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The effects of information communication technology policy alternatives on South Africa's agro-processing industries

By

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Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Agricultural Economics

In the Faculty of Natural & Agricultural Sciences
Department of Agricultural Economics, Extension & Rural Development
University of Pretoria
Pretoria

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DEDICATION

This thesis is dedicated to all the agro-processing firms in South Africa.

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DECLARATION

I declare that the thesis, which I hereby submit for PhD in Agricultural Economics at the University of Pretoria, is my work and has not previously been submitted by me for a degree at another university. Some parts of the thesis have been published in journals or submitted for publications in journals.

Signed: ……………………………

Name: Mapula Hildah Lefophane

Date: 12 July 2021

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ABSTRACT

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Degree: PhD Agricultural Economics

Department: Agricultural Economics, Extension and Rural Development

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Since 1994, the South African Government has developed various policy plans to ensure South Africa's economic growth and development. The agro-processing subsector has been earmarked in the policy plans as one of the sectors with the potential to achieve South Africa's economic growth and development. Despite this, statistics show that the subsector has been ineffective in driving the required growth and development. Against this backdrop, the study aimed to examine the contribution of ICT investment to the growth of the agro-processing subsector. Four objectives were identified as follows: (1) to examine whether ICT policies contributed to the labour productivity growth of the agro-processing industries; (2) to estimate effects of ICT intensity on the growth of labour productivity, output and employment; (3) to examine the relationship between ICT intensity and the growth of labour productivity, output and employment; and (4) to forecast the potential effects of ICT intensity on growth of labour productivity, output and employment.

The ICT intensity index was applied to rank 10 agro-processing industries into two groups: "more ICT-intensive industries" and "less ICT-intensive industries". Thereafter, the annual growth rates of labour productivity, output and employment for all the industries were calculated. Four econometric techniques were applied to achieve the objectives of the study as follows. The Difference-in-Differences (DD) technique was used to achieve the first objective. The Pooled Mean Group (PMG) estimations were performed to achieve the second objective. The Toda and Yamamoto (TY) Granger non-causality tests were applied to achieve the third objective. The Impulse Response Function (IRF) and Variance Decomposition (VDC) analyses were conducted to achieve the fourth objective.

The findings from the ICT intensity index indicated that the more ICT-intensive industries (i.e. food, beverages, textile, paper and rubber) accounted for 78% of ICT investment, while the less ICT-intensive industries (i.e. tobacco, wearing apparel, leather, wood and furniture) accounted for the remaining 22%. In the case of individual industries, the food industry accounted for the largest share of ICT investment (37.20%), while the tobacco industry accounted for the smallest share (0.84%). This implies that the food industry has invested the most in ICT, whereas the tobacco industry has invested the least.

The DD findings showed that the more ICT-intensive industries experienced a slightly higher acceleration (i.e. increase overtime) in labour productivity growth than the less ICT-intensive industries. However, the DD estimator was insignificant, which means that the difference in labour productivity between the two groups cannot be attributed to ICT use. The policy implication is that there was no evidence to support that ICT policies contributed to the labour growth of industries.

The PMG findings indicated that ICT intensity had no significant effect on the growth of the aggregated industries. These findings conform to studies that found zero and negative significant effects of ICT when industries were aggregated. This implies that the lower growth contributions of the industries that invested less in ICT outweighed the relatively higher growth contributions of the industries that invested more ICT.

The findings further showed that positive and significant effects were notable only in the short run for the more ICT-intensive group. Furthermore, whereas in the long run ICT intensity yielded positive and significant effects on the output growth of both the less and more ICT-intensive industry groups, its effect was higher for the more ICT-intensive group. The findings conform to previous studies that found higher effects for the more ICT-intensive industries. This implies that the impact of ICT on agro-processing industries varied per group of industries, such that an industry group that invested more in ICT (i.e. more ICT-intensive industries) experienced higher growth than those that invested less (i.e. less ICT-intensive industries). The findings for individual industries revealed that ICT intensity contributed more to the growth of an industry that invested more in ICT (i.e. food industry) and less to the growth of an industry that invested less (i.e. tobacco industry).

The findings from the TY Granger non-causality tests showed that there was no evidence of causality for the less ICT-intensive industries. In contrast, the results showed that there was evidence of a causal relationship for the more ICT-intensive industries. This implies that causal effects occur in line with ICT intensity given that evidence of causality was evident for the industry group that invested more in ICT. The findings for individual industries showed that there was evidence of causality for the food industry. This implies that evidence of causality was notable for an industry that invested more in ICT.

