



The effects of the fourth industrial revolution on employment in South Africa: Variance decomposition analysis

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ABSTRACT

This study investigates the effect of the fourth industrial revolution on levels of employment in South Africa. The fourth industrial revolution is proxied by ICT development with the components of mobile telephony, fixed-line telephony and internet penetration. The data used in this study were obtained from the World Bank's World Development Indicator database spanning from 1980 to 2019, while the labour market data was obtained from Statistics South Africa for the same time period. The study employed the Johansen Cointegration test and variance decomposition techniques to determine existence of long run equilibrium and possible shocks impact respectively. The results indicated that there exists a long run relationship between employment levels and the hypothesised determinants. The ICT revealed a positive relationship with employment in both the short and long run which is an indication of importance of fourth industrial revolution to employment in modern society. Policy recommendation were provided for the South African policy-makers in line with further deployment of ICT tools that promote employment.

1. Introduction and background to the study

As technological advances and breakthroughs are rapidly shifting the frontier between the work and tasks performed by human beings and those performed by algorithms and machines, the global labour markets are undergoing major transformation which will see a disruption in economics, technology, politics, society, business and even moral ethics [18]. The introduction of the fourth industrial revolution (4IR) is promising major economic and social challenges and opportunities which requires formal institutions to respond fittingly towards supporting the anticipated societal transformation [10]. These transformations brought about by the Fourth Industrial Revolution, if managed poorly could pose risk of widening the skills gap, increasing inequality and unemployment, with the end result being poverty. However, managed wisely, this could lead to a new age of works, jobs and improved quality of life in general [10].

The Fourth Industrial Revolution is said to be fourth major industry era since the initial revolution of the 18th century. This term describes a world where human beings move between digital domains with the use of connected technology to enable and manage their lives [5]. According to Ref. [13], the crucial components of the 4IR are big data, the Internet of Services (IoS), the Internet of Things (IoT), artificial intelligence (AI),

cyber-physical systems, and smart production. The integration of artificial intelligence and robotics for automating processes and decision-making, utilizing big data to create more efficient value chains, and the expansion of the IoT are predicted to bring dramatic changes to the labour market, potentially leading to increased productivity in global industries and institutions ([5,8]).

Technological advancements are driving the development of smart societies and enabling remote work tasks, reducing production costs as less labour may be needed in production lines, thereby potentially creating unemployment ([19,31]). These technological changes are characterised by development trends across all industries and institutions with the objective of achieving more intelligent production and service processes, giving rise to simple operational systems of smart institutions [10]. The 4IR has ushered in a new era where technology, communication, data, and analytics reshape the way people live, interact, and work. This new era of artificial intelligence and robotics has been widely viewed as a disruptor to the labour market due to the blurring of the traditional meaning of formal and informal employment resulting from the automation of millions of jobs [5]. Scholars argue that societies are not yet prepared for the creative destruction brought by the advancement of these technologies ([32,33]). These concerns hold merit particularly in the case of a developing country like South Africa, where

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unemployment, poverty, and inequality levels are high, additional layers of complexities are added to this issue [18].

All industries and institutions are currently at various stages of digitalisation with others more innovative than others depending on complexities of organizational structure with smaller organizations having a higher propensity to adopting latest technological trends [31]. Labour, along with land, capital, and entrepreneurship have been fundamental factors of production in economic transformation (production). Production has throughout history been a key driver of growth and innovation which has seen numerous economies realising accelerated growth because of industrialization. These traditional approaches to developmental growth are threatened as they may not be feasible in the future [6].

The emergence of information and communication technology (ICT) and artificial intelligence in industries such as manufacturing, has threatened a reduction in human interference on the production line – now termed the “smart production” [31]. The effect of such technological innovations on employment trends require policy makers to ensure a balance in socio-economic factors so that full benefits are realized by both institutions and the labour force. A report by the WEF notes that most of these new industries are in fact creating fewer jobs which furthermore demand advanced skills [9,29]. They have estimated that sixty-five (65) per cent of children currently in primary schools are going to be working new jobs that do not presently exist. Advanced robotics for example can perform various scopes of work, which previously required intensive human capital, with much more efficiency resulting in higher production levels [11]. These advances in automation have escalated to levels of threatening, not just jobs which required low levels of education and training, but also high skilled jobs [1].

This type of transformation in developing countries like South Africa may result in catastrophic consequences, especially for a society that already exhibits high levels of unemployment, poverty, inequality, and most skills levels in the lower categories [10]. One of the key strategies by the South African government to deal with the above-mentioned societal factors is to use job creation as a means to reduce the gap, and therefore the implementation of these disruptive innovations may be met with resistance. Socio-economic inclusion and Initiatives by both formal and informal institutions would thus need to be adequately adapted in line with the context of this country, specifically in terms of up-skilling and reskilling the current and future workforce [10,28].

This study seeks to look specifically at this problem statement in terms of the measures that are being taken by the government and corporate institutions to ensure that this transformation is managed wisely with minimum effects on the country’s labour force and better socio-economic yields. The major objectives will be to gain an overall understanding on how these institutions are adapting to this revolution with regards to the shaping of the country’s economy. This will be undertaken by determining the gaps that previous studies have not addressed on formal institutions, the 4IR and work force. In general, this study will serve as a “call-to-action” that evaluates and sheds light on the future of the labour market in the country and proposed partnerships between businesses, labour, government and education institutions towards mitigating the impact of the 4IR on education, skills and jobs [14].

This study will be focusing on the effects that the 4IR (ICT) has on the work force (employment) in South Africa. The study will be looking specifically at this problem statement in terms of the measures that are being taken by the government and corporate institutions to ensure that this transformation is managed wisely with minimum effects on the country’s labour force and better socio-economic yields. The major objectives will be to gain an overall understanding on how ICT mechanism transmit to employment equilibrium in South Africa. This study will try and indicate if that there is a positive relationship between employment rate and 4IR in the short run and long run. Other elements that will be addressed in this paper is shocks impact on each variable by deploying variance decomposition analysis.

2. Literature review and theoretical framework

The introduction of the 4IR is promising to major economic and social challenges and opportunities which requires a response fitting towards supporting the anticipated societal transformation [10]. These transformations are bringing shifts in knowledge, wealth and power, and it is only through increasing our knowledge about these transformations and the rate at which these changes occur that it can be ensured these advances reach and benefit everyone [30]. The rise of artificial intelligence (AI) and robotics for process automation and decision making, big data used in creating smarter value chains, and the internet of things (IoT), are expected to cause dramatic changes in the world of work with the potential of delivering productivity gains for institutions in South Africa ([5,8,19]. These technological changes are characterized by development trends across all industries and institutions with the objective of achieving more intelligent production and service processes, giving rise to simple operational systems of smart institutions [10]. This new era of AI and robotics has been widely viewed as a disruptor to the labour market due to the blurring of the traditional meaning of informal and formal employment resulting from the automation of millions of jobs [5]. The effect of such technological innovations on employment trends require policy makers to ensure a balance in socio-economic factors so that full benefits are realized by both institutions and the labour force. Proper implementation of these innovative systems will drastically improve levels of production and the work-life balance of employees. To understand this multifaceted and interdisciplinary complexity requires a thorough qualitative analysis of the 4IR’s theoretical framework [1]. The rest of the article is structured as follows: Section 2 presents the theoretical framework and literature review of the study. Section 3 presents research methodology, data and empirical model specification. Section 4 presents the empirical results and discussion, and section 5 presents conclusion of the study. Section 6 presents the recommendations of the study.

