in the sample of Ghanaian manufacturing firms analyzed, found support for the positive relation between innovation and labor productivity. Our study, which is similar to theirs in including informal economy firms in the analysis, extends their analysis by investigating the relation between the use of digital communication technologies and firms' innovation performance.

A few studies have extended the CDM modeling approach to explore the relation between investments in ICT technology and innovation. Most of these have focused on developed countries. Van Leeuwen and Farooqui (2008), in a study using CIS data for the Netherlands, argue

[6] For a discussion of the evolution of research based on the original CDM model during the 20 years following the publication of Crepon et *al.* (1998), see Lööf et *al.* (2017).

that ICTs can enable innovation for several reasons, including the use of e-commerce to roll out new products, the use of ICTs for capturing and processing knowledge developed elsewhere and their use for managing knowledge flows within and between firms. They test this in a model using two measures of ICT use: the share of sales sold electronically and the firm's level of broadband intensity use. Their results show that ICT use measured in this way significantly increases the chances of successful product innovation and has indirect effects on productivity. Bertschek et *al.* (2013) found that broadband had a positive and significant impact on innovation activity in a sample of German firms in 2001-2003. Polder et *al.* (2010), in a study that also uses CIS survey data for the Netherlands, argue that ICTs can impact innovation in various ways, including the introduction of new services such as online banking and the implementation of new ways of producing goods and services such as integrated management. In addition to measuring ICTs in terms of broadband intensity and e-commerce use, they include a measure of investments in ICT capital, including computers and software. They find that these three types of ICT use all impact positively on product, process and organizational innovation in services. The results are more nuanced in the case of manufacturing. Broadband is found to be an important driver of both product and organizational innovation in manufacturing and e-commerce is positively related to process innovation.

A few developing country studies have been undertaken on the relation of ICT use to innovation using the CDM approach. Unlike the studies referred to above, they measure ICT use solely in terms of ICT capital investments in hardware, software and computer services and lack measures of broadband intensity or e-commerce. Aboal et *al.* (2018) in a study of Uruguayan firms using the 2004–2006 and 2007–2009 waves of the Service Innovation Survey focus on the distinction between technological (product and process) and non-technological (organizational and marketing) innovation. They find that ICT investments are more important for product and process innovation in services than in manufacturing. The reverse is true for their impact on organizational and marketing innovation. Alvarez (2016) in a study of Chilean business using the 2007 and 2009 Longitudinal Enterprise Surveys finds that ICT investments impact positively on both technological and non-technological innovation in services and manufacturing. When predicted ICT investments are introduced into the productivity equation, however, the effect of innovation on productivity disappears. On this basis, it is included that the effects of ICT capital on productivity is direct rather than being indirect through innovation.

In summary, the econometric research based on national innovation surveys finds support for the importance of ICTs for at least certain measures of innovation. While the two developing country studies reviewed do support this conclusion, they limit their measurement of ICTs to the firm's investments in hardware and software and do not include the firm's internet bandwidth intensity use or its use of e-commerce. This limits their relevance for understanding the impact of the current digital transformation, which has witnessed an unprecedented increase in broadband internet access in Africa and other developing countries based on mobile telephony. As the study by Polder et *al.* (2010) argued for the case of a developed country, the Netherlands, broadband internet access can be a means of acquiring new knowledge inputs for innovation and for sharing knowledge across partners and the use of e-commerce may contribute to successfully rolling out new products and services. Further, there is a large theoretical and case study-based literature in business management on the role of social media in driving and enabling innovation (Bhimani et *al.*, 2019). Several use cases show how social media can be used to support knowledge sharing and open innovation (Brandtzaeg et *al.*, 2016; Hitchen et *al.*, 2017). Social media may promote innovation by providing a tool for interacting with and drawing on users' ideas (Dong and Wu, 2015). Muninger et *al.* (2019) develop an organizational capabilities perspective, arguing that social media supports agile processes that facilitate rapid decision making and knowledge flows across teams within the firm.

The survey on which this study is based includes indicators for mobile phone-based internet browsing, having a social media presence, and accessing markets through online sales. Moreover, it is the only survey to our knowledge that measures the adoption of these technologies by micro-enterprises with less than five employees, including non-registered businesses. The results of the analysis show that MSEs can benefit in their innovation performance from the use of these digital technologies and that innovation conditional on their use increases the level of labor productivity.