The IRF findings showed that, in the long run, ICT intensity would impact positively on the growth of labour productivity, output and employment of both the less and more ICT-intensive industries. This finding varied from the TY test in which there was no causal relationship between ICT intensity and growth for the less ICT-intensive industries. Therefore, the fact that positive effects for the less ICT-intensive industries were only detected in the long run implies that the returns on ICT investment for the less ICT-intensive industries would be notable over a long period. However, the VDC results, which captured the magnitude of the effect, showed that, while ICT intensity would contribute to the growth of all industry groups, its contribution would be higher for the more ICT-intensive industry group. The findings for individual industries indicated that, while ICT intensity would contribute to the growth of all agro-processing industries, it would contribute more to the growth of the industry that invested more in ICT (i.e. food industry). In contrast, it would contribute less to the growth of an industry that invested less in ICT (i.e. tobacco industry).

Two main findings have been derived from this study for policy decision making. Firstly, the study found that the existing ICT policies have not yet contributed to the labour productivity growth of the agro-processing industries. This is attributable to the observation that the existing policies do not currently focus on ensuring access to and usage of ICT by other non-ICT industries, including the agro-processing industries.

Secondly, the study found that, whereas ICT investment would contribute to the growth of all agro-processing industries, in the long run, it would contribute more to the growth of the food industry, which invested more in ICT, and less to the growth of the tobacco industry, which invested less in ICT. Against this backdrop, the key drivers that could have restricted ICT use by the tobacco industry were identified as (a) value-chain information intensity, (b) size of the industry and (c) policy environment. In particular, the tobacco industry invested less in ICT and consequently realised low growth because it is low-value chain information-intensive and is comprised of fewer firms. In addition, lower ICT investment and growth is attributable to policies that prohibit the advertisement and promotion of tobacco products, and the distribution and sale of tobacco products through postal services, the internet, or any electronic media.

This study recommends the integration of ICT into the growth and development policy plans for agro-processing. This can be achieved through the inclusion of skills development and ICT infrastructure development in the policy plans for the effective use of ICT. Where private firms invest in skills development and ICT infrastructure, it is recommended that the government should compensate such firms through the proposed ICT Tax Incentive Programme. The aim of the proposed ICT Tax Incentive Programme should be to stimulate investment in ICT given that the present study has established that the more an industry invests in ICT, the higher the growth in labour productivity, output and employment. The proposed programme should be implemented over a longer period, in line with the study’s finding that the returns on ICT investment take time to materialise. It is further recommended that priority should be given to the more ICT-intensive industries as the returns on investment would be higher.

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LIST OF ACRONYMS

ADEP	Aquaculture Development and Enhancement Programme
ADF	Augmented Dickey-Fuller
ADF-GLS	Augmented Dickey-Fuller-Generalised Least Squares
AIC	Akaike Information Criterion
APAP	Agricultural Policy Action Plan
APSS	Agro-Processing Support Scheme
ARCH	Autoregressive Conditional Heteroscedastic
ARDL	Autoregressive distributed lag
AsgiSA	Accelerated and Shared Growth Initiative for South Africa
CDP	Cluster Development Programme
CGE	Computational General Equilibrium
CIP	Critical Infrastructure Programme
CTCP	Clothing and Textiles Competitiveness Programme
COSATU	Congress of South African Trade Unions
DAFF	Department of Agriculture, Forestry and Fisheries
DD	Difference-in-Differences
DEA	Data Envelopment Analysis
DOLS	Dynamic Ordinary Least Square
DTI	Development of Telecommunications Infrastructure
DTPS	Department of Telecommunications and Postal Services
DOC	Department of Communications
ECM	Error Correction Model
ECT	Error Correction Term
EU	European Union
FAO	Food and Agricultural Organisation
FCTC	Framework Convention on Tobacco Control
FMOLS	Fully Modified Ordinary Least Squares
GCIS	Government Communication and Information System
GDP	Gross Domestic Product