2.1. Theoretical framework

2.1.1. Technophile and technophobia

Technology has nowadays made its way into all aspects of human life and this rapid growth in new ICT has increased discomfort and fear (technophobia) on the one extreme, and visionary and enthusiastic expectations (technophilia) on the other extreme in all societies [16]. Similar to other emotionally connected relationships that humans are involved in, there has been an increasing similar relationship between people and machines, and because this relationship generates a multi-mediated environment brought about by appealing innovations, rejecting the materiality of ICT becomes almost impossible [3].

Humans attracted to technology, referred to as “technophiles”, enthusiastically adopt all technologies in a positive manner to combat issues in society and improve their way of life. Technophilia is defined as “the enthusiasm generated by the use of technology, particularly new technologies, such as: personal computers, Internet, mobile phones and even the technologies of home cinema” [20]. These are the people who have no fear of technology and are strongly invoked towards activities involving the use of technology. According to Ref. [27], technophiles possess an idea that societies are powerless to resist the influence of ICT, and it is this attitude that may block the realistic assessment of the impact of ICT on social and environmental aspects.

Technophobia on the other hand is defined as the “irrational fear or anxiety caused by side effects of advances in technology” [20]. Technophobes are those who harbour negative emotions towards advances in new technologies and try by all means to avoid their usage. Despite the huge ICT infusion into work and everyday life, they prefer to resort to traditional ways of completing tasks or would rather limit those high-performance devices by using functionalities that basic and thus not utilizing the device to its full capability [16]. With the infiltration of ICT in all sectors of business, learning and even the household,

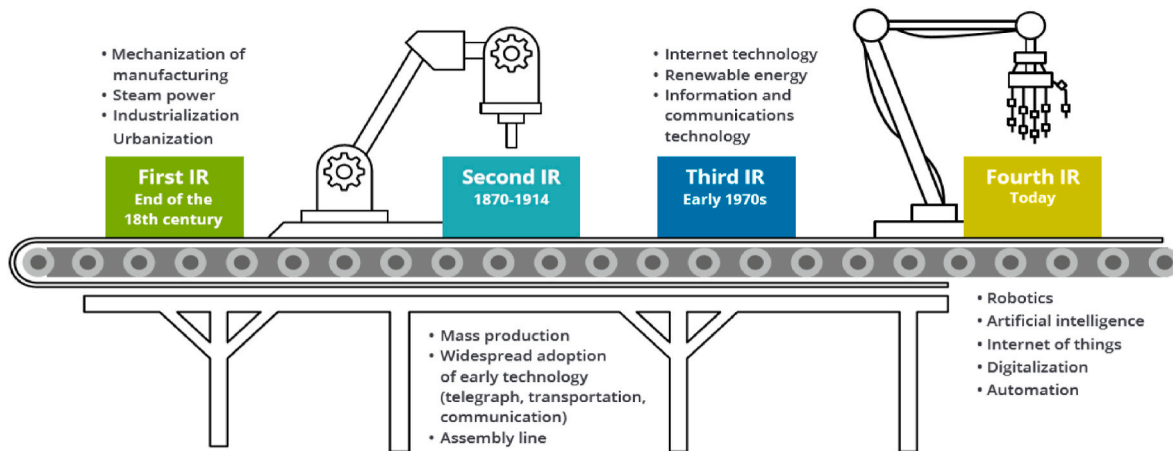


Fig. 1. Progression of the industrial revolutions. Source: Deloitte, (2018b:8).

technophobes pose an issue of poor performance, ineffectiveness, vulnerability, and security risk to name but a few [16]. The relevance of technophobia is however crucial in societies as it helps to point out the risks and effects that technological advances may pose on humanity.

2.2. Industry trends

Towards the end of 18th century humanity got exposed to the beginning of industrialization with the introduction of mechanical production fuelled by water power and steam engines and thus giving rise to what was termed the first industrial revolution which continued for almost a hundred years ([4,10,22]). The steam engine enabled the shift from farming to new methods of manufacturing which saw a domination of the steel and textile industries in terms of capital investments, outputs, and employment [28]. This transformation in technology set an irreversible platform that saw paradigm shifts in the socio-technical and socio-economic perspectives and set the foundation for all other industrial revolutions to follow [10]. The second industrial revolution followed towards the end of the 19th century characterized by rapid industrialization through the discovery and use of electricity for mass production and the improvement of other energy sources - particularly gas and oil technologies [10]. These transformations gave rise to various labour-intensive industries and branches such as chemical, electrical and mechanical engineering, and the automotive industry which saw its boom in early 20th century [22]. The second industrial revolution was subsequently phased-out by the third industrial revolution which was characterised by the employment of information communication and technology (ICT) and electronics for automation ([10]. This era of the digital technology included a shift from energy-intensive industries to more advanced processing of natural resources and precision mechanics, through the use of electronics enabling the computerization of industries (more especially the manufacturing) and thus the rise to "smart factories" [22]. The environment created by this revolution laid grounds for a new era of reindustrialization and digital economy now known as the 4IR. Fig. 1 schematically summarizes the progression of the above-mentioned transformation and the major divers of those specific eras.

Today, the digitization of institutional systems has involved the interdependence and connectivity of all mechanical and human processes in a centralised value chain [10]. This technological fusion between digital, physical and biological aspects brings with it a shift in the way societies work, live, and interact with each other due to the extent to which analytics, AI, communication, big data, and the internet of things has had an effect [21]. ([5,21]). The pace of these current transformations in relation to previous revolutions is unprecedented as it has shown exponential growth and disrupting every industry in terms

of governance, management, and production systems [28,41].

2.3. Labour market

Advances in technology pose great opportunities for economic growth through increased productivity and overall enhanced standards of living, however there has been increasing fears with regards to the ultimate impact of automation on the labour market [12]. This issue has been widely debated by industry specialists (from policy-makers to academics) with inadequate research data to confidently reach a conclusion. Some of the arguments are hinted on by Ref. [2] when they cited studies conducted in the US and EU as follow:

"The study by Ref. [37] finds that the ICT revolution is putting about 47% of current US jobs at risk due to the ability of machines to substitute humans in routine tasks. Applying Osborne and Frey's methodology to the EU, Bowels (2014) finds that the share of jobs at risk of substitution is even higher in Europe. On the other hand [39,40], argues forcefully in two recent books that the ICT revolution is having profound impact on the labour market and we (humans) are currently experiencing a race against the (ICT-driven) machine – one we could possibly lose".

