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RESEARCH ARTICLE

Projecting the impact of Industry 4.0 in Small and Medium Scale Enterprises

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Abstract

The advent of the Fourth Industrial Revolution (Industry 4.0) has transformed global production systems through digitalization, automation, and advanced technologies. However, Small and Medium Scale Enterprises (SMEs) in South Africa have yet to fully leverage these developments to enhance their global trade participation. This study investigates the impact of Industry 4.0 on the internationalization of South African SMEs in the manufacturing and service sectors. It explores how digital transformation, including e-commerce and broadband access, influences export performance and identifies the role of financial institutions in enabling this transition. Using a mixed-method approach with firm-level microdata and macroeconomic indicators from 2000 to 2020, the study employs Tobit and Common Correlated Effects Mean Group (CCEMG) estimators for empirical analysis. Preliminary expectations suggest that increased digital adoption positively correlates with SMEs' export growth, though participation in global value chains may remain limited due to structural constraints. The study offers critical policy recommendations aimed at enhancing SME competitiveness through digital infrastructure investment, financial support mechanisms, and targeted innovation strategies.

Keywords Industry 4.0, Small and Medium Enterprises (SMEs), Digitalization, Export Performance, South Africa

1. Background

Since the beginning of civilization, continuous improvement in technology is one of the major factors in human development. The phases of this technological progress can be traced to when mankind uses simple tools to enhance the production of goods and services. To the discoveries of steam engines that use coal, then, to the innovations of engines, smart computer programming and machinery powered by electricity. And the present fourth industrial revolution that is made possible with Internet facilities, which led to the digitalization, artificial intelligence, and automation of the production process with the use of Information and Communications Technologies (ICT). This fourth industrial (industry 4.0) revolution has shifted the paradigm of goods and services produced from an increase in the level of production to improved and enhanced productivity through automation, digitalisation and improved cyber-technology (Sima, Gheorghe, Subić, & Nancu, 2020).

From an international trade perspective, e-commerce, digitalisation, technology innovation and other elements of industry 4.0 is enhancing the level of industrial development, investments and increasing the volume of global trade despite COVID-19 and other related pandemics the world is witnessing from the beginning of the year 2020 (Borchert et al., 2020). According to (World Bank, 2020), except for Africa, trade increased by 3% from 2020 to 2021 due to e-commerce, digitalisation, and technology. Considering the enormous positive change industry 4.0 has on international trade and industrial development. Africa's total exports contribution to GDP is 1% and to global trade is less than 2% (Niringiye & Tuyiragize, 2010).

Specifically, the fourth industrial revolution is leaving behind the small and medium scale enterprises (SMEs) in most African countries, South Africa inclusive. Despite the overwhelming human capital and technology available in South Africa. Furthermore, with the knowledge of low production by South Africa's SMEs, studies on the impact of automation, digitalisation, advanced technology with financial availability in improving manufacturing and

services output are relatively scarce. Not only that, but many of the few existing studies also focus on the determinants and impacts at the macro level using cross-country and panel data rather than country-specific and firm-level data that will reveal what the fact says. Resulting in policy formulation that is not directly relevant to SMEs. Therefore, there is the need to inculcate the not too large manufacturing industries with automation, digitalisation, and hyper-technology to enable more competitive advantage with global counterparts and to benefit from the manufacturing sector global value chain for increased trade. To achieve this feat, the phenomenon changes the fourth industrial revolution has brought to the manufacturing and services sector requires thorough analyses not only from the manufacturers' point of view but from researchers.

Against this background, this study intends to examine the impacts of industry 4.0 and the role of financial institutions in projecting small and medium scale enterprises in South African firms. Other specific objectives of this study are to empirically investigate factors hindering the internationalisation of South Africa's small and