GEAR	Growth, Employment and Redistribution
GLS	Generalised Least Squares
IAA	Innovation Accounting Approach
IICD	Institute for International Cooperation and Development
ICASA	Independent Communications Authority of South Africa
ICT	Information and Communication Technology
ISIC	International Standard Industrial Classification
IPAP	Industrial Policy Action Plan
IPS	Im-Pesaran-Shin
IRFs	Impulse Response Functions
IV	Instrumental Variable
JJ	Johansen-Juselius
LM	Lagrange Multiplier
MCEP	Manufacturing Competitiveness Enhancement Programme
MFP	Multifactor Productivity
MLE	Maximum Likelihood Estimation
NGP	New Growth Path
NDP	National Development Plan
NIE	Newly Industrialised Economy
NIPF	National Industrial Policy Framework
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PMG	Pooled Mean Group
PP	Phillips and Perron
PURT	Panel Unit Root Testing
R&D	Research and Development
RAAVC	Revitalisation of the Agriculture and Agro-Processing Value Chain
RDP	Reconstruction and Development Programme
RESET	Ramsey Regression Specification Error Test
SABC	South African Broadcasting Corporation
SBC	Schwartz Bayesian criterion
SD	Standard Deviation

SEDA	Small Enterprise Development Agency
SITA	State Information Technology Agency
2-SLS	2-Stage Least Square
SMMEs	Small Medium and Micro Enterprises
SMEs	Small and Medium Enterprises
SPII	Support Programme for Industrial Innovation
STATS SA	Statistics South Africa
STP	Seda Technology Programme
TFP	Total Factor Productivity
the dtic	the Department of Trade Industry and Competition
THRIP	Technology and Human Resource for Industry Programme
UN	United Nations
USAASA	Universal Service and Access Agency of South Africa
UNDP	United Nations Development Programme
US	United States
VDCs	Variance Decompositions
VAR	Vector Autoregressive
VIF	Variance Inflation Factor
WHO	World Health Organization
WHO FCTC	World Health Organization Framework Convention on Tobacco Control
WPC	Workplace Challenge Programme

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

The South African Government has, since the advent of democracy in 1994, developed policy plans to ensure South Africa's economic growth and development. Among the country's numerous national policy plans, some of the most notable include, sequentially, the Reconstruction and Development Programme (1994), the Growth, Employment and Redistribution strategy (1996), the Accelerated and Shared Growth Initiative for South Africa (2006), the National Industrial Policy Framework (2007), the Industrial Policy Action Plan (2008), the New Growth Path (2010), the National Development Plan (2011), the Nine-Point Plan (2015) and the Agricultural Policy Action Plan (2015).[1] However, it is noted that the policy plans implemented thus far have had limited outcomes as evidenced by the persisting challenges of sluggish economic growth and high rates of unemployment.

To illustrate the above assertion, the NDP, for instance, was introduced in 2011 as the country's vision for 2030 aiming to achieve, among other things, gross domestic product (GDP) of 5.4% each year up to 2030, reduce rates of unemployment and inequality, and eliminate poverty by 2030 (National Planning Commission, 2012). Yet, the economy failed to achieve an annual GDP growth of more than 3.5% between 2011 and 2017. Moreover, in the same period, the annual unemployment rate was above 24% (Stats SA, 2019a). In respect of poverty, Stats SA (2017a) estimated that more than half of households lived below the national poverty line.[2] With reference to inequality, the World Bank ranked South Africa as the most unequal country in the world with an income inequality score of 63 (World Bank, 2018).[3] These statistics demonstrate, to a certain extent, that policy plans have been unsuccessful in achieving the targeted GDP growth and in reducing unemployment, poverty and inequality.

[1] The details of these policies including their goals, successes and inadequacies are fully discussed in chapter two of the thesis. The RDP, the GEAR and the AsgiSA have been abolished. The current national policy frameworks, at the time of writing, are the NGP, the NDP, the IPAP and the APAP.

[2] The national poverty line is defined as persons living below the 2015 Food Poverty Line of R441 per person per month. However, the Food Poverty Line is inflation-based and thus varies from year to year, with the amount being R561 per person per month (2019 prices), at the time of writing (Stats SA, 2017).

[3] Income inequality is measured on a scale of 0 to 100, where 0 signifies total equality and 100 total inequality.

Given the severity of the challenges that continue to face South Africa, it is imperative to explore solutions that have been effective in the resurgence of economic growth and development in other economies. An interesting case study is that of the United States (US), which witnessed significant changes in the growth of output and labour productivity performance during the 1990s compared to European Union (EU) countries (Jorgenson and Stiroh, 2000; van Ark, Inklaar and McGuckin, 2003; van Ark, O'Mahony and Timmer, 2008). These changes prompted researchers to investigate the sources of growth performance in the US and the EU.