It has been suggested however that since this debate is highly polarized between the optimists who envisage vast opportunities and the pessimists who see massive destruction in the labour market, the reality in question is in fact occupation, region, and industry/sector specific, and the ability of all parties involved to manage change [28]. According to Ref. [2] trying to quantify and model the impact that ICT has on the demand for labour is quite a difficult task. While historic studies focused on variable such as ICT infrastructure (both ICT investments and capital), such models may be interesting on macro levels, but fail to capture the fullness of ICT applications introduced in recent years and therefore current research has proposed more sophisticated ICT forms and applications towards studying its impact on employment [2].

Transformations of business models as a result of these technological innovations have begun threatening the labour markets' skills set, with the potential of rendering millions of current jobs obsolete [26,28]. argues that "As entire industries adjust most occupations are undergoing a fundamental transformation. While some jobs are threatened by redundancy and others grow rapidly, existing jobs are also going through a change in the skill sets required to do them".

The traditional workforce structure of industries in previous revolutions entailed labour intensive profiles that were able to absorb a large portion of the society into the labour market. Those systems were more concerned about the mutual interactions between traits of the labour force, such as skills and value added, and the processes of attaining production outputs [10]. Ref [38] states that "in this period, the need for

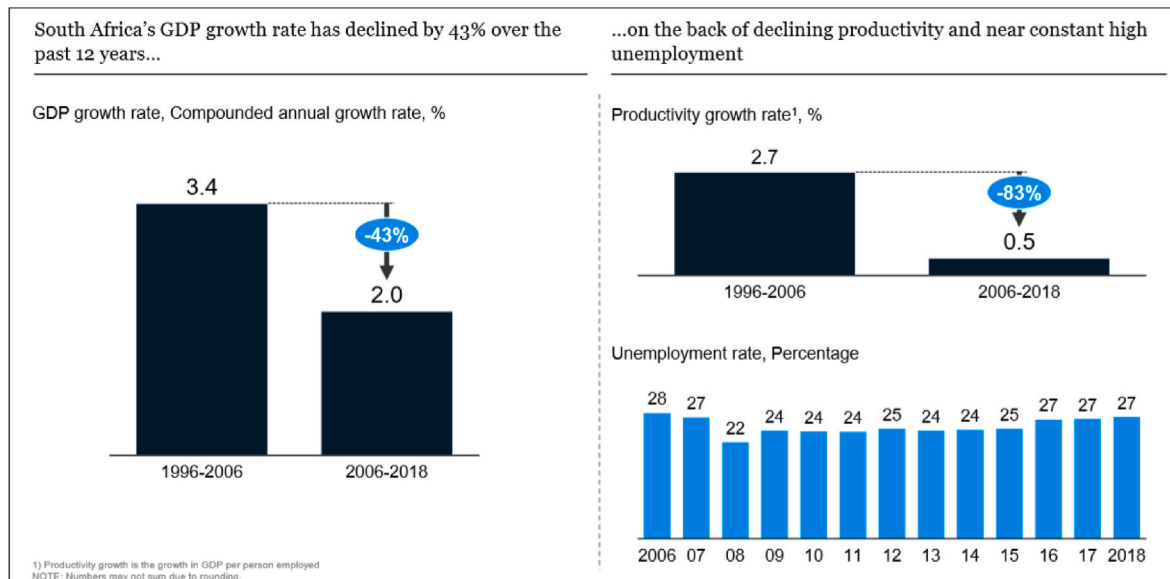


Fig. 2. South Africa's GDP growth, productivity, and unemployment. Source: McKinsey and Company (2019:3).

arm and muscle power, which are the traditional labour factors, almost disappeared and the machines started to manage both themselves and the production processes on their own". In previous industrial revolutions, computerization was characterised as an auxiliary function which supported routine activities executed by manpower. Now, advanced robotics for example can perform various scopes of work, which previously required intensive human capital, with much more efficiency resulting in higher production levels [10]. This ability of high-tech systems to self-operate and multitask between disciplines has led to significant changes in work portfolios and the need for a new method of interaction between machines and humans [15]. According to Ref. [1] these advances in automation have escalated to levels of threatening, not just jobs which required low levels of education and training, but also high skilled jobs.

This type of transformation in developing countries like South Africa may result in catastrophic consequences, especially for a society that already exhibits high levels of unemployment, poverty, inequality, and most skills levels in the lower categories [10,24]. In the South African context, an important challenge has been the inadequate focus on developing and encouraging skills required for industries to grow and compete in a fast and unstoppable world driven by ICT [17]. The countries education system has also been criticised of failing to produce enough graduates in science, technology, engineering, and mathematics (STEM) and thus not being able to meet required demand for labour in these new sectors [25]. Unemployment in South Africa remains very high with little growth in wages which has contributed significantly to the high levels of inequality. This has been largely attributed to by underperformance in the country's economy as a result of stagnant productivity. A study by Ref. [17] showed that South Africa's GDP growth averaged at 2% per year between the years 2006–2018 (a 43% drop from the prior decade), with growth in productivity levels falling to almost zero (an 83% drop) in the same time period as can be seen in Fig. 2.

One of the key strategies by the South African government to deal with the above-mentioned societal factors is to use job creation as a means to reduce these gaps of poverty and inequality [21]. This long-standing debate around the opportunities and challenges posed by the 4IR and its impact on jobs therefore threatens the implementation of these disruptive innovations as they may be met with resistance from the portion of society which stands to receive the losing end of the stick. In order to prevent unintended consequences of technological advances complemented by increasing inequality, widespread unemployment,

and skills shortages, socio-economic inclusive and initiatives by both formal and informal institutions would thus need to be adequately adapted in line with the context of this country, specifically in terms of upskilling and reskilling the current and future workforce in ICT ([10, 28]). Policy-makers are therefore encouraged to actively spearhead initiatives which direct the economy towards this "techno-economic" shift by focusing on policies, the management of private institution stakeholder engagements, implementation of these technologies, expectations, and the physical workspace itself [1].

2.4. Drivers of the 4IR

A 2016 report by the World Economic Forum (WEF) alludes the drivers of this industrial change to the "development of previously disjointed fields such as AI and machine learning, robotics, nanotechnology, 3D printing and genetics and biotechnology" which are now interconnected and amplified on each other [28]. The report also notes that smart systems (from entire cities, to industries, grids, and even homes) are developing to manage issues ranging from societal factors such as supply chain to environmental factors such as climate change [28]. Successful adoption and implementation of these transformation into smart and modern societies, driven by innovative technologies, new sets of skills, and responsive policies, will depend a lot on the ability and commitment of private sector, government institutions, and the public to cooperate [10]. A list of key drivers observed from literature are listed and briefly summarized below:

2.4.1. ICT infrastructure

Technological advancements such as big data, the internet of things (IoT), and cloud computing require high quality and reliable infrastructure such as broadband and 5G wireless connectivity for a faster network and more effective integration between systems, humans and machines ([5,10]).