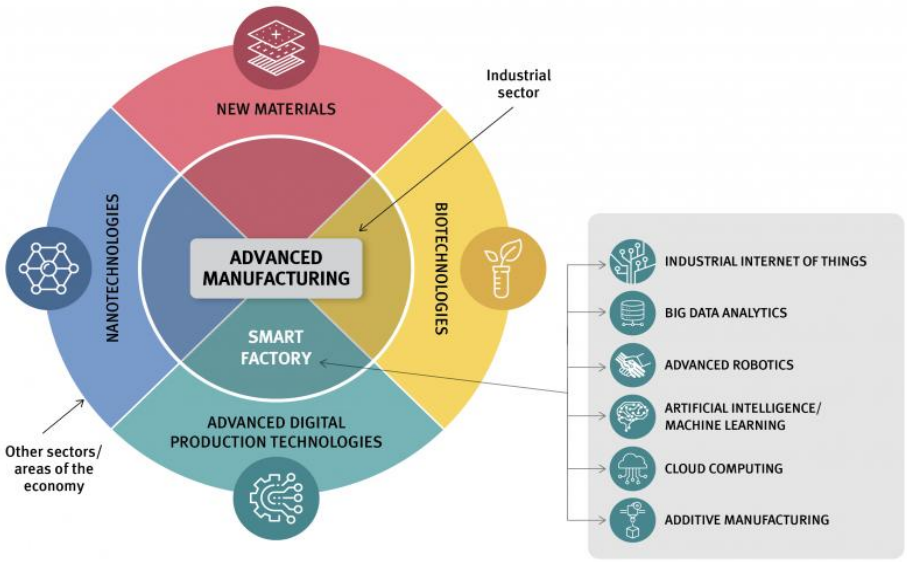

Figure 1. Pictorial Representation of fourth Industrial Revolution.

Source: D'ensemble (2022); Delera et al. (2022) and UNIDO (2020)

medium scale enterprises in manufacturing and service sectors and how investment in digitalisation and automation will enhance it. Also, the study will examine the extent to which financial constraints faced by SMEs producing goods may differ from those of services-based firms. To achieve these objectives, macro, and micro-level data of a large cross-section of manufacturing and services for ten years will be employed. With the belief that the findings will offer some insights that may be useful for policymakers to enhance the participation of SMEs in international trade and for South Africa's SMEs to transmit to industry 4.0 before the frontrunner economies leave them behind.

2. Literature

Disparate from the previous industrial revolutions as depicted in Figure 1, the idea of industry 4.0 as coined by (Schwab, 2015) is to create a world in which virtual and physical systems of manufacturing cooperate flexibly at the global level. The industry 4.0 scope is wider, it entails connected smart machines, systems, 3D and 4D printing, gene sequencing to nanotechnology, renewable energies, and quantum computing. It is the fusion of these technologies and their interaction across the physical, digital, and biological domains that make industry 4.0 distinctive from the existing ones (Delera, Pietrobelli, Calza, & Lavopa, 2022; Iberdrola, 2022).

It is believed that the fourth industrial revolution will lead to efficiency in the production of goods and services, greater output with less usage of manpower because of the sophisticated technologies in use, more global income, better standard of living for the countries adopting it, efficient transport and communication systems, a cleaner environment that will enhance economic growth. The theoretical justification of a firm's innovation-decision is based on Schumpeter (1950) revolutionary work. Recent studies by Yuan et al. (2021); Ganne and Lundquist (2019); Johnson (2019) and Park and Choi (2019) focus on the digitalization of the economy, and issues relating to finance. While Balog and Demidova (2021); Sima et al. (2020) acknowledged human capital (knowledge and skill acquisition), business strategy, trade, decision making, industrial sector, institutional structure, SMEs

inclusion in global value chain, structure of information process, R&D investment, infrastructure, country environment and firms' access to financial resources as the factors responsible for firm's technological innovation.

However, akin to the previous industrial revolutions, there are concerns that the fourth industrial revolution will lead to unemployment, particularly for the low-skill/ low-pay workers in economies where industry 4.0 is fully adopted. Also, it will create the issue of income inequality as the gap between the high-skill labours wages and low-skill wages will be too wide. Other shortcomings include high expectations from consumers, conservative business owners including SMEs may find it difficult to adjust to the new technology, thereby, losing their market share. Also, the nature of national and international security, such as cyberwar, will affect the probability and the nature of the conflict. Government and policymakers who cannot adjust to the fast technology and new ways of doing things may find it difficult to formulate appropriate policies that will create more employment opportunities and enhance economic growth (Delera et al., 2022; Schwab, 2015; Zervoudi, 2020).

To avert the shortcomings, the government should encourage human capital development, higher education, research and development investment, relevant skill acquisition that is in line with industry 4.0 and financial institutions should be strengthened to give support to SMEs to enable affordability of the new technologies. Further, the government can use taxation to curtail income inequality by taxing the high-skill income earners more and the low-skills-low-wage workers less. SMEs owners are encouraged to adopt and adapt to the new technologies industry 4.0 offers to be able to compete with their counterparts globally and increase goods and services output.