Noteworthy researchers include van Ark *et al*. (2008) who found that the US's labour productivity growth accelerated from 1.2% (from 1973 to 1995) to 2.3% (from 1995 to 2006). In comparison, the productivity growth of the EU countries (EU-15) decelerated from 2.4% to 1.5% during the same periods. At the same time, the US's GDP was nearly 1% higher than that of the EU between 1995 and 2006. Previous researchers have attributed the US-EU growth performance gap to the slower emergence of information and communication technology (ICT) and the lower share of investment in ICT in Europe compared to the US (van Ark and Piatkowski, 2004; van Ark *et al.*, 2008). ICT is defined, in this study, as any technology used to process, communicate, transmit and display information through electronic means (Organization for Economic Co-operation and Development (OECD), 2011; Stats SA, 2015).[4] ICT investment is defined as expenditure on ICT products and services. Other researchers have also given prominence to the higher level of investment in ICT in the US as responsible for the gap in growth performance between the US and EU (Oliner and Sichel, 2000; Strauss and Samkharadze, 2011; Bloom, Sadun and Van Reenen, 2012).

Despite the aforementioned empirical finding, empirical evidence from Colecchia and Schreyer (2002) has shown that other countries, besides the US, have also benefited from ICT investment. Specifically, Colecchia and Schreyer (2002) found that ICT investment contributed to the economic growth of OECD countries, and not just the US.[5] However, akin to van Ark *et*

[4] The justification for using this definition is that it delineates which industries, commodities and activities are part of ICT and which ones are not. The detailed classification of ICT products and industries is presented in chapter two.
[5] The OECD countries are, namely, the United States, Australia, Finland, Canada, France, Italy, Germany, United Kingdom and Japan.

al. (2008), a comparative study of the US and European countries by Bloom *et al.* (2012) observed that the US's productivity growth accelerated relative to that of the European countries.

Based on findings by the above-cited studies, the key conclusive point is that the impact of ICT investment varies per country, such that countries that invested highly in ICT experienced higher growth than those that invested less. It is on the premise of the aforementioned empirical findings that key international organisations such as the World Bank and the United Nations (UN) have and continue to promote investment in ICT as one of the prerequisites for developing countries to attain economic growth and development. The World Bank, in particular, holds the optimistic view that ICTs can create jobs and enhance the economic growth of developing countries (World Bank, 2012; World Bank, 2017). In the same vein, the UN views supporting innovation and technology development, and increasing access to ICT as some of the key strategies for developing countries to boost economic growth (United Nations Development Programme (UNDP), 2016).

Despite such optimistic views, comparative studies have widely found positive and significant effects for developed countries relative to developing countries (Lee, Gholami and Tong, 2005; Dewan and Kraemer, 2000; Papaioannou and Dimelis, 2007; Pradhan, Arvin, Bahmani, Norman and Bele 2014; Niebel, 2018). These findings are attributable to numerous factors, the key factor being the low level of ICT investment in developing countries, in comparison with developed countries.[6] These latter findings, however, do not negate the evidence that developing countries that have invested more in ICT have experienced a resurgence in their growth performance.

Against the above backdrop, empirical evidence from Vu (2013) affirmed that ICT investment contributed nearly 1 percentage point to the GDP growth of Singapore from 1990 to 2008. Similarly, a study by Kuppusamy, Raman and Lee (2009) showed that investment in ICT had a significant impact on the economic growth of Malaysia, while Nair, Kuppusamy and Davison (2005) also affirmed that other Asian countries, namely, Japan, Korea and Taiwan, have also

[6] Other factors include the late adoption of ICT, limited complementary factors such as human capacity and skills, the lack of high-quality data and the quality of the analytical approaches used (Wu and Liang, 2017; Niebel, 2018).

benefited from ICT investment. However, a comparative study of the ASEAN-5 countries by Ahmed and Krishnasamy (2012) found a positive and significant contribution of ICT investment to the economic growth of Malaysia and Singapore relative to other ASEAN-5 countries.[7] The contributions of ICT investment to the economic growth of Malaysia and Singapore are attributed to the countries' vigorous endeavours to embrace ICT as a tool for achieving economic growth, by complementing it with the required infrastructure and human capital. This implies that, although several Asian countries have benefited from ICT investment, higher growth has been experienced by countries that invested more in ICT.