2.4.2. education and training

Fears around the displacement of people by AI and automation poses both opportunities and challenges which demands a focus on the development of future skills [28]. This entails identifying the types of skills required to integrate with future systems, and for institutions to adapt learning and training content and channels in developing those skills.

2.4.3. 2.4.3. innovation

Research and development has taken centre stage as institutions realize innovation as a leading driver of the 4IR. Globalization and the integration of world markets though technology has demanded the development of innovative business models and production techniques to gain competitive advantage [10].

2.4.4. Policy

Challenges brought about by the 4IR are said to require legislative and policy frameworks which will allow government institutions to allocate adequate resources in an effort to mitigate them. Some of these challenges include security of institutional data, privacy of personal data, trade restrictions, etc [18].

It is imperative for institutions and policymakers to develop a conducive environment for smart industries to succeed through responsive labour market policies, industrial policies, and economic policies which will better equip and prepare employers and employees [10].

2.5. Empirical studies

This section of the paper will be briefly examining empirical models of research work conducted on the main theme of this paper – “the fourth industrial revolution and the labour market”.

2.5.1. The impact of ICT and e-commerce on employment

In their study [2], aims to find the relationship between broadband access and employment using data collected at country and municipality level. From their literature study, they observed the following:

- a) Studies by Refs. [34,35] found that access to broadband positively and significantly lead to an increase in employment rate using country-level data from the USA (between 1999 and 2007), while Jayakar and Park (2013) observed countries with better access to broadband had lower rates of unemployment;
- b) On the other hand [36], found that employment growth in the UK is not affected by broadband availability using organisation-level data.

The aim of their study was thus to contribute to research through empirical exploration of the relationship between labour demand and e-commerce/ICT activities using internationally comparable data from ten countries in Europe. In contrast to previous studies which relied on cross-sectional methods, their model used robust regression methods centred on “both a specification in first-differences and dynamic panel data methods while accounting for group effects (by industry-firm size pairs for each country) in particular [considering] different types of ICT capacities, ranging from websites and broadband internet access to ERP and other complex systems”. Their empirical model was assessed using.

From their analysis of data, they concluded that there is no evidence to support the hypothesis that ICT application negatively affect employment, but rather these enablers have no effect on employment.

2.5.2. Automated pastures and the digital divide: how agricultural technologies are shaping labour and rural communities

Automation, artificial intelligence, and digitization have increasingly become important to all stakeholders in the food and agriculture field. As technological advances are rapidly infiltrating the agriculture space, there have been arguments that these “agricultural technologies entrench land degradation, capital accumulation, and the exploitation of marginalized and racialized labourers by land owners, government and corporations”. Ref [23] investigates two main questions in this regard; 1) “how might these technologies restructure labour in agriculture, for better or worse, and reshape rural communities in North America”; and 2) “how could policy and research help support more equitable development for currently marginalized groups in agri-food”.

The paper by Ref. [23] emerged from an interdisciplinary workshop

that included twenty experts and scholars from fields such as agri-food, rurality, and digitization, who focused on gaps and trends in existing research analysis in order to understand these complexities. They used “automation and labour-saving technologies as the main components of digital agriculture to organize the analysis, focusing on precision-tech, robotics, sensors, data software systems, drones, and mobile phones as opposed to communication and transparency technologies like RFID chips or social media platforms” to collect some of their data and together with peer-reviewed papers, they were able to conduct a thorough analysis. From their analysis they could conclude that while automation or agricultural activities may lead to net employment losses for unskilled employees, a greater consequence may be the exploitation and marginalization of those unskilled workers who may still have jobs.

After a thorough review of the existing literature, the study contributes to the existing literature on the topic of the impact of technological advancements on employment in developing countries, with a focus on South Africa. This is because South Africa’s unique history has shaped its socio-economic characteristics, such as high levels of unemployment and inequality. Further validating the relevance of this study. The study contributes by adding various methodology and empirical models such as the variance decomposition analysis. This model and methodology employed provide a comprehensive understanding on the extent the impact of 4IR could have on the South African labour dynamics. The findings of this study could offer valuable insights into the intricate relationship between 4IR and labour dynamics in South Africa, which can inform evidence-based policymaking to shape the country’s development policies in response to the ever-evolving environment.

3. Research methodology

3.1. Research method and data

The main aim of this article is to investigate and test the interrelationship between advancements in information, communication and technology (ICT) and its impact on employment in South Africa. This investigation will be based on a time-series data design and therefore a quantitative methodology was viewed as the best approach. For the purposes of this study, secondary data for ICT development is obtained from the World Bank’s World Development Indicator (WDI) database, while the labour market data like labour force (LABF) and employment level (EMPR) were obtained from Statistics South Africa (Stats SA).

3.2. Data analysis and model specification

The model that will be used in this study is The Classical Linear Regression Model to assist in examining the nature and form of the relationship among the chosen variables. This study focuses on employment levels as the dependent variable with its determinants (independent variables) including labour force, income/wage, level of education, and 4IR (ICT development). The data was analysed using the EViews Version 11 software to determine descriptive statistics and linear regressions in testing for the correlation between these variables. This model was specified using the following equation:

$$Y_t = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_t \quad (1)$$

Where Y_t is the employment rate (quarterly employment statistics pooled to form an average annual figure), β_0 is the constant that captures average employment (intercept on the regression model), β_1 is the constant coefficient associated to X_1 which is the labour force (15yrs–64yrs), β_2 is the constant coefficient associated to X_2 which is the wage rate, β_3 is the constant coefficient associated to X_3 which is the level of education, β_4 is the constant coefficient associated to X_4 which is the ICT development, and ε_t is the error term. With these variables the model and the primary objective of this investigation, the equation for this model is a follow:

Table 1

Explanation of variables.

Variable	Description
EMPR	Employment Rate: percent of persons employed in both formal and informal sectors and across industries
LABF	Labour Force: Comprises of all persons either employed or unemployed between the ages of 15 and 64
WAGE	Income: in the form of GDP per capita
EDUL	Education Level: from secondary qualification upwards
ICTD	ICT development: index consisting of mobile and telephone subscriptions, and individuals using the internet (computed with principal component analysis)

$$EMPR_t = \beta_0 + \beta_1 LABF_t + \beta_2 WAGE_t + \beta_3 EDUL_t + \beta_4 ICTD_t + \varepsilon_t \quad (2)$$

In this equation, the annual employment rate (EMPR) forms the dependent variable, while the labour force (LABF), wage rate (WAGE), levels of education (EDUL), and 4IR ICT development (ICTD) serves as independent variables. Indicators for ICT development as summarized in [Table 1](#).