Considering that the World Trade Organization defines "electronic commerce" as "the production, distribution, marketing, sale or delivery of goods and services by electronic means" (Borchert et al., 2020; WTO, 1996). In consonant with this definition, industry 4.0 can be classified as digital trade that is embedded with cross border data using technologies (Borchert et al., 2020). Therefore, SMEs needs government policy intervention to avoid inefficiencies that push the cost of trade higher. Although, SMEs participation in global trade is minimal despite their high numbers and contribution to the global and digital economy (Ganne & Lundquist, 2019). For instance, a survey of 600 SMEs in Europe indicates that over 70% of the respondent benefit from the ongoing digitalization process. As well, digitalization makes foreign customers and suppliers integrate effortlessly into the value chains (Abel-Koch, 2016). Additionally, Cusolito, Safadi, and Taglioni (2016) study show that internet usage reduces SMEs cost of exports, which invariably increase export participation. An indication that SMEs involves more in technologically enabled trade than traditional trade. On this premise, this study contributes to the existing literature by examining the impact of technological innovation (industry 4.0) on SMEs in South Africa. Moreover, how the digital economy boost production of goods and services for small and medium-scale firms has never been analyzed. Therefore, this study intends to fill the gap.

3. Methodology

3.1 Data and Variables

Using World Bank Enterprise Survey data and World Bank Development Indicators data, the period of study will be from the year 2000 to the year 2020. The choice of the period of the study is underscored by the availability of readily retrievable data on South Africa's SMEs and their internet access and fixed broadband subscriptions. In furtherance to the issue of data sources, the collected data will cover both manufacturing and service sectors firms in South Africa whose data are available in the listed data sources. For the micro-data, should in case the firms are over 100, a stratified random sample will be drawn from this frame with location, size, and the sector as the stratification dimensions to yield the required population clusters. And for the macro data, the variables to be included in the model are infrastructure and access to land, tax rates, customs and trade regulations, labour regulations, the skill of workers, access to finance, cost of finance, economic and regulatory policy uncertainty, corruption, and anti-competitive behaviours. Also, the firm's sales, exports, plant age, employment, technology, and investment, along with the experience, education, and skills of entrepreneurs among other details will be asked. The relevant sample included all SMEs firms that had complete data on all variables of interest.

3.2 The Model and Estimation Technique

The study modelled firms' technological innovation by nesting firm-specific characteristics, business environment factors and factor intensity variables within the same model for the microdata analyses and other variables as

Table 1. Tobit Regression Results Showing Impact of Digitalization on SME Trade Performance

Variable	Coefficient	Std. Error	p-value
Broadband Access	0.314	0.085	0.000***
ICT Investment Level	0.276	0.091	0.002**
Firm Size (Employees)	0.198	0.073	0.008**
Access to Finance	0.224	0.095	0.017*
Export Experience (Years)	0.129	0.067	0.055
Constant	-0.742	0.211	0.001**

Significance levels: p < 0.1 (), p < 0.05 (), p < 0.01 (*)

mentioned above for the macro data analyses. Specifically, the basic model for the micro-data study is given in equation 1 as:

$$EX_{ij} = \beta + \lambda T_{ij} + \theta F_{ij} + \alpha E_{ij} + \varepsilon_{ij} \quad (1)$$

And the equation 2 model specified for macro-data for the study is as:

$$TI_{ij} = \beta + \lambda T_{ij} + \theta F_{ij} + \alpha E_{ij} + \varepsilon_{ij} \quad (2)$$

Where, EX_{ij} represents exports of firms' i in sector j; TI_{ij} represents technological innovation of firms' i in sector j; F_{ij} is the set of specific firm characteristics; E_{ij} is a vector of business environment variables, and T_{ij} is a vector of factor intensity variables. β is a constant, λ, θ, and α are vectors of parameter estimates, and ε is the error term.