It is noted that most of the recent empirical analysis has shifted away from the aggregate-level analysis towards the disaggregate level to examine whether the effects of ICT investment are higher for sectors or industries that invest more in ICT. The significant view emanating from the disaggregate-level studies is that the impact of ICT varies according to the industry, with industries that invested more in ICT (more ICT-intensive industries) exhibiting higher growth than those that invested less (less ICT-intensive industries). In support of this, Stiroh (2002a) indicated that the upsurge in the US's productivity originated in those industries that produced and used ICT most intensively. Another study by Engelbrecht and Xayavong (2006) showed that labour productivity growth was higher for New Zealand's manufacturing industries that are more ICT-intensive industries. While a study by Abri and Mahmoudzadeh (2015) found positive effects on the productivity of all the manufacturing industries in Iran, effects were higher for the high IT-intensive industries. Other industry-level studies also showed that industries that invested more in ICT had higher growth rates than those that invested less (Moshiri, 2016; Niebel, O'Mahony and Saam, 2016; Corrado, Haskel and Jona-Lasinio, 2017).

This study serves to examine the extent to which ICT investment would contribute to the growth of South Africa's agro-processing subsector. The agro-processing subsector is defined, in this study, as a subset of the manufacturing sector that processes raw materials and intermediate products derived from the agricultural sector. The focus of this study is on the agro-processing subsector for both economic and technical reasons.

[7] The ASEAN-5 countries are Singapore, Malaysia, Philippines, Indonesia and Thailand.

Economically, the agro-processing subsector has been earmarked in South Africa's various policy strategies (i.e. the NGP, the NDP, the Nine-Point Plan and the APAP) as a catalyst to create jobs, and spur economic growth and development. The rationale is that the subsector has strong backward linkages with the agricultural sector and strong forward linkages with other economic sectors (IPAP, 2013; NGP, 2010; NDP, 2011; Nine-Point Plan, 2015).[8] Accordingly, the growth of the agro-processing subsector stimulates the demand for agricultural products by creating an output market, thus triggering agricultural production and employment. The subsector also has strong forward linkages through the sale of its products to the wholesale, retail, and business sectors. However, the subsector has been ineffective in driving the required growth and development at the national level.[9] Therefore, this study examines the extent to which the growth performance of the subsector could be strengthened by leveraging on ICT investment.

Technically, focusing on the agro-processing subsector explains the network effects of ICT (i.e. productivity effects from the use of ICT in the non-ICT sectors) (Stiroh 2002a; van Ark, 2014). Following Szewczyk (2009), it is assumed that developments in ICT at the national level would spill over to the industries, depending on their levels of ICT investment (expenditure), such that industries investing highly in ICT would benefit the most. In this regard, an industry's share of ICT investment is used to measure its ability to utilise advancement in ICT at the national level.

In the case of South Africa, various ICT policy frameworks were implemented at the national level after 1994 to ensure that ICTs are actively used to achieve development (Department of Telecommunications and Postal Services (DTPS), 2015). These reforms resulted in a series of initiatives, including the creation of several policy frameworks, the establishment of institutions to govern the ICT Sector and the emergence of various ICTs, and subsequently positioned South Africa's ICT sector as one of the largest in Africa (Gillwald, Moyo and Stork, 2012). In this context, it is imperative to examine the extent to which ICT policies contributed

[8] This is because the agro-processing industries can generate demand for the products of other industries and thus encourage investment and pull along growth in those sectors. In addition, the subsector has favourable feedback effects on primary agriculture by stimulating increased agricultural production through market growth and thus creates employment for the agricultural sector.
[9] This is evident through its negative average output and employment growth from the launch of the NDP to 2017.

to the growth of the agro-processing industries. It is further assumed that higher ICT-led growth would arise in those industries that are investing more in ICT. This assumption is supported by empirical findings, which validated the hypothesis that industries that invest more in ICT have higher growth rates than those that invest less (Kuppusamy *et al.*, 2009; Vu, 2013; Moshiri, 2016). For this reason, agro-processing industries are ranked according to their ICT intensity (i.e. more ICT-intensive industries and less ICT-intensive industries) using the ICT intensity index. The disaggregation of industries is important for this study since the agro-processing subsector comprises various industries, with varying levels of ICT use. Consequently, the effects of ICT on growth performance would vary across industries. By disaggregating industries, this study informs policy on which specific industry or group of industries is likely to benefit most from the exploitation of ICT investment. The next section provides the problem statement and gap in the literature concerning ICT and agro-processing that the study attempts to fill.