The scope of this study is from 1980 to 2019. The data were sourced from World Development Indicators (WDI) of the World Bank and

StatsSA in 2020. To test for order of integration between individual variables, an Augmented Dickey Fuller (ADF) and Philip Perron (PP) tests were deployed followed by cointegration analysis test which was helpful in explaining if the long run relationships exist among the variables. The study further deployed, restricted vector autoregressive (VAR) model to evaluate the short and long run dynamics among the variable based on the I(1) order of integration suggested by the unit root tests. Lastly, the shocks presence and impacts in the variables are evaluated through impulse response and variance decomposition analysis.

4. Results and interpretation

4.1. Summary statistics

The overall summary statistics of the variables being analysed are shown in [Table 2](#).

Employment level – the mean annual employment has been at 39.52% while the minimum and maximum reaching 36.75% and 43.26% respectively. The distribution of employment is positively skewed and the rate of employment is not normally distributed, as is indicative of the rejection of the null hypothesis of normality of the

Table 2

Summary statistics of variables.

Statistics	EMPLOYMENT	ICT(4IR)	LABOUR FORCE	EDUCATION LEVEL	WAGE
Mean	39.52355	32.01700	60.77121	3500285.	48089.10
Median	39.48900	11.74601	61.25410	4081455.	47048.64
Maximum	43.26400	113.0852	65.69501	4904846.	55514.43
Minimum	36.74900	1.059348	55.24539	1199665.	40394.93
Std. Dev.	1.081027	39.29088	4.347298	1259436.	5171.941
Skewness	0.339786	1.004760	-0.110557	-0.70334	0.123554
Kurtosis	6.295682	2.436782	1.294306	1.901390	1.540189
Jarque-Bera	18.87223	7.258975	4.930474	5.309492	3.653515
Probability	0.000080	0.026530	0.084989	0.070317	0.160935
Sum	1580.942	1280.680	2430.849	1.40E+08	1923564
Sum Sq. Dev.	45.57620	60207.14	737.0610	6.19E+13	1.04E+09
Observations	40	40	40	40	40

Source: Authors' computations, 2021

Table 3

Unit root tests.

Variable level	Test with Intercept		Test with Intercept and Trend		Test with no Intercept or Trend		Decision
	ADF Test	PP	ADF Test	PP	ADF Test	PP	
Levels							
LEMPLOYMENT_LEVEL	0.1689	0.1169	0.1333	0.2515	0.6937	0.6963	Non-Stationary
LICT	0.8385	0.9393	0.4248	0.6479	0.8249	0.9934	Non-Stationary
LLABOUR_FORCE	0.0470	0.8357	0.0548	0.8841	0.7945	0.9980	Non-Stationary
LLEVEL_OF_EDUCATION	0.0676	0.0221	0.9531	0.9906	0.9984	0.9966	Non-Stationary
LWAGE	0.7772	0.8361	0.2280	0.6622	0.7318	0.8014	Non-Stationary
First Difference							
D(LEMPLOYMENT_LEVEL)	0.0001*	0.0001*	0.0007*	0.0007*	0.0000*	0.0000*	Stationary
D(LICT)	0.1575	0.1377	0.4294	0.3921	0.1010*	0.1177	Stationary
D(LLABOUR_FORCE)	0.8188	0.7057	0.9315	0.0240*	0.0438*	0.0514*	Stationary
D(LLEVEL_OF_EDUCATION)	0.0005*	0.0005*	0.0003*	0.0000*	0.0001*	0.0001*	Stationary
D(LWAGE)	0.0067	0.0059	0.0125	0.0103	0.0003	0.0003	Stationary

Unit root tests developed by Dickey and Fuller (1981) – the Augmented Dickey Fuller (ADF) test – and Philip and Perron (1988) – Phillips-Perron (PP) test – were preliminary tests applied to determine the order of integration and natural logs of all variables were determined. These results are summarized in [Table 3](#). The p-values are considered evaluating the stationarity of the series and shown in [Table 3](#) using Schwarz Info Criterion (SIC) automatic selection..

* = 10% significance level..

Source: Authors' computations, 2021

Table 4
Cointegration test statistics.

	Test Statistics	0.05 Critical Value	Probability Value
Trace Statistics			
None *	107.4213*	69.81889	0.0000
At most 1 *	68.77954*	47.85613	0.0002
At most 2 *	35.83974*	29.79707	0.0089
At most 3 *	18.34309*	15.49471	0.0181
At most 4 *	6.121779*	3.841465	0.0133
Max-Eigen Statistics			
None *	38.64171*	33.87687	0.0125
At most 1 *	32.93981*	27.58434	0.0093
At most 2	17.49664	21.13162	0.1498
At most 3	12.22131*	14.26460	0.1026
At most 4 *	6.121779*	3.841465	0.0133

* = 10% significance level respectively.

Source: Authors' computations, 2021.

Note: Trace test indicates 5 cointegrating eqn(s) while the MaxEigen test indicates 4 cointegrating eqn(s).

Jarque-Bera test statistic.

ICT – the mean annual ICT index (which comprises of Mobile, fixed/landline, and internet usage) have been at 32.02 people per 100 people while the minimum and maximum are at 1.06 and 113.09 respectively. The distribution of ICT is positively skewed and ICT is not normally distributed, as is indicative of the acceptance of the null hypothesis of normality of the Jarque-Bera test statistic.

Labour force – the mean annual labour force population has been at 60.77% while the minimum and maximum reaching 61.25% and 65.70% respectively. The distribution of the labour force is negatively skewed and the labour force is normally distributed, as is indicative of the rejection of the null hypothesis of normality of the Jarque-Bera test statistic.

Level of education – the mean annual Level of education has been at 3500285 general pupils while the minimum and maximum reaching 1199665 and 4904846 respectively. The distribution of the Level of education is negatively skewed and the level of education is normally distributed, as is indicative of the rejection of the null hypothesis of normality of the Jarque-Bera test statistic.

Wage – the mean annual wage has been at 48089.10 GDP per capita (constant LCU) while the minimum and maximum is at 40394.93 and 55514.43 respectively. The distribution of wages is positively skewed and the wages are normally distributed, as is indicative of the acceptance of the null hypothesis of normality of the Jarque-Bera test statistic.

4.2. Unit root test

In Table 3, the p-value of the ADF and PP tests were recorded to evaluate the presence of the unit roots in the data series for employment (LEMPLOYMENT_LEVEL), ICT development (LICT), labour force (LLABOUR_FORCE), human capital development (LLEVEL_OF_EDUCATION)

Table 5
Lag length test.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	212.7765	NA	9.12e-12	-11.23116	-11.01347	-11.15441
1	504.4318	488.7198	5.09e-18	-24.33881*	-24.33881*	-25.18448
2	538.8429	48.36148*	3.31e-18*	-26.15367*	-23.75906	-25.30946*
3	560.1430	24.17847	4.99e-18	-25.95367	-22.47061	-24.72573

* indicates lag order selected by the criterion.