3. Digitalization, innovation and productivity: A sequential modelling approach

Our empirical analysis draws inspiration from the sequential modelling approach associated with Crepon, Duguet and Mairesse (1998), often known as the CDM model. The CDM literature has focused on investigating sequentially the link between R&D and innovation and the link between innovation and productivity conditional on R&D. We expand on this framework by including in the first part of our analysis the impact of digital communication technologies on product innovation. Our econometric specification includes two equations: the first one focuses on the determinants of innovation, including the effect of digital communication technologies; and the second one focuses on the relation between innovation and productivity. We use two-stage least squares (2SLS) instrumenting innovation in the second stage equation with the predicted values from the first stage equation in order to address possible problems of endogeneity between innovation and productivity.

3.1 Predicting innovation outcomes

Our dependent variable ($Innovation$) in the first stage refers to the introduction of a new or significantly improved product during the fiscal year 2019. Since our dependent variable is dichotomous, we fit the model with a maximum likelihood probit model at the firm i level as specified in equation (1):

$$Innovation_i = c + \beta_1 Log(size_i) + \beta_2 Log(age_i) + \beta_3 Fixed\ capital_i + \beta_4 ICT\ capital_i + \beta_5 X_i + \beta_6 Y_i + \varepsilon_i \qquad (1)$$

where $Innovation_i$ is a dichotomous variable equal to 1 if the firm has introduced onto the market a new or significantly improved product, c is the constant term, $Log(size_i)$ is the number of employees, $Log(age_i)$ is the age of the firm. Both of them are expressed in natural logarithms. $Fixed\ capital_i$ is the intensity of fixed capital defined as the value of vehicles, furniture and machinery (excluding ICT equipment) per employee and $ICT\ capital_i$ is the value of ICT capital over the number of employees where ICT capital includes the firm's stock of computers, fixed-line telephones, printers, scanners and fax machines. As discussed below, a variety of research has shown that computerization can result in increased productivity by substituting for the use of manual labor in both manual and information processing tasks. Thus, we expect higher intensity of use of ICT capital to result in higher labor productivity[7].

X_i is a vector of binary variables measuring the use of four selected digital communication technologies including having a social media presence, developing online sales, making use of a business mobile phone for browsing the internet and for interacting with customers. As discussed above, we expect these variables to have a positive effect on innovation. Y_i is a vector of controls for whether the location of the business is in the Johannesburg central business district, whether or not the firm is formal in the sense of being registered with the South African Revenue Service (SARS), whether it has engaged in R&D expenditures, whether its sector of activity is classified as high-tech (HT) or low-tech (LT), and whether it has cooperated with other firms in the same industry[8]. As widely discussed in the innovation systems literature, an important mechanism for increasing access to knowledge that can contribute to better innovation performance is inter-firm cooperation promoting interactive learning (Lundvall, 2010; Jensen et *al.*, 2007). Several studies focusing on African countries support the importance of inter-firm cooperation for innovation, including for small firms (Van Dijk, 2002; Oyelaran-Oyeyinka and McCormick, 2007). Correspondingly, we expect that cooperation between firms will result in improved access to knowledge and increased innovation capabilities. β_1 to β_6 are the coefficients associated with the previous variables and $\varepsilon_{\mathrm{i}} \sim N(0,1)$ is the error term.

Digital technologies are transforming both the way firms produce and the way they interact with other firms and with consumers. Our expectation is that while computers and other forms of ICT capital will have a direct effect on productivity, the impact of digital communication technologies depending on the internet will tend to be indirect through their effect on the development and marketing of new products and services[9].

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[7] See notably the literature on routine-biased technical change associated with the work of Autor et *al.* (2003).
[8] The description of all variables is provided in Table 1.
[9] OECD (2019) observes that even if the gains from digitalization have been substantial, there is no consensus on the direct causality between digital communication technologies and productivity. For example, more productive firms

3.2 The link between innovation and productivity

In the second stage, we estimate the relation between innovation and productivity. This estimation is likely to present a problem of endogeneity due to simultaneity since more productive firms may be better placed to invest additional resources in innovation activities. In order to address this problem, we employ 2SLS using two excluded exogenous variables from the first stage equation as instruments: (i) the use of social media and (ii) the use of business mobile phone for accessing the internet. As we discussed above, we expect these variables to have a positive and statistically significant impact on innovation. They should meet the exclusion restriction condition of only affecting productivity indirectly through their impact on innovation.