1.2 PROBLEM STATEMENT AND KNOWLEDGE GAP

South Africa has experienced severe economic challenges over the last two decades. Such challenges include sluggish economic growth of not more than 2%, an unemployment rate of more than 24% in the last decade, and one of the highest rates of poverty and inequality in the World (Stats SA, 2017a; World Bank, 2018; Stats SA, 2019a; Stats SA, 2019b). The agro-processing subsector has been identified in various policy plans as one of the sectors with the potential to overcome these challenges (IPAP, 2013; NGP, 2010; NDP, 2011; Nine-Point Plan, 2015). However, statistics show that efforts to develop the subsector have been ineffective in driving the required economic growth and development at the national level.

Overall, from 2008 to 2017, this subsector in particular has performed fairly well, as is evident from the positive average output growth (Table 1.1).[10] However, according to the NDP's GDP growth target of 5.4%, the subsector has been underperforming as indicated by the negative average output growth since the launch of the NDP in 2011 to 2017. Over the same period, the economy achieved an average GDP growth of 1.0%.

[10] The average growth rates were calculated in line with the era in which each policy plan was launched to examine the extent to which the subsector contributed to growth. The era is limited to current policy plans and excludes previous policy plans. The period covers that from 2008 (i.e. when the current policies were first launched) to 2017. The period ends in 2017 due to the non-availability of data.

Table 1.1: Average output/GDP growth for each policy era

		Total agro-processing	**Total Manufacturing**	**Total Economy**
Policy	**Era**	Average Output (%)	Average GDP (%)	Average GDP (%)
IPAP	2008-present	0.1	0.4	1.8
NGP	2010-present	0.24	1.6	2.0
NDP	2011-present	-0.1	1.0	1.8
APAP	2014-present	-0.3	0.1	1.2
Nine-Point Plan	2015-present	-0.6	0.1	1.0
Total policy era	**2008-present**	**0.1**	**0.4**	**1.8**

Source: Author based on Quantec (2018a) and Stats SA (2019c)

In brief, although the agro-processing subsector has been identified as one of the sectors with the potential to stimulate GDP growth, it has been unsuccessful in driving the required growth. Hence, this study examines the extent to which investment in ICT could contribute to the growth of South Africa's agro-processing subsector. From the available empirical studies, it is notable that studies on the impact of ICT on the South African economy did not explore its impact on the growth of the agro-processing subsector (Fredderke and Bogetic, 2009; Salahuddin and Gow, 2016; Khan, Lilenstein, Oosthuizen and Rooney, 2017). In particular, there are three gaps in the literature concerning ICT investment and agro-processing that this study attempts to fill.

Firstly, there is no available information base on the ICT intensity of the agro-processing industries. The most conclusive point derived from the disaggregated studies is that the impact of ICT varies according to the intensity of usage, such that the more ICT-intensive industries exhibit higher growth compared to the less ICT-intensive industries (Stiroh, 2002a; Abri and Mahmoudzadeh, 2015; Moshiri, 2016; Niebel *et al.*, 2016; Corrado *et al.*, 2017). However, there is no information base on which of the agro-processing industries are more or less ICT-intensive.

Although several studies used various indexes to rank industries into more and less ICT-intensive (Stiroh, 2002a; van Ark *et al.*, 2002; Engelbrecht and Xayavong, 2006; Abri and Mahmoudzadeh, 2015; Niebel *et al.*, 2016), these studies did not explicitly focus on agro-processing industries due to the scope of their analyses. For instance, the study by Niebel *et al.*

(2016) did not provide knowledge about which of the agro-processing industries were more ICT-intensive and which were not. This is because the agro-processing industries were embedded in the manufacturing sector group.

Although earlier studies included agro-processing industries in the analyses, it is notable that not all industries were included in the analyses and that some of the industries were bundled together (Stiroh, 2002a; van Ark *et al.*, 2002; Engelbrecht and Xayavong, 2006; Abri and Mahmoudzadeh, 2015). For example, the food, beverages and tobacco industries were bundled as a single industry group. Consequently, these studies were inconclusive; regarding which parts of this industry group could be ranked as more or less ICT-intensive. As such, questions remain in the literature regarding which of the agro-processing industries are more or less ICT-intensive.