LR: sequential modified LR test statistic (each test at 5% level).

FPE: Final prediction error.

AIC: Akaike information criterion.

SC: Schwarz information criterion.

HQ: Hannan-Quinn information criterion.

Source: Authors' computations, 2021.

and income (LWAGE) in South Africa. The ADF results from Table 3 indicate that LEMPLOYMENT_LEVEL, LICT, LLEVEL_OF_EDUCATION, and LWAGE are stationary at first difference in the no intercept and trend scenarios, thus these four variables are integrating order 1, i.e. the key variables of this study are I(1). LLABOUR_FORCE and LICT since they are stationary at first difference.

The PP results from Table 3 also indicate that LEMPLOYMENT_LEVEL, LLEVEL_OF_EDUCATION, and LWAGE are stationary at first difference in all scenarios (Intercept, Intercept and Trend, No Intercept and Trend), thus making these four variables of integrating order 1, i.e. I(1). LLABOUR_FORCE and LICT are non-stationary in all scenarios at first difference.

4.3. Johansen Cointegration test

A cointegration test was done to determine if there is a long run relationship between all logged variable at automatic estimated 1 Lag.

Table 4 summarizes the cointegration rank in both Trace and Max-Eigen tests at a 5% significance level.

The results indicate that the p-values – for the Trace statistics – under “None”, “At most 1”, “At most 2”, “At most 3” and “At most 4” cointegrations are all less than the 10% level of significance. We therefore reject all the null hypotheses which states that; i) there is no cointegration, ii) there is at least one cointegration, iii) there are at least 2 cointegration, iv) there are at least 3 cointegrations, or v) there are at least 4 cointegration.

Using the Max-Eigen test, the p-values under “None” and “At most 1” cointegrations are less than then the 10% level of significance. We therefore reject the null hypothesis which states that; i) there is no cointegration, ii) there is at least one cointegration. The p-values of “At most 2”, is however greater than the 5% level of significance and therefore we cannot reject the null hypothesis. This means that there is at most 4 cointegrated equations indicating that there is cointegration among all the variable and that employment, ICT, labour force, level of education and wages have a long run relationship.

From the results outcome, it can be observed that there is no agreement between Trace and Max-Eigen statistics and therefore in this study, we will be proceeding with the Max-Eigen results indicating the existence of a long run association between employment, ICT, labour force, level of education and wages have a long run relationship in South Africa. Subsequently, a vector error correlation model (VECM) was estimated and analysed but the appropriate lag selection would be determined first.

4.4. Long run relationship between the variables

$$ECT_{t-1} = [Y_{t-1} - \eta_j X_{t-1} - \xi_m R_{t-1}]$$

$$ECT_{t-1} = [1.000 \ln EMP_{t-1} - 0.012921 \ln ICT_{t-1} + 2.736091 \ln LBF_{t-1} - 0.263147 \ln LOE_{t-1} - 0.284129 \ln WAG_{t-1} - 7.870572]$$

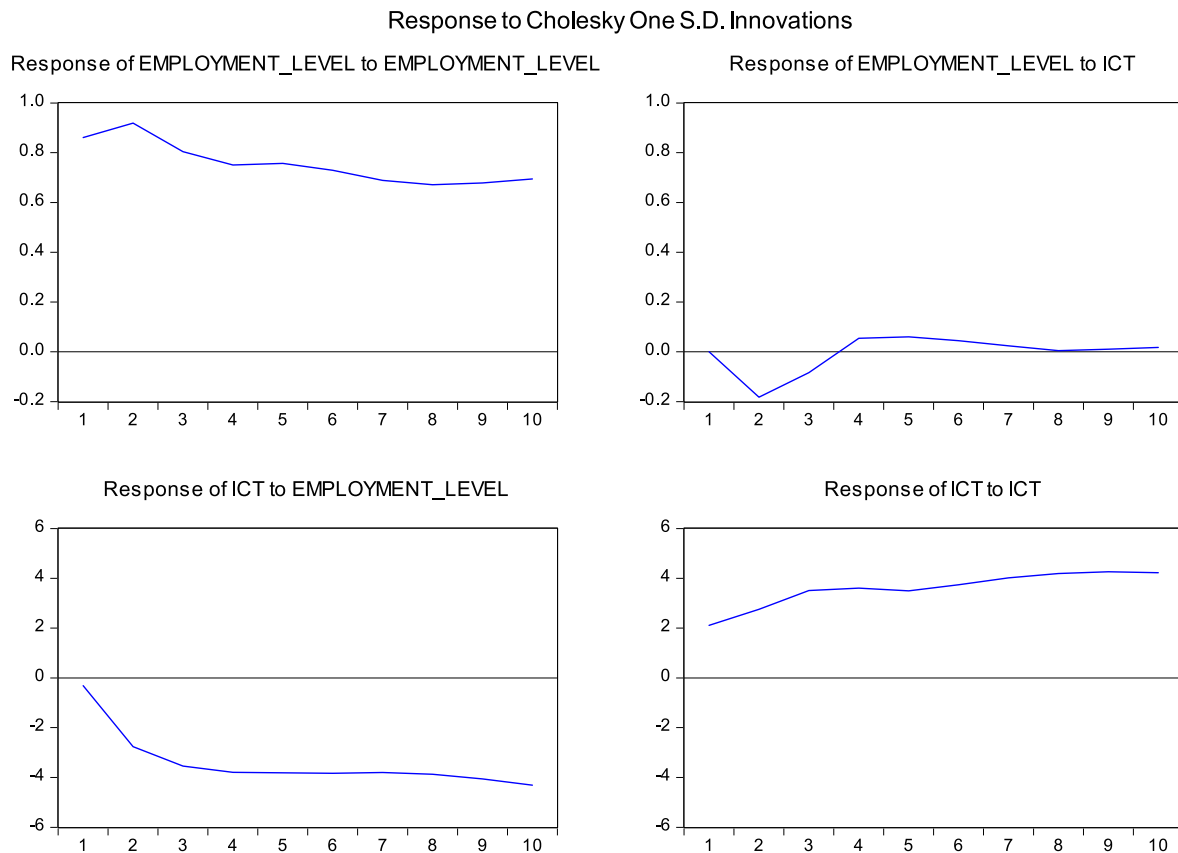


Fig. 3. Response of employment level and ICT to Cholesky one standard deviation innovations.

Table 6

Breakdown of error correction term signifying a (long run relationship between the variables).

Cointegrating Eq:	CointEq1	t-statistic
L_EMPLOYMENT_LEVEL(-1)	1.000000	
L_ICT(-1)	-0.012921	-0.37428
L_LABOUR_FORCE(-1)	2.736091*	3.01408
L_LEVEL_OF_EDUCATION(-1)	-0.263147*	-4.48835
L_WAGE(-1)	-0.284129	-0.96361
C	-7.870572	

Source: Authors' computations, 2021.