Our dependent variable ($Productivity$) in the second stage refers to labor productivity measured as the natural logarithm of the value of the firm's turnover per employee in 2019. Due to missing observations, data on the absolute value of turnover are only available for 273 firms. For 318 firms, we have interval data on their turnover but not absolute values. On this basis, we make use of multiple imputations to generate absolute turnover values for the 318 firms for which only interval data is available. Our resulting sample for the second stage productivity regression is 591 firms[10]. The second stage of the 2SLS regression model takes the following form at the firm i level as specified in equation (2):

$$Productivity_i = c + \beta_1 Innovation_i + \beta_2 Log(size_i) + \beta_3 Log(age_i) + \beta_4 Fixed\ capital_i + \beta_5 ICT\ capital_i + \beta_6 Y_i + \varepsilon_i \quad (2)$$

where c is the constant term, $Innovation_i$ is the instrumented value derived from the first stage innovation equation (1). Y_i is a vector of same binary variables appearing in the first regression to which we add the two remaining digital communication technologies (i.e. developing online sales

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may benefit from digitalization because they are more likely to have access to knowledge for developing new products or implementing new organization methods than other firms. Our sequential approach allows us to explore the possible indirect effect of digitalization on productivity through innovation.

[10] We exclude firms for which we have neither the absolute value nor an interval range for turnover.

and making use of a business mobile phone for interacting with customers). The other two digital communication technologies (i.e. having a social media presence and making use of a business mobile phone for browsing the internet) are excluded from this vector since they are used as exogenous instrumental variables. β_1 to β_6 are the coefficients associated with these variables and ε_i is the error term.

The possible impact of ICT capital on productivity is discussed in the literature on firm heterogeneity in their investment patterns and productivity performances (Draca et *al.*, 2009). In this context, several studies have estimated the impact on the firm's productivity of the use of computers in the production process either directly or in interaction with changes in work organization. With respect to developed countries, Brynjolfsson and Hitt (2002) present direct evidence that the use of computers in the production process contributes to higher productivity and output growth in US firms. Mohnen et *al.* (2018), using firm-level data for the Netherlands, find that investments in ICT, R&D and organizational innovation are complementary in the sense that joint investments lead to higher total factor productivity growth. For developing countries, Commander et *al.* (2011) look at the consequences of ICT capital adoption and use on firm performance in Brazil and India[11] and find a strong positive association between investments in ICT capital and productivity in manufacturing firms. Based on these results, our expectation is that the intensity of ICT capital impacts positively on productivity.

4. Data source, sample and descriptive statistics

4.1 Data source

A research team at the University of Johannesburg conducted in 2019 an innovation survey among micro and small firms located in the city of Johannesburg[12], which we refer to as the "MSE

[11] ICT capital is measured on a 5-point scale in terms of the degree to which office and production processes are *"automated and integrated into a centralized system"*, (Commander et *al.,* 2011, p. 22).

[12] This survey was conducted under the project "Community of Practice in Innovation and Inclusive Industrialisation", coordinated by one of the authors in this paper and hosted by the South African Research Chair in Industrial Development, at the College of Business and Economics, University of Johannesburg.

Survey"[13]. The survey focused on the central business district of Johannesburg, the capital of the Gauteng province, which accounts for 16% of South Africa's GDP and 40% of Gauteng's economic activity[14]. The MSE survey focuses on manufacturing firms. It aims to understand some of the challenges faced by micro and small manufacturing firms in their innovation activities as well as understanding the environment in which these firms operate. This survey consists of a set of 74 questions capturing from the background of the owner to the characteristics of the workforce and financial issues. The data collection spanned a period of 3 months, from June to August 2019. Finally, the sample covered 711 micro and small firms in 2019.

