Digitalisation, Innovation and Productivity in South African Micro- and Small Enterprises

Cyrielle Gaglio, Erika Kraemer-Mbula, Edward Lorenz

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DSI/NRF SOUTH AFRICAN RESEARCH CHAIR IN INDUSTRIAL DEVELOPMENT

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Abstract

This paper studies 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 relationships sequentially, firstly estimating the relationship between digitalisation and innovation, and secondly the relationship between innovation and productivity. Our results show that selected digital communication technologies, including the use of social media and of a business mobile phone for surfing the internet, have a positive effect on innovation, and that innovation conditional on the use of these technologies has a positive effect on labour productivity.

Keywords: Digital communication technologies, Product innovation, Productivity, MSEs, Johannesburg

JEL classification: O14; O31; O4

About the Authors

Cyrielle Gaglio: Corresponding author. University of Helsinki, Department of Economics and Management, Finland and Sciences Po, OFCE, France. Email: cyrielle.gaglio@helsinki.fi. Address: University of Helsinki, Department of Economics and Management, Latokartanonkaari 5, FI-00014 Helsinki.

Erika Kraemer-Mbula: DSI/NRF/Newton Fund Trilateral Chair in Transformative Innovation, the Fourth Industrial Revolution and Sustainable Development, University of Johannesburg, South Africa. Email: erikakm@uj.ac.za.

Edward Lorenz: University of Côte d'Azur, France, University of Johannesburg, South Africa and Aalborg University, Denmark. Email: edward.lorenz@gredeg.cnrs.fr.

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1. Introduction: Digital Transformation in South Africa

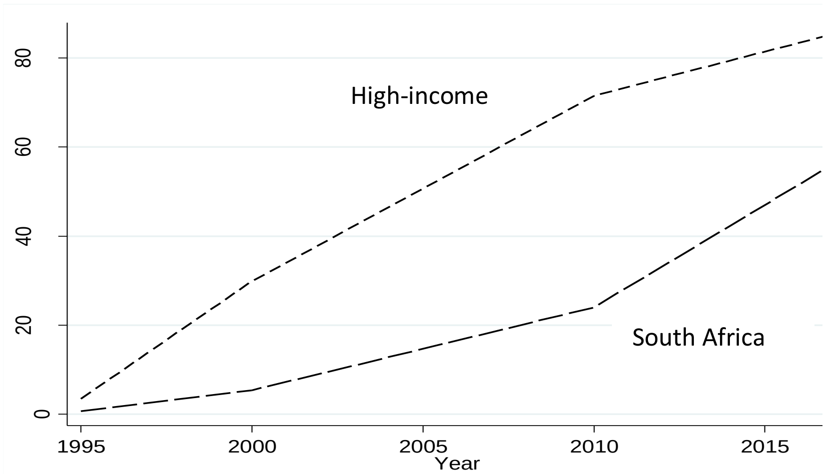
Digital transformation is reshaping all economies, including the economies of Africa. The African Union's recent "Digital Transformation Strategy for Africa 2020-2030" argues that digital transformation is a driving force for innovative, inclusive and sustainable growth. The African Union's strategic 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 digitised 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 (South African Department of Telecommunications [SADT] 2017) 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 (SADT 2020).

There has been 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.[1] 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 dialling up a connection using a modem.

[1] The data for internet use and for mobile and fixed-line subscriptions is taken from the World Development Indicators series of the World Bank Group (April 2021). For more information, see https://datatopics.worldbank.org/world-development-indicators/

Figure 1: Individuals Using Internet (in % of Population)