Secondly, there is no empirical evidence on how long it would take for ICT to yield a positive significant effect on the growth of the agro-processing industries. Whereas previous studies examined the effects of ICT on the disaggregated industries, it is notable that the studies did not explicitly focus on agro-processing industries with the exception of the study by Kuppusamy *et al.* (2009). The latter study showed the insignificant effect of ICT investment on the GDP growth of the agricultural sector, suggesting that the agriculture sector is yet to gain from ICT technological investments. The limitation of that study was that it negated the notion that economic performance gains from ICT investment manifest only after a certain time (Becchetti, Bedoya and Paganetto, 2003). This shortcoming is attributed to the use of econometric approaches that do not account for the future potential effects of ICT.

Accounting for the future effects of ICT is imperative as the impact of ICT on the economy follows a Schumpeterian trend, which begins with a negative or zero impact followed by acceleration and then dying out (Moshiri, 2016). The reason for this trend is that the ICT investments might be counter-productive at the start due to training of labour, redesigning of job practices, and realignment of work structures and scope; hence, returns are only notable over a long period (Lee *et al.*, 2005). However, previous studies did not explore how long it would take for ICT to yield a positive and significant impact on the agro-processing industries.

Thirdly, there is a lack of empirical evidence on which of the agro-processing industries would exhibit higher growth in productivity and output due to ICT investment. The agro-processing subsector is composed of various industries with varying levels of ICT investment. For this reason, the contribution of ICT to the growth of the industries would vary in accordance with the intensity of ICT investment. This assertion is validated by empirical studies, which found that the more ICT-intensive industries exhibited higher growth compared to the less ICT-intensive industries (Stiroh, 2002a; Abri and Mahmoudzadeh, 2015; Moshiri, 2016; Niebel *et al.*, 2016; Corrado *et al.*, 2017). However, to date, there is no empirical evidence on which of the agro-processing industries would exhibit higher growth as a result of ICT investment (i.e. ICT-led growth).

This study, therefore, contributes to knowledge in the following ways. The ICT intensity index was used to calculate the ICT intensity of 10 agro-processing industries.[11] The results from the index were used to disaggregate the industries into more ICT-intensive and less ICT-intensive industry groups. By so doing, this study provides an information base on which of the agro-processing industries are more ICT-intensive and which ones are less ICT-intensive. Thereafter, the annual growth rates of labour productivity, output and employment were calculated.

Ultimately, econometric techniques, which account for the future effects of ICT, were applied to estimate and forecast the effects of ICT on growth. By so doing, this study provides knowledge on how long it would take for ICT to yield a positive and significant impact on the agro-processing industries. The analyses were performed on more ICT-intensive and less ICT-intensive industry groups as well as on the individual industries embedded in the industry groups. By so doing, this study provides an insight into which of the industry groups and individual industries would exhibit higher growth through ICT investment.

[11] The 10 agro-processing industries are food, beverages, tobacco, textile, wearing apparel, wood, leather, paper, rubber and furniture. The details on these industries are provided in section 2.2 of chapter two.

1.3 AIM AND OBJECTIVES

The aim of the study was to examine the contribution of ICT investment to the growth of the agro-processing industries. The specific objectives were to:

(i) Examine whether ICT policies contributed to the labour productivity growth of agro-processing industries;
(ii) Estimate short-run and long-run effects of ICT intensity on the growth of labour productivity, output and employment;
(iii) Examine the causal relationship between ICT intensity and the growth of labour productivity, output and employment; and
(iv) Forecast the potential effects of ICT intensity on the growth of labour productivity, output and employment.

1.4 HYPOTHESES

The following hypotheses were formulated for this study.

(i) ICT policies contribute to the labour productivity growth of the agro-processing industries.

The implementation of ICT policies that create conditions for ICT investment and promote both the production and use of ICT is associated with improving labour productivity growth. This hypothesis is supported by empirical studies, which have shown that ICT contributed to labour productivity growth in other countries (Lee *et al.*, 2005; Vu, 2013). From this perspective, South Africa has implemented various ICT policy frameworks post-1994. At the same time, Rankin (2016) found that the labour productivity of manufacturing industries grew post-1994. Given this, it is imperative to test whether the South African ICT policies have contributed to the labour productivity growth of the agro-processing industries.