The full description of the different variables built from the survey and associated descriptive statistics are reported in Table 1. Innovation refers to the introduction onto the market of a new or significantly improved product. To count as an innovation, the product needs to be new to the firm but not necessarily new to the firm's market and, as many authors have observed, innovations introduced by firms located in low- and middle-income countries often have an imitative and incremental nature because these firms are far from the technological frontier (Crespi and Peirano, 2007; Goedhuys, 2007; Fagerberg et *al.*, 2010; Srholec, 2011). This definition of an innovation, to include incremental and imitative activities, can help account for what may appear to be an exceedingly high rate of innovation success, with 49% of the sample of 711 classified as innovators.

The MSE survey includes both measures of investments in ICT assets, including computers, fax machines and fixed-line telephones, and the use of digital communication technologies that depend on having internet access and may be used to increase the firm's visibility on the market or for communication and exchange with other firms and clients. These digital communication technologies include having a social media presence (34%), developing online sales (13%), using a mobile phone to browse on the internet (7%) and using a mobile phone to interact with

[13] Accession date: February 2020.
[14] For more details, see: https://www.joburg.org.za/about-the-city.

customers (28%). As noted in the above discussion of the choice of instruments, we assume that the impact on productivity of having a social media presence and using a mobile phone to browse the internet will be indirect through their effects on innovation.

Table 1 – Descriptive statistics

	Description of variables	Type of variables	Mean (over full sample)
Dependent variables			
Product innovation	Whether the firm has introduced entirely new or significantly improved products	Binary	0.49
Labor productivity[1]	Average value of the log of productivity over 10 imputations	Nominal	9.73
Independent variables			
Size	Natural logarithm of the number of employees (full-, part-time and occasional)	Nominal	1.36
Age	Natural logarithm of the age of the firm in year	Nominal	2.35
Fixed capital	Total value of fixed assets (i.e. vehicles, furniture, machinery, etc.) in 10s of thousands of Rands/Number of employees	Nominal	22.42
ICT capital	Total value of ICT equipment (i.e. computers, telephones, printers, scanners, fax machines, etc.) in 10s of thousands of Rands/Number of employees	Nominal	1.58
Registration (formal or informal firm)	Whether the firm is registered with South African Revenue Service (SARS)	Binary	0.27
Cooperation	Whether the firm has cooperated with other firms in the same industry	Binary	0.48
Location	Whether customers are located locally (i.e. the inner city and surrounding suburbs)	Binary	0.72
Sector	Main manufacturing activities conducted by the firm – Following the OECD classification (Hatzichronoglou, 1997), an activity is either considered as high-tech (HT) or low-tech (LT)[2]	Binary	0.09
R&D	Whether the firm has engaged in R&D activities for innovation	Binary	0.15
Digital communication technologies			
Social media	Whether the firm has a social media presence for the business	Binary	0.34

Internet surf	Whether the firm use a mobile phone for surfing the internet	Binary	0.07
Mobile customer	Whether the firm use a mobile phone to interact with customers	Binary	0.28
Online sales	Whether the firm has developed online sales	Binary	0.13

[1]The survey results provide the absolute value of sales in 2019 for 273 firms and interval data for a further 318 firms. Based on these variables and the other variables in the productivity equation, we use multiple imputations to estimate the value of turnover for the 318 firms for which only interval information on 2019 sales exists. This provides a sample of 591 firms.
[2]See Tables A1 and A2. HT covers high- and medium-high tech sectors. LT covers low- and medium-low tech sectors.
Source: MSE Survey, authors' calculations.

4.2. Differences according to sector

The data collected cover only manufacturing firms, so we split our sample between high-tech (HT) and low-tech (LT) sectors (Hatzichronoglou, 1997) as explained in Table 1. Table A1 in the appendix provides descriptive statistics according to sector for the firm's size in terms of employment, its age, the capital intensities and the use of digital communication technologies. A number of salient characteristics emerge from the summary statistics. Firstly, the large majority of the firms (90.7%) belong to LT sectors: 27.6% of them are active in the manufacture of wearing apparel and 17.9% in the manufacture of furniture. Manufactures of textiles and basic metals represent respectively 10.1 and 9.4% of the firms. More than half of the firms in HT sectors are distributed between the manufacture of chemicals (3.2% of the firms) and other manufacturing (2.5%). So, the distribution of the manufacturing firms located in Johannesburg is left-skewed towards LT sectors.