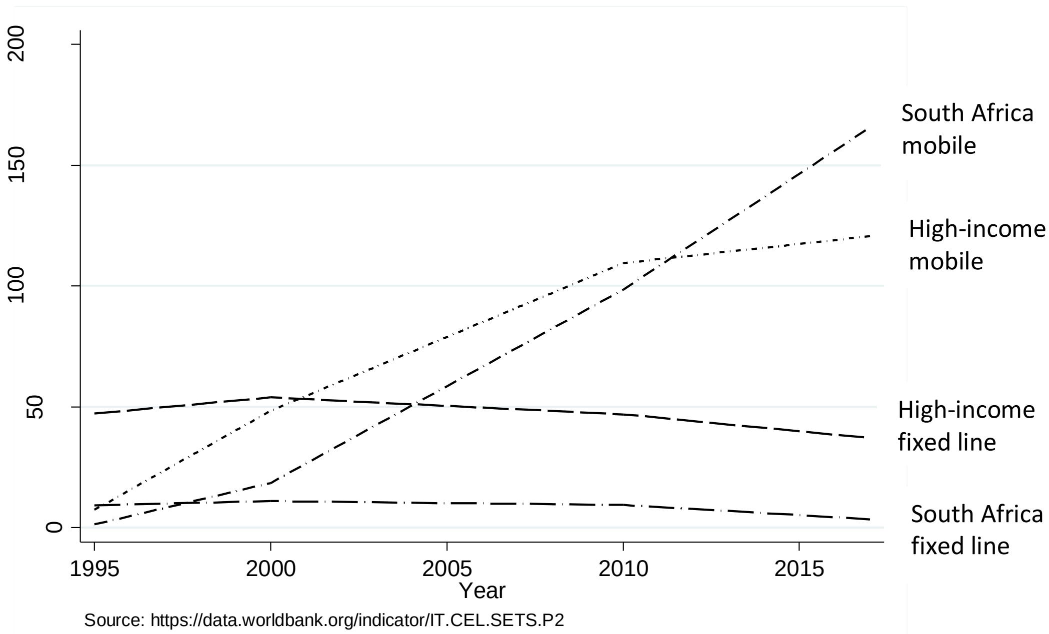
Source: https://data.worldbank.org/indicator/IT.CEL.SETS.P2

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 caught up fully and subsequently 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).[2]

[2] At present, the three largest mobile network operators in terms of market share are MTN, Vodacom and Cell C. Telkom is at 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 and Mauritius.

Figure 2: Number of Fixed-line and Mobile Cellular Subscriptions per 100 Persons



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 affecting 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 recognised 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 influence of innovation for MSEs in South Africa. In part, this reflects the lack of data as, for the most part the national innovation surveys carried out in South Africa and other African countries are limited to registered firms with a minimum of five employees.

This paper aims to contribute to filling this gap in our knowledge through a study of the relationship between digitalisation, innovation and productivity at the enterprise level for a sample of 711 manufacturing MSEs in South Africa, including businesses in the informal sector. 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 digitalisation, including social media and access to the internet. Our main findings point, first of all, to a positive relationship between the use of selected digital communication technologies and product innovation, and secondly to a positive relationship between innovation performance and labour productivity conditional on the use of these technologies.

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

2. The Link Between Digitalisation 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 modelling approach, from which we draw inspiration in this paper.[3] In a 2009 overview of studies on eight developing countries using the CDM framework, Fagerberg et al. (2010) observed that statistically significant effects were confirmed on the labour productivity of at least one of the innovation measures used. In a study of six Latin American countries, Crespi and Zuñiga (2012) found that innovation has a significant effect 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 on productivity in services, although firm size appears to be a less relevant determinant of innovation in services compared to manufacturing. Fu et al. (2018), in one of the rare studies including informal or non-registered businesses in a sample of Ghanaian manufacturing firms analysed, found support for the positive relationship between innovation and labour productivity. Our study, which is similar to theirs in including informal economy firms in the analysis, extends their analysis by investigating the relationship between the use of digital communication technologies and firms' innovation performance.

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

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

sample of German firms in the period 2001 to 2003. Polder et al. (2010), in a study that like Van Leeuwen and Farooqui (2008), extend the classic CDM model by investigating the impact of digitalisation on process and organizational innovation as well as product innovation. They find that in services all types of innovation are positively affected by more e-purchasing, although only marginally in the case of process and organisational innovation. The results are more nuanced for manufacturing broadband being an important driver of both product and organisational innovation in manufacturing while e-commerce is positively related to process innovation.

A few developing-country studies have been undertaken on the relationship between ICT use and 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. in a study of Uruguayan firms using the 2004 to 2006 and 2007 to 2009 waves of the Service Innovation Survey, Aboal and Tacsir (2018) focus on the distinction between technological (product and process) and non-technological (organisational 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 influence on organisational and marketing innovation. In a study of Chilean business using the 2007 and 2009 Longitudinal Enterprise Surveys, Álvarez (2016) finds that ICT investments have a positive effect 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 concluded that the effects of ICT capital on productivity are direct rather than being indirect through innovation.