From Table 5, ICT in South Africa (InICT) is negative meaning that a percentage change in InICT is associated with a 0.012921 percent increase in InEMP. In terms of significance, its t-statistic of -0.37428 is less than 2.05 for the 5% critical value hence we accept the null hypothesis that ICT is not a significant determinant of employment in South Africa.

The Labour Force (InLBF): The coefficient for InBF is positive meaning that a percentage change in InLBF is associated with a 2.736091 percent decrease in InEMP. In terms of significance, its t-

statistic of 3.01408 is more than 2.05 for the 5% critical value hence we reject the null hypothesis that labour force is not a significant determinant of employment, concluding that it is indeed a significant determinant of employment level in South Africa.

Level of Education (InLOE): The coefficient for InLOE is negative meaning that a percentage change in InLOE is associated with a 0.263147 percent increase in InEMP. In terms of significance, its t-statistic of -4.48835 is less than -2.05 for the 5% critical value hence we reject the null hypothesis that level of education is a significant determinant of employment in South Africa.

The coefficient for wage (InWAG) is negative meaning that a percentage change in InWAG is associated with a 0.284129 percent increase

Table 8

Causality statistics.

Null Hypothesis:	Obs	F-Statistic	Prob.
ICT does not Granger Cause L_EMPLOYMENT_LEVEL	38	1.11439	0.3401
L_EMPLOYMENT_LEVEL does not Granger Cause ICT		3.14371*	0.0563

Source: Authors' computations, 2021.

Table 7

Short run relationship between variables.

Error Correction:	D(L_EMPLOYMENT_LEVEL)	t-statistic	p-value
CointEq1	-0.12864	-1.717210	0.0879
D(L_EMPLOYMENT_LEVEL(-1))	0.041484	0.245501	0.8064
D(L_ICT(-1))	0.002073	0.052301	0.9578
D(L_LABOUR_FORCE(-1))	-1.561982	-1.27657	0.2037
D(L_LEVEL_OF_EDUCATION(-1))	-0.049058	-0.83169	0.4069
D(L_WAGE(-1))	0.459486*	2.57929	0.0108
C	0.007560		

Source: Authors' computations, 2021.

Table 9
VEC residual serial correlation LM tests.

Null hypothesis: No serial correlation at h						
Lag	LRE*stat	df	Prob.	Rao F-Stat	df	Prob.
0	23.77635	25	0.5323	0.949815	(25, 83.2)	0.5398
1	21.22744	25	0.6799	0.836214	(25, 83.2)	0.6860

Source: Authors' computations, 2021.

Table 10
VEC residual normality tests.

Null Hypothesis: Residuals are normally distributed			
Component	Jarque-Bera	df	Prob.
1	16.63796	2	0.0002
2	10.88315	2	0.0043
3	12.32084	2	0.0021
4	46.42342	2	0.0000
5	0.434978	2	0.8045
Joint	83.70035	10	0.0000

Source: Authors' computations, 2021

Table 11
VEC residual Heteroskedasticity tests (levels and Squares).

Null Hypothesis: Model is homoskedastic		
Joint Test:		
Chi-sq	df	Prob
190.4026	180	0.2833

Source: Authors' computations, 2021

in InEMP. In terms of significance, its t-statistic of -0.96361 is less than -2.05 for the 5% critical value hence we accept the null hypothesis that level of education is not a significant determinant of employment in South Africa.

4.5. Vector error correction estimations

The short run equilibrium equation for estimation is stated below:

$$\begin{aligned}\Delta \ln EMP_t = & -0.12864 \Delta ECT_{t-1} + 0.04184 \Delta \ln EMP_{t-1} \\ & + 0.002073 \Delta \ln ICT_{t-1} - 1.561982 \Delta \ln LBF_{t-1} - 0.049058 \Delta \ln LOE_{t-1} \\ & + 0.459486 \ln WAG_{t-1} + 0.007560\end{aligned}$$

The previous period's deviation from the long run equilibrium is corrected in the current period with an adjustment speed of 12.864%.

ICT in South Africa (InICT): The coefficient for InICT is positive meaning that a percentage change in InICT is associated with a 0.002073 percent increase in InEMP on average in the short run. In terms of significance, its t-statistic of 0.052301 is less than 2.05 for the 5% while the p-value is 0.9578 which is greater than 0.05 for the 5% significance level critical value hence we accept the null hypothesis that ICT is not a significant determinant of employment in the short run.

The coefficient for InLBF is negative meaning that a percentage change in InLBF is associated with a 1.561982 percent decrease in InEMP on average in the short run. In terms of significance, its t-statistic of -1.27657 is less than 2.05 for the 5% critical value while the p-value is 0.2037 which is greater than 0.05 for the 5% significance level, hence we accept the null hypothesis that labour force is not a significant determinant of employment in the short run.

The percentage for InLOE is negative meaning that a percentage

change in InLOE is associated with a 0.049058 decrease in InEMP on average in the short run. In terms of significance, its t-statistic of -0.83169 is less than 2.05 for the 5% critical value while the p-value is 0.4069 which is greater than 0.05 for the 5% significance level, hence we accept the null hypothesis that level of education is not a significant determinant of employment in the short run.

Wage (InWAG): The coefficient for InWAG is positive meaning that a percentage change in InWAG is associated with a 0.459486 increase in InEMP on average in the short run. In terms of significance, its t-statistic of 2.57929 is more than 2.05 for the 5% critical value while the p-value is 0.0108, hence we reject the null hypothesis that wages are not a significant determinant of employment, concluding that it is indeed a significant determinant on employment levels.

4.6. Causality test

Looking at the first p-value of 0.3401, it is greater than 0.10 for 10% level of significance therefore we accept the null hypothesis that ICT does not Granger Cause L_EMPLOYMENT_LEVEL. This means that the historical values of ICT do not contain information that assists in predicting L_EMPLOYMENT_LEVEL above and beyond the information found in historic values of L_EMPLOYMENT_LEVEL alone in South Africa.

Looking at the second p-value of 0.0563, it is greater than 0.10 for 10% significance level therefore, we reject the null hypothesis that L_EMPLOYMENT_LEVEL does not Granger Cause ICT. This means that the historical values of L_EMPLOYMENT_LEVEL do contain information that assists in predicting ICT and beyond the information found in historic values of ICT alone in South Africa. These results imply that employment level actually has spill over impact on ICT development, as level of employment increases, ICT deployment rises to ensure accuracy in the tasks performed by labour.

4.7. Autocorrelation test

The probability under the LM test is 0.5398 which is greater than 0.05 for 5% significance level therefore, accept the null hypothesis that there is no serial correlation (see Table 9).

4.8. Normality test

The joint p-value of Jarque-Bera is 0.0000 which is less than 5% level of significance therefore we reject the null hypothesis that the residuals are normally distributed. Although the residuals are normally distributed only at the 5th components estimation (see Table 10).