Secondly, firms have on average 16 years in the LT sectors and 21 years in the HT sectors. These firms seem to be mature and well-established in the productive tissue of the city. Almost half of them (0.48 cf. Table 1) cooperate with other firms in the same industry, and most of them (0.72) predominantly work in local markets, with customers located in the inner city or surrounding suburbs. So, in other words, these firms penetrate the market and develop distribution channels.

Thirdly, a quarter of the total workforce is employed in the manufacture of furniture (1,349 workers). Manufactures of wearing apparel, wood, basic metals, textiles and food products employ between 7.2% and 12.5% of the remaining workforce. The workforce in all sectors is made up of full-time contracts. Part-time and occasional contracts concern respectively 14% and 8% of the workers. As proposed by Fu et *al.* (2018), another way to evaluate this workforce refers to a decomposition between micro (less than or equal to 9 employees), small (10 to 29 employees), medium (30 to 99 employees) and large firms (equal or more than 100 employees). For each sector, by relating the number of employees to the number of total firms, we have a proxy of this decomposition: 78.1% of the firms are micro ones and 18.4% are small ones. So, the distribution of the number of employees is left-skewed towards micro and small firms (maybe artisanal ones).

Fourthly, the South African firms differ significantly in terms of the relative intensity of use of fixed capital and ICT capital. For example, the manufacture of rubber and plastic products represents 12.3% of total fixed capital but a very small part of total ICT capital (1.4%). The manufacturers of other non-metallic mineral products face the same gap between fixed and ICT capital (6.2% for the former, 1.1% for the latter). The manufactures of furniture and wearing apparel, the two largest sectors both in terms of the numbers of firms and total employment, also differ from one another in their capital intensity. While the manufacture of furniture holds 51.3% of total fixed capital but only 4.9% of total ICT capital, the manufacture of wearing apparel covers 15.2% of total fixed capital and 24.5% of total ICT capital. Conversely, certain sectors hold a larger share of ICT capital and a smaller share of fixed capital: this means that firms belonging to these sectors are relatively advanced in terms of computerization. Moreover, four sectors (the manufacture of food products, the manufacture of machinery and equipment, the manufacture of wearing apparel and the manufacture of wood) account for 76.4% of the ICT capital while they account for only 23.5% of total fixed capital and for only 28.6% of the total employment. So, the diffusion of ICT capital is very uneven. Even if firms in HT sectors represent a small part of our sample, it is interesting to note that the manufacture of machinery and equipment holds 7.1% of total ICT capital, the fourth-highest percentage.

Fifthly, looking at the use of digital communication technologies, it seems that an important share of MSEs in South African manufacturing sectors use social media for their business (34% of the total population, see Table 1). Social media may be used not only to increase the exposure of the firm to prospective clients but also for purposes of information exchange with other firms and organizations. In the context of South African manufacturing firms, the manufactures of wearing apparel and furniture – which have the most weight in this sample in terms of employees and capital intensities – have clearly the most intensive use of these digital communication technologies: respectively, 29% and 14% for social media, 18% and 12% for internet surfing, 29.1% and 12.1% for mobile customer, 19.6% and 22.8% for online sales. The manufacture of textiles uses these four digital technologies in a very complementary way, between 10% and 12.1%. The other manufactures mainly use one of the four digital communication technologies rather than all four combined. For example, for manufactures of chemicals and wood, the use of mobile phone for browsing the internet prevails (respectively 10% and 14.1%). For manufactures of wood and printing and reproduction of recorded media, online sales are the most used (5.4% for each). For the manufacture of basic metals, the use of mobile phone for interacting with customers is clearly more used than the other three (11.1%). So, the use of digital communication technologies is relatively heterogeneous between sectors.

These shares motivate our study of the relation between digitalization and innovation especially compared with the R&D efforts engaged by South African MSEs: only 15% of the firms in our sample have engaged in R&D activities for innovation (see Table 1). Maybe because R&D requires substantial capital investments which are out of the reach for most MSEs. However, digital communication technologies that rely only on broadband connection seem to more accessible for South African MSEs.