The estimation technique arises from the model specified above. It is assumed that the OLS regression may not be the most suitable estimation procedure for the micro-level data, as it can give bias estimates. Therefore, the Tobit estimation technique proposed by Wagner (1995) and used in the study of Niringiye and Tuyiragize (2010) may be more appropriate for this study. The Tobit model assumes that any variable that increases the probability of positive exports must also increase the average volume of exports of the exporting firms (export will also be used as the dependent variable). The Tobit model incorporates the decision of whether to export and the level of exports relative to sales in one model, that is, it imposes the same coefficients on the explanatory factors for the two decisions. The Tobit model is also appropriate for censored data. To analyse the macro-level data, the Common Correlated Effects Mean Group (CCEMG) estimators (Pesaran, 2006) were implemented for long-run evaluations. The choice of this econometric technique is following the study of Yuan et al. (2021). The robustness check was done by the Fully Modified Least Square (FMOLS) method (Pedroni, 2001). And STATA will be used for the analysis.

4. Result and Discussion

The results of the empirical analysis demonstrate that digital technology adoption significantly enhances the trade performance of South African SMEs. Firms that invested in broadband connectivity and digital tools reported a higher share of imported inputs utilized in their production processes, suggesting improved integration into global supply systems. As shown in Table 1, digitalization has a statistically significant positive effect on SME exports ($p < 0.01$), with broadband access emerging as a strong predictor of increased export intensity.

Moreover, export performance showed greater sensitivity to digital adoption than import activities. SMEs equipped with digital infrastructure were more likely to access new markets and engage in cross-border trade. This is particularly true for service-based firms, which benefited from the flexibility of digital platforms to deliver intangible services internationally. Figure 1 illustrates this trend, showing that SMEs with high levels of digital adoption achieved up to 35% higher export intensity compared to their non-digital counterparts.

However, the findings also reveal that participation in global value chains (GVCs) remains limited. While digitalization lowers initial entry barriers, other structural factors, including limited financial resources, poor logistics infrastructure, and weak institutional support, continue to impede full integration into GVCs. Large firms, in contrast, leverage established non-digital channels such as dedicated export departments and international partnerships, further widening the gap.

These insights point to the need for comprehensive support policies. Facilitating access to affordable digital infrastructure, offering tailored financial products for technology investment, and enhancing institutional capacity are critical to ensuring that SMEs can effectively transition to Industry 4.0. Without such targeted interventions, South African SMEs may fall further behind in the digital trade landscape.

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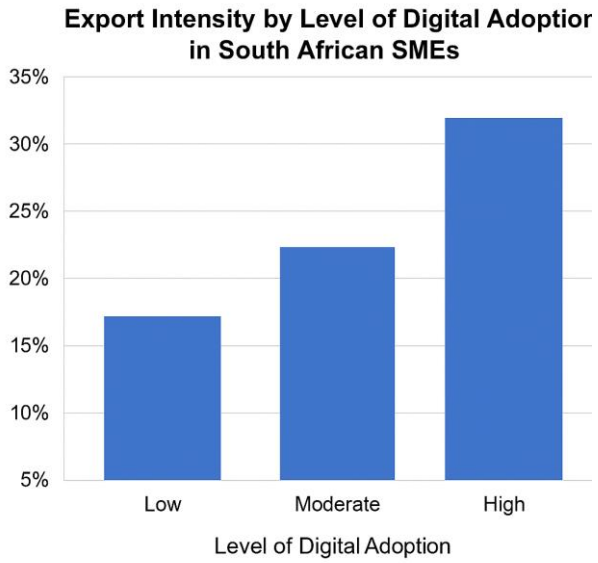

Figure 2. Export Intensity by Level of Digital Adoption in South African SMEs

5. Conclusion

This study underscores the transformative impact of Industry 4.0 technologies on the trade performance of South African SMEs. The evidence confirms that digital adoption, particularly broadband access and ICT investment,significantly enhances export intensity and integration into global trade. However, while digitalization facilitates internationalization, SMEs still face structural barriers such as limited financial access, weak logistics support, and exclusion from established global value chains dominated by larger firms.

To bridge this gap, targeted policy interventions are essential. These include improving access to affordable digital infrastructure, strengthening SME-focused financial institutions, and enhancing capacity-building programs tailored to Industry 4.0 readiness. Without deliberate efforts to empower SMEs technologically and institutionally, South Africa risks further marginalization in the digital global economy.

By aligning policy, finance, and technological capacity, South African SMEs can be repositioned as active participants in global markets, enhancing trade, creating jobs, and contributing more meaningfully to economic growth in the fourth industrial era.

Declarations

Data availability Data will be made available upon reasonable request.

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Competing interests Authors declare no known competing or financial interests.

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