4.9. Heteroskedasticity test

The probability of 0.2833 is greater than 0.05 for 5% significance level therefore we accept the null hypothesis that model is homoscedastic. With this result, it is an indication that the variance associated with the model is constant which satisfies one of the assumptions of the classical linear regression models (see Table 11).

4.10. Variance decomposition analysis

A variance decomposition and impulse analysis was conducted to further validate the extent of causation using the orthogonalised Cholesky ordering approach. The results tabulated in Table 12 show the variance decomposition of employment level and ICT for 10 periods – whereby period 5 represents the short run while period 10 represent the long run. The results shown under decomposition of employment levels refer to the response of employment levels to own shocks, shocks in labour force, shocks wage, shocks in level of education, and shocks in ICT. It can be observed that employment levels' response to shocks in itself causes 84.555% fluctuation in the short run dropping slightly

Table 12
Variance decomposition of employment levels and ICT.

Decomposition of EMPLOYMENT_LEVEL:						
Period	S.E.	EMPLOYMENT_LEVEL	LABOUR_FORCE	WAGE	LEVEL_OF_EDUCATION	ICT
1	0.860806	100.0000	0.000000	0.000000	0.000000	0.000000
5	1.996029	84.55478	0.979051	10.93299	2.356714	1.176462
10	2.641730	82.64178	0.992825	11.85732	3.792623	0.715450
Variance Decomposition of ICT						
Period	S.E.	EMPLOYMENT_LEVEL	LABOUR_FORCE	WAGE	LEVEL_OF_EDUCATION	ICT
1	2.637640	1.424923	26.14743	0.453726	8.080304	63.89362
5	12.70935	30.47218	30.82745	0.760060	7.263134	30.67718
10	22.83193	24.63288	34.74311	5.561850	9.491525	25.57063

Source: Authors' computations, 2021

down to 82.642% fluctuations in the long run in South Africa. Shocks in labour force causes 0.979% and 0.993% fluctuations to employment levels in the short and long run respectively, while shocks in levels of education contributed 2.357% fluctuations in the short run and 3.793% fluctuations in the long run. In the short run, shocks in wage causes 10.933% fluctuations to employment levels but increases to fluctuations of 11.857% in the long run. Shocks in ICT leads to short run fluctuations of 1.176% in employment levels, however dropping to long run fluctuations of 0.715% in employment levels. Under decomposition of ICT, the results refer to the response of ICT to own shocks, shocks in employment levels, shocks in labour force, shocks wage, and shocks in level of education. What can be observed from the empirical results is that own shocks of ICT cause 30.677% fluctuations to ICT in the short run but 25.571% fluctuations in the long run. The shocks in employment levels in the short and long run contribute to 30.472% and 24.632% fluctuations to ICT respectively. Shocks in labour force accounted for 30.827% fluctuations in ICT in the short run increasing to fluctuations of 34.743% in the long run. In the short run, shocks in wages represents 0.760% fluctuations in ICT while rising to 5.562% in the long run. Shocks in level of education causes fluctuations in ICT of 7.263% in the short run and 9.492% in the long run.

4.11. impulse response analysis

From these shocks-fluctuations analysis, an impulse response analysis was formed, however focusing only on employment levels and ICT as indicated in Fig. 3. The unit shock exerted on each series and the effect it has on the VAR system can be measured through the impulse response, thus identifying the extent to which endogenous variables react to shocks in the exogenous variables [7]. The idea behind this analysis is to determine how the VAR system responds to shocks over the time path of different shocks and in this study the duration shocks/innovation assumed 10.

In Fig. 3, employment levels react positively to own one standard deviation shock in the short and long run although showing a gentle decline over the 10 periods. One standard deviation shock in ICT has caused a negative reaction to employment levels in the short run reaching a minimum in period 2. However, employment levels begin reacting positively in the long run (from period 4 to period 10) to one standard shock in ICT in South Africa. ICT reacted to own one standard deviation shock in a positive way both in the short and long run showing a steady incline from the first to the tenth period. On the other hand, one standard deviation shock on employment levels caused a negative reaction to ICT in the short run while further steadily decreasing towards the long run.

5. Conclusion

This study investigated the effects of the fourth industrial revolution

on employment in South Africa, looking at the following variables; employment, ICT components (Fixed and mobile telephone subscriptions, and individuals using the internet), labour force, level of education, and wages. Testing for stationarity using the ADF and PP test indicate that only three (employment, level of education, and wage) out of the five variables are stationary at first difference. The Johansen cointegration technique was applied to determine the long run relationship between the variables. The results from the Max-Eigen test reveal that there is at most two cointegrated equations indicating that there is cointegration among all the variable and that employment, ICT, labour force, level of education and wages have long run relationship.

The Vector Error Correction Mechanism was used to determine the short run association in relation to the long run association, and the results summarized in Tables 5 and 6. In the long run there appears to be a slightly negative relationship between ICT and employment levels indicating that if left unchecked, ICT has the potential of affecting employment negatively. These results however also indicate that ICT is not a significant determinant of employment levels in the long run. Contrary to the long run association, the short run shows a positive relationship between levels of employment and ICT. Granger Causality Test was used to determine the direction of causality and the empirical results given in Table 7 reveal that ICT does not granger cause employment level and that employment level also does not in reality granger cause ICT. This means that the historical values of employment level do not contain information that assists in predicting ICT above and beyond the information found in historic values of ICT alone. Similarly, historical values of ICT do not contain information that assists in predicting employment level above and beyond the information found in historic values of employment level alone. The model passed through two out of three diagnostics tests as given in Tables 8–10. There is no serial correlation, no heteroskedasticity but the residuals are not normally distributed.

6. Recommendations

From the observed results, the positive relationship between ICT and employment levels in the short run should form the basis on which policy is formed. The South African government should enhance its economic activity by aligning skills development in terms of re-skilling and up-skilling the workforce in order for the future working class to be in sync with the future work requirements because in the long run there's a negative relationship that exists between employment levels and ICT. South Africa had developed the National Development Plan (NDP) with its main focus on reducing inequality and eliminating poverty, and some of the growth enablers and employment creation strategies was to focus on the ICT sector by prioritising on the establishment of a municipal, regional, and national fibre optic network which will set the foundation for access to broadband. The prerequisite however is an enabling regulatory and policy environment. Policy-

makers are encouraged to review the broadband plan and its proposed strategies in order to apply swift procedures of implementation by looking into more efficient competitive models that are able to deal with international communication systems. The country needs to manage the supply-side gap by enabling a competitive market that will allow multiple industry players to discourage oligopolies enjoying all the market powers. When it comes to infrastructure development, the state needs to put in place structures that prevent SOEs from competing amongst themselves and look into privatising those operations so as to make them economically viable through the efficient use of their asset base.

CRedit authorship contribution statement

Hlanganani Rabia Matjokana: Conceptualization, Investigation, Methodology, Writing – original draft. **Oladipo Olalekan David:** Data curation, Formal analysis, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing.

Data availability

The authors do not have permission to share data.

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