5. Econometric results

5.1. The impact of digital communication technologies on product innovation

In Table 2 below, we provide the results of the equation (1). The regression in column (a) includes only the four digital communication technologies. Column (b) adds the variables for R&D, cooperation between firms and the two measures of capital intensity. Column (c) is the complete specification, including the different controls. Of the four digital communication technologies, internet surfing and social media have a positive and significant effect on innovation, and this result is robust to adding the different controls and other covariates. Social media differs from online sales in that it is a technology that can be used for interaction and exchange. For example, communities sharing a specialized interest can establish online groups through social media platforms for purposes of discussion and knowledge exchange. Surfing on the internet, as we noted above, is a way of acquiring knowledge and ideas that can feed into the process of developing a new product. The coefficient on the variable measuring communicating with customers electronically with tools like WhatsApp or Skype is positive but, contrary to our expectation, is not significant. There is also a positive and significant coefficient on the variable measuring cooperation with other firms in the same industry or trade, and undertaking R&D has a positive and significant impact on product innovation.

Table 2 – Probit regression predicting product innovation

	(a)	**(b)**	**(c)**
		Product innovation	
Social media	0.177***	0.172***	0.161***
	(0.0421)	(0.0422)	(0.0437)
Internet surfing	0.219***	0.178**	0.187**
	(0.0758)	(0.0837)	(0.0832)
Mobile customer	0.0574	0.0532	0.0518
	(0.0450)	(0.0452)	(0.0455)
Online sales	0.0415	0.00636	9.00e-05
	(0.0614)	(0.0627)	(0.0648)
R&D		0.131**	0.130**
		(0.0579)	(0.0600)
Cooperation		0.0919**	0.0937**
		(0.0390)	(0.0390)
Fixed capital		8.19e-09	8.10e-09
		(1.25e-08)	(1.24e-08)
ICT capital		-3.97e-08	-2.63e-08
		(1.36e-07)	(1.27e-07)

Size			0.00822
			(0.0213)
Age			-0.0251
			(0.0238)
Location			0.0157
			(0.0457)
Registration			0.0437
			(0.0477)
Sector			0.101
			(0.0678)
Observations	711	711	711
Pseudo R^2	0.0424	0.0554	0.0597
Wald χ^2	39.49***	50.47***	57.77***
Correctly classified	60.76%	61.74%	61.74%

Note: Marginal effects are reported in this table. Robust standard errors are given in parentheses.
***P<0.01, **P<0.05, *P<0.1.

Neither of the measures of capital intensity are statistically significant, and we find no significant impact for any of the control variables including of the size or the age of the firms. In the context of SMEs in Sri Lanka, De Mel et *al.* (2009) find that firm size plays a larger role in process and organizational innovations than in product innovation. As in the case of our sample, they do not find for manufacturing firms a significant correlation between innovation and the age of the firm. Being registered has a small positive but statistically insignificant effect on innovation.

Based on Wooldridge's (1995) robust score test for endogeneity, the null hypothesis of exogeneity is rejected. The two instruments we use for the two-stage least squares regression – the use of social media and the use of mobile phones to browse the internet – are both positively correlated with innovation and highly significant, pointing to their being informative. The value of the F-statistic for the instruments is over 15 showing that the instruments are not weak.

5.2. The impact of product innovation on labor productivity

In the Table 3, Column (a) features the results of the second stage of the two-stage IV regression, equation (2). The results show a significant and positive effect of product innovation on labor productivity. Our measure of the intensity of use of ICT capital has a positive and statistically significant impact on product innovation. This supports the literature cited above on the positive impact of the computerization of work processes and internal knowledge flows on productivity. The coefficient of the measure of fixed capital intensity surprisingly is negative but it is statistically insignificant. Neither online sales nor using mobile phones to communicate with clients have a significant impact on productivity. We find that formal firms in the sense of being registered have higher productivity on average than unregistered firms and that firms that have been established longer have higher labor productivity.

Table 3 – 2nd stage Instrumental variable regression explaining labor productivity

	(a)	**(b)**
	Labor productivity	
Product innovation	2.455**	2.418**
	(0.983)	(0.955)
Mobile customer	-0.230	-0.167
	(0.175)	(0.172)
Online sales	-0.349	-0.343
	(0.282)	(0.279)
R&D	-0.149	-0.218
	(0.344)	(0.347)
Cooperation	-0.131	-0.127
	(0.186)	(0.182)
Fixed capital	-4.80e-08	-4.84e-08
	(1.02e-07)	(1.01e-07)
ICT capital	1.36e-06*	1.49e-06*
	(8.07e-07)	(8.03e-07)
Size	0.147	-0.0730

	(0.0903)	(0.102)
Age	0.245***	0.202**
	(0.0889)	(0.0874)
Location	-0.103	-0.0775
	(0.203)	(0.198)
Registration	0.336*	-0.878**
	(0.196)	(0.396)
Sector	-0.461	-0.414
	(0.334)	(0.215)
Registration * Size		0.724***
		(0.215)
Constant	8.836***	9.063***
	(0.751)	(0.714)
Observations	591	591
Wald χ^2	34.60***	40.80***

Note: Robust standard errors are given in parentheses.