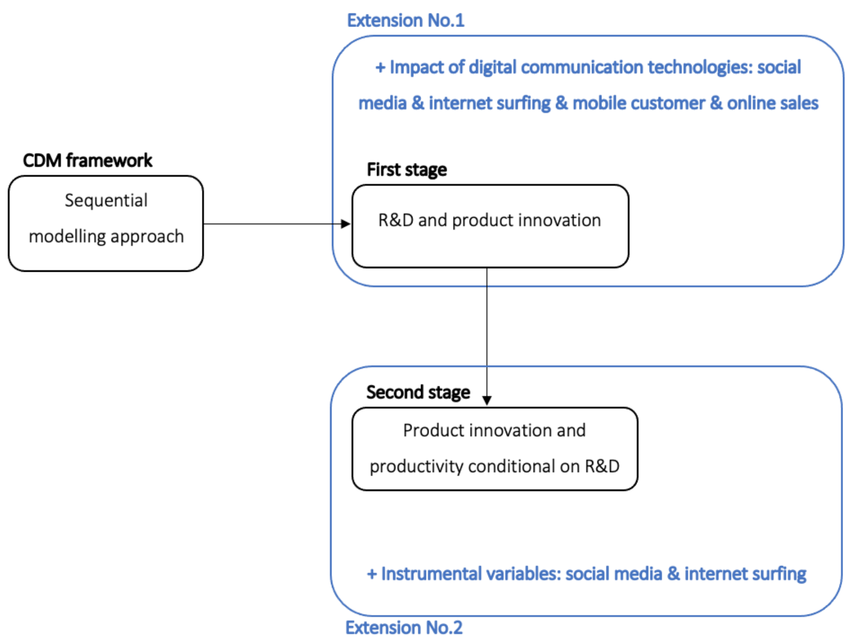
In summary, the econometric research based on national innovation surveys finds support for the importance of ICTs for at least certain measures of innovation. While the two developing country studies reviewed support this conclusion, they limit their measurement of ICTs to firms' investments in hardware and software and do not include the firms' internet bandwidth intensity use or their use of e-commerce. This limits their relevance for understanding the effect 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) argues for the case of a developed country, viz. the Netherlands, broadband internet access can be a means of acquiring new knowledge inputs for innovation and for sharing knowledge between partners, and the use of e-commerce may contribute to successfully rolling out new products and services. Furthermore, there is a large theoretical and case study-based literature on business management regarding 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) developed an organisational capabilities perspective, arguing that social media support 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 of the use of social media and the use of a business mobile phone for surfing the internet 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 fewer 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 communication technologies, and that innovation conditional on their use increases the level of labour productivity.

3. Digitalisation, Innovation and Productivity: A Sequential Modelling Approach

Our empirical analysis draws inspiration from the sequential modelling approach associated with Crepon et al. (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. We extend this framework by including in the first stage of the analysis the impact of digital communication technologies on product and process innovations. The second stage of the analysis focuses on the link between innovation and productivity conditional on the use of digital communication technologies. As discussed below, to address problems of endogeneity between innovation and productivity, we employ two-stage least squares (2SLS) using one or both of two digital communication technologies (i.e. social media and internet surfing with a mobile phone) as instruments for innovation in the second stage equation. Figure 3 below describes the extended CDM model.

Figure 3: Research Design: Extension of the CDM Framework



3.1 Predicting Innovation Outcomes

In the first stage, our dependent variable ($Innovation$) 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):

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

where $Innovation_i$ is a dichotomous variable equal to 1 if the firm has introduced into the market a new or significantly improved product, c is the constant term, $Log(size_i)$ is the number of employees, and $Log(age_i)$ 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 computerisation can result in increased productivity by substituting for the use of manual labour in both manual and information-processing tasks. Thus, we expect higher intensity of use of ICT capital to result in higher labour productivity.[4]

X_i is a vector of binary variables measuring the use of four selected digital communication technologies, namely using social media, developing online sales, and making use of a business mobile phone for surfing 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 business is located in the Johannesburg central business district, whether the firm is formal in the sense of being registered with the South African Revenue Service (SARS), whether it has engaged in R&D expenditure, 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. 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 (Jensen et al. 2007; Lundvall 2010). Several studies focusing on African countries support the importance of inter-firm cooperation for innovation, including by 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 influence of digital communication

[4] See the literature on routine-biased technical change associated with the work of Autor et al. (2003).

technologies depending on the internet will tend to be indirect through their effect on the development and marketing of new products and services.[5]

3.2 The Link Between Innovation and Productivity

In the second stage, we estimated the relationship between innovation and productivity. This estimation was 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 employed 2SLS using two excluded exogenous variables from the first stage equation as instruments: (i) the use of social media and (ii) the use of a business mobile phone for accessing the internet. As we discussed above, we expected these variables to have a positive and statistically significant effect on innovation. They should meet the exclusion restriction condition of only affecting productivity indirectly through their effect on innovation.