***P<0.01, **P<0.05, *P<0.1.

Column (b) includes an interaction term between size and being registered. The result shows that being registered has a greater positive impact on productivity for larger firms than for smaller firms. We can only surmise as to the reasons for this. A possible explanation is that the combination of being registered and having a larger volume of sales improves the firm's access to finance for investing in new ICT equipment or its ability to recruit skilled labor, thus improving its level of productivity.

6. Conclusion

There is a considerable debate about the impact of digitalization and Industry 4.0 technologies. A major focus has been around automation and the extent to which cyber-physical systems involving the use of advanced robotics and big data analytics based on artificial intelligence will result in the development of the 'smart factory' in which human intervention is significantly reduced. These technologies involve large capital investments and are adapted to the needs of large enterprises engaged in large scale production, notably in sectors like automobiles, chemicals and plastics and consumer electronics. The limited evidence available for developing countries shows these advanced technologies are adopted to a very limited extent and rarely in small firms[15]. The debate on the adoption of Industry 4.0 manufacturing technologies ignores the wider impact of the current digitalization process underway in developing countries which involves the use of technologies based on mobile telephones and the internet that involve smaller capital investments and are within the reach for micro and small firms.

In this study, we explore the relation between using these internet-based digital technologies, innovation and productivity for a sample of micro and small manufacturing firms in Johannesburg, South Africa. Our findings show, firstly, that selected digital communication technologies, including the use of social media and using a mobile phone to browse the internet have a positive effect on innovation. These results support the literature arguing social media and using the internet can enable innovation by supporting interaction and knowledge exchange among firms and with consumers. Secondly, innovation conditional on the use of these digital technologies has a positive impact on labor productivity, a result which is consistent with the large literature for developed and developing countries showing a positive relation between innovation and productivity.

There are several ways in which the results of this study could be usefully extended. First, we have only examined the impact of a limited range of digital communication technologies that are accessible to micro and small firms. Other technologies that are highlighted in the literature on digitalization include cloud computing and the use of services available on digital platforms.

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[15] Recent surveys of the adoption of advanced manufacturing technologies coordinated by UNIDO in Argentina, Brazil, Viet Nam, Thailand and Ghana find that only a small percentage of enterprises are adopting these technologies. (UNIODP 2019, Ch. 3). Kupfer et *al.* (2019) in a summary of the results, while only distinguishing between firms with more or less than 100 employees, find that slightly more than 86% of the firms with less than 100 employees use only basic forms of digitalization in their manufacturing processes involving tools such as CAD or CAD-CAM which have been available for several decades.

Secondly, the analysis could be extended to larger populations of micro and small firms, including service sector firms which are some of the most active users of online digital services. This points to the need for a large-scale measurement program in Africa and other developing country regions designed to investigate the adoption and impact of digital communication technologies, including micro and small firms, which account for the majority of firms and for a large share of employment. It is our hope that the results of this study will provide motivation and guidance for pursuing this.

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Appendix

Table A1 – Sample description of firms according to sector for size, age, capital intensities and digital communication technologies

	Number of firms (share)	Number of employees (share)	Mean of age	Share of fixed capital	Share of ICT capital	Share of each digital communication technology			
						Social media	Internet surf	Mobile customer	Online sales
HT sectors									
Manufacture of chemicals	23 (3.2)	305 (5.7)	20	1.4	3.4	4.1	10.0	4.5	6.5
Manufacture of pharmaceuticals	10 (1.4)	39 (0.7)	24	0.04	0.1	0.8	2.0	0.5	0.0
Manufacture of electrical equipment	5 (0.7)	22 (0.4)	36	0.3	0.1	0.4	2.0	1.0	1.1
Manufacture of machinery and equipment	6 (0.8)	57 (1.1)	26	1.1	7.1	0.8	2.0	1.0	1.1
Manufacture of motor vehicles	1 (0.1)	8 (0.2)	15	0.0	0.0	0.0	0.0	0.0	0.0
Other manufacturing (includes jewelry, musical instruments, etc.)	18 (2.5)	205 (3.9)	12	0.1	0.9	4.1	8.0	4.0	2.2
Repair and installation of machinery and equipment	2 (0.3)	6 (0.1)	16	0.04	0.02	0.0	0.0	1.0	0.0
LT sectors									
Manufacture of food products	29 (4.1)	383 (7.2)	20	2.6	16.7	6.2	8.0	4.0	2.2
Manufacture of beverages	1 (0.1)	100 (1.9)	12	0.003	0.05	0.4	0.0	0.0	1.1

Manufacture of tobacco products	1 (0.1)	25 (0.5)	7	0.0	0.0	0.4	0.0	0.0	0.0
Manufacture of textiles	72 (10.1)	390 (7.3)	11	1.3	3.4	12.4	10.0	12.1	11.0
Manufacture of wearing apparel	196 (27.6)	666 (12.5)	11	15.2	24.5	29.0	18.0	29.1	19.6
Manufacture of leather and related products	34 (4.8)	126 (2.4)	18	0.1	0.3	3.7	4.0	2.0	4.3
Manufacture of wood	46 (6.5)	414 (7.8)	14	4.6	28.1	8.3	14.0	5.5	6.5
Manufacture of paper	6 (0.8)	87 (1.6)	18	0.3	0.6	1.2	0.0	1.5	5.4
Printing and reproduction of recorded media	13 (1.8)	212 (4.0)	21	0.6	2.1	3.3	4.0	2.0	5.4
Manufacture of coke and refined petroleum products	1 (0.1)	4 (0.1)	39	0.01	0.2	0.0	0.0	0.5	0.0
Manufacture of rubber and plastic products	10 (1.4)	129 (2.4)	20	12.3	1.4	2.9	0.0	1.5	4.3
Other non-metallic mineral products	23 (3.2)	188 (3.5)	14	6.2	1.1	3.3	0.0	3.5	2.2
Manufacture of basic metals	67 (9.4)	397 (7.5)	12	0.6	0.4	3.3	2.0	11.1	2.2
Manufacture of fabricated metal products	20 (2.8)	205 (3.9)	17	2.0	4.8	1.2	4.0	3.0	2.2
Manufacture of furniture	127 (17.9)	1,349 (25.4)	13	51.3	4.9	14.0	12.0	12.1	22.8
TOTAL	**711 (100)**	**5,317 (100)**	**--**	**100**	**100**	**100**	**100**	**100**	**100**

Source: MSE Survey, authors' calculations.

Table A2 – Innovation in manufacturing firms by size and sector (in %)

Sector	Product innovation		
	[1;9]	[10;49]	[50;100]
Basic metals	5.2	1.2	0
Beverage products	0.3	0	0
Chemicals	2.3	0.6	0.3
Coke and refined petroleum	0	0	0
Electrical equipment	0.9	0	0
Fabricated metal products	1.4	1.2	0
Food products	2	2.3	0
Furniture	12	5.5	0.3
Leather	5.5	0.6	0
Machinery and equipment	0.3	0.6	0
Motor vehicles	0	0	0
Other manufacturing	2.3	0.9	0
Other non-metallic minerals	2.3	1.4	0
Paper	0.3	0.6	0
Pharmaceuticals	0.6	0	0
Printing and reproduction	1.4	0.3	0.3
Repair and installation	0	0	0
Rubber and plastic products	0.3	0.6	0
Textiles	6.3	2	0
Tobacco products	0	0.3	0
Wearing apparel	28	2.6	0
Wood	5.5	2.6	0
TOTAL	**347**		

Source: MSE Survey, authors' calculations.

ABOUT OFCE

The Paris-based Observatoire français des conjonctures économiques (OFCE), or French Economic Observatory is an independent and publicly-funded centre whose activities focus on economic research, forecasting and the evaluation of public policy.

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Its research community includes over two hundred twenty members and three hundred fifty PhD candidates. Recognized internationally, their work covers a wide range of topics including education, democracies, urban development, globalization and public health.
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