In the second stage, our dependent variable ($Productivity$) refers to labour 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 is only available for 273 firms. We have interval data on their turnover for 318 firms, but not absolute values. On this basis, we made use of multiple imputations to generate absolute turnover values for the 318 firms for which only interval data was available. We excluded firms for which we had neither the absolute value nor an interval range for turnover. Our resulting sample for the second stage productivity regression comprised 591 firms. 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, and $Innovation_i$ is the instrumented value derived from the first stage innovation equation (1). Y_i is a vector of the same binary variables appearing in the first regression, to which we added the two remaining digital communication technologies (viz. developing online sales and making use of a business mobile phone for interacting with customers). The other two digital communication technologies (viz. making use of social media and making use of a business mobile phone for surfing 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 effect of ICT capital on productivity is discussed in the literature on firm heterogeneity in terms of investment patterns and productivity performance (Draca et al. 2009).

[5] The OECD (2019) observes that, even if the gains from digitalisation have been substantial, there is no consensus on the direct causality between digital communication technologies and productivity. For example, more productive firms may benefit from digitalisation because they are more likely to have access to knowledge for developing new products or implementing new organisational methods than other firms. Our sequential approach allows us to explore the possible indirect effect of digitalisation on productivity through innovation.

In this context, several studies have estimated the effect on the firm's productivity of the use of computers in the production process, either directly or in interaction with changes in work organisation. 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 organisational 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 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 has a positive influence on productivity

4. Data Source, Sample and Descriptive Statistics

4.1 Data Source

In 2019, a research team at the University of Johannesburg conducted an innovation survey (under the project *Community of Practice in Innovation and Inclusive Industrialisation*, hosted by the South African Research Chair in Industrial Development) among micro- and small firms located in the city of Johannesburg, which we refer to as the MSE survey.[6] The survey focused on the central business district of the city, which is the capital of Gauteng province and accounts for 16% of South Africa's GDP and 40% of Gauteng's economic activity. The MSE survey focused on manufacturing firms. It aimed to understand some of the challenges faced by micro- and small manufacturing firms in their innovation activities, as well as the environment in which these firms operate. The survey consisted of a set of 74 questions capturing information from the background of the owner to the characteristics of the workforce and financial issues. The data collection spanned a period of three months, from June to August 2019. Finally, the sample covered 711 micro- and small firms.

The full description of the different variables built from the survey and the associated descriptive statistics are reported in Table 1. Innovation refers to the introduction into 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, by including incremental and imitative activities, can help account for what may

[6] This survey was conducted in 2019 under the project 'Community of Practice in Innovation and Inclusive Industrialisation', hosted by the DSI/NRF South African Research Chair in Industrial Development, University of Johannesburg". Accession date: February 2020

appear to be an exceedingly high rate of innovation success, with 49% of the sample of 711 classified as innovators.

The MSE survey included the 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 in the market, or for communication and exchange with other firms and clients. These digital communication technologies include making use of social media (34%), developing online sales (13%), using a mobile phone to browse the internet (7%), and using a mobile phone to interact with customers (28%). As noted in the above discussion of the choice of instruments, we assumed that the influence on productivity of using social media and using a mobile phone to browse the internet would 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
Labour 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 years	Nominal	2.35
Fixed capital	Total value of fixed assets (i.e. vehicles, furniture, machinery, etc.) in tens of thousands of rand/number of employees	Nominal	22.42
ICT capital	Total value of ICT equipment (i.e. computers, telephones, printers, scanners, fax machines, etc.) in tens of thousands of rand/number of employees	Nominal	1.58
Registration (formal or informal firm)	Whether the firm is registered with the 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 considered either 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 (second generation of ICTs)			
Social media	Whether the firm uses social media for its business	Binary	0.34
Internet surfing	Whether the firm uses a mobile phone for surfing the internet	Binary	0.07

Mobile customer	Whether the firm uses 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 for 273 firms in 2019 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 sales exists for 2019. This provides a sample of 591 firms.

[2] See Tables A1 and A2 in the Appendix. 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 covers only manufacturing firms, so we split our sample into 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. First, a 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. The manufacture of textiles and basic metals represents 10.1% and 9.4% of the firms respectively. More than half of the firms in the 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.

Second, 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) work predominantly 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.

Third, 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 14% and 8% of the workers respectively. As proposed by Fu et al. (2018), another way to evaluate this workforce entails a decomposition between micro- (fewer than or equal to nine employees), small (10 to 29 employees), medium (30 to 99 employees) and large firms (equal to or more than 100 employees). For each sector, we have a proxy of this decomposition by relating the number of employees to the number of total firms: 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).

Fourth, 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 only 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 number 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. In contrast, 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 computerisation. 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 ICT capital, while they account for only 23.5% of total fixed capital and only 28.6% of 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.

Fifth, 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 the purpose of information exchange with other firms and organisations. In the context of South African manufacturing firms, the manufacture of wearing apparel and furniture – which have the most weight in this sample in terms of employees and capital intensities – clearly have the most intensive use of these digital communication technologies: at 29% and 14% for social media, 18% and 12% for internet surfing, 29.1% and 12.1% for mobile customers, and 19.6% and 22.8% for online sales respectively. The manufacture of textiles uses these four digital technologies in a very complementary way, at 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 phones for surfing the internet prevails (10% and 14.1% respectively). For manufactures of wood and the printing and reproduction of recorded media, online sales are used the most (5.4% for each). For the manufacture of basic metals, the use of mobile phones for interacting with customers is clearly used more than in the other three (11.1%). So, the use of digital communication technologies is relatively heterogeneous between sectors.

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

5. Econometric Results

5.1 The Influence of Digital Communication Technologies on Product Innovation

In Table 2 below, we provide the results of 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 specialised interest can establish online groups through social media platforms for the purpose of discussion and knowledge exchange. Surfing 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 of the variable measuring communicating with customers electronically using 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 effect 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 found no significant effect for any of the control variables, including 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 organisational innovations than in product innovation. As, in the case of our sample, they do not find a significant correlation between innovation and the age of the firm for manufacturing firms. 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 used 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 Influence of Product Innovation on Labour Productivity

In Table 3, column (a) features the results of the second stage of the two-stage IV regression, as in equation (2). The results show a significant and positive effect of product innovation on labour productivity. Our measure of the intensity of the use of ICT capital has a positive and statistically significant influence on product innovation. This supports the literature cited above on the positive effect of the computerisation of work processes and internal knowledge flows on productivity. The coefficient of the measure of fixed capital intensity surprisingly is negative, although it is statistically insignificant. Neither online sales nor using mobile phones to communicate with clients has a significant influence 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 labour productivity.

Table 3: Second Stage Instrumental Variable Regression Explaining Labour Productivity

	(a)	(b)
	Labour 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 effect on productivity for larger firms than for smaller firms. We can only surmise 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 labour, thus improving its level of productivity.

6. Conclusion

There is considerable debate on the influence of digitalisation and Industry 4.0 technologies. A major focus has been on 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 firms engaged in large-scale production, notably in sectors such as automobiles, chemicals and plastics and consumer electronics. The limited evidence available for developing countries shows that these advanced technologies are adopted to a very limited extent and rarely in small firms. The debate on the adoption of Industry 4.0 manufacturing technologies ignores the wider effect of the current digitalisation process under way 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 of micro- and small firms.

In this study, we have explored the relationship 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 that 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 influence on labour productivity, a result that is consistent with the considerable literature on developed and developing countries showing a positive relationship between innovation and productivity.

Our original contribution is twofold: (i) We have reduced the shortage of data as, for the most part, the national innovation surveys have limited data covering micro enterprises. (ii) We have shown how the digital transformation affects firm performance (particularly MSEs’ performance in South Africa) in terms of innovation and productivity, since these firms are creative and contribute to the generation of new products. Digitalisation changes the production process, but it is also an engine of improvement in product quality. In the context of digitalisation, firms are more likely to have access to knowledge to develop new products or implement new organisational methods. The most productive firms, however, may benefit more from these changes than the least productive firms, since they are able to invest in digital technologies. This implies inequalities among South African firms in their ability to become digital. Public policy support is therefore necessary. In the same way, over the last 10 to 15 years, South Africa’s digital transformation has been based on the broad adoption of mobile phones and an increase in internet access, but inequalities between citizens in their access to these technologies remain. Although digital transformation is intended to alleviate poverty through employment creation and helping countries' economic development, it requires large investments and government initiatives to effectively support these changes.

There are several ways in which the results of this study could be extended usefully. Firstly, we have only examined the influence 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 digitalisation include cloud computing and the use of services available on digital platforms.

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 programme in Africa and other developing country regions that is designed to investigate the adoption and effect 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 aim.

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7. 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 surfing	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 jewellery, 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

DSI/NRF South African Research Chair in
Industrial Development (SARChI-ID)
31 Henley Road, Auckland Park,
Johannesburg, South Africa

General enquiries:
Koketso Manyane - Dlangamandla
Email: koketsom@uj.ac.za
Tel: +27 011 559 7454