(ii) ICT intensity has positive and significant short-run and long-run effects on the growth of labour productivity, output and employment of the more ICT-intensive industries, and vice versa for the less ICT-intensive industries.

There is a general acknowledgement from industry-level studies that the effect of ICT is associated with its intensity in industries, with the result that higher ICT-led growth is experienced by industries that use ICT more intensively. In support of this view, Engelbrecht and Xayavong (2006) observed that the labour productivity growth of the more ICT-intensive industries accelerated (increased over time) relative to that of the less ICT-intensive industries. Equally important, Niebel *et al.* (2016) found that the contribution of ICT intangible assets to labour productivity was significantly higher for the more ICT-intensive industries. Moshiri (2016) also established that industries that are more ICT-intensive benefited from ICT investment much more, in terms of GDP growth, than the less-ICT-intensive industries. The most conclusive point derived from these studies is that ICT investment (intensity) has a positive and significant effect for industries that are more ICT-intensive relative to the less ICT-intensive industries. In line with this reasoning, it is hypothesised that ICT intensity has positive and significant effects on the growth of the more ICT-intensive industries and vice versa in the case of the less ICT-intensive industries.

(iii) There is a causal relationship between ICT intensity and the growth of labour productivity, output and employment of the more ICT-intensive industries, and vice versa for the less ICT-intensive industries.

Industry-level studies identified a causal relationship between ICT and productivity for industries with higher levels of ICT investment. For example, Hu and Quan (2005) found that a unidirectional relationship (one-way causality from productivity to ICT) exists between ICT investment in the case of information-intensive industries. Similarly, Vu (2013) found a strong positive correlation between ICT investment and labour productivity growth for sectors with higher ICT intensity. In the same vein, Kuppusamy *et al.* (2009) found that GDP growth is driven by those sectors investing highly in ICT. Other studies found a positive correlation between ICT and employment (Etro, 2009; Crandall and Singer, 2010; Kolko, 2012; Jayakar and Park, 2013; Atasoy, 2013; Pantea, Biagi and Sabadash, 2014; Khan *et al.*, 2017). Overall, these studies revealed that a causal relationship between ICT and growth exists for the more ICT-intensive industries. Consequently, it is hypothesized that there is a causal relationship between ICT intensity and the growth of labour productivity, output and employment of the more ICT-intensive industries and the opposite in the case of less ICT-intensive industries.

(iv) ICT intensity would contribute more to the growth of labour productivity, output and employment of the more ICT-intensive industries relative to the less ICT-intensive industries.

According to Becchetti *et al.* (2003), the economic performance gains from ICT investment manifest only after a certain time. Therefore, it is expected that ICT investment would contribute to labour productivity growth, output and employment of both the more and less ICT-intensive industries. However, empirical studies that have positive and significant effects for both the more and less ICT-intensive industries have found that higher growth was realised by the industries that are more ICT-intensive (Engelbrecht and Xayavong, 2006; Niebel *et al.*, 2016). On this account, it was hypothesised that ICT intensity would contribute more to the growth of labour productivity, output and employment of the more ICT-intensive industries relative to the less ICT-intensive industries.

Four hypotheses were formulated from the four objectives of the study to define the relationship between ICT intensity and the three growth variables (i.e. labour productivity, output and employment). Accordingly, four different analytical techniques were used in achieving the four objectives of the study. The findings from the analytical techniques were used to ascertain whether the findings were in line with the stated hypotheses. Since the focus of this study is on examining the contribution of ICT investment to the growth of the agro-processing industries, the following section provides the theoretical basis for focusing on labour productivity, output and employment.

1.5 THEORETICAL FRAMEWORK

The theoretical nexus between ICT, labour productivity, output and employment is presented in this section. Theoretically, ICT can stimulate the economy through its effects on key macro-economic variables such as productivity, GDP, employment, trade, and investment. This makes it difficult to unbundle one specific effect from others. In this study, the focus is on three variables – productivity, output and employment. Therefore, the theoretical nexus between ICT and these variables is discussed in this section.

Productivity refers to the efficient use of inputs, such as labour, land, capital, energy and information, in the production of goods and services. In this context, higher productivity is achievable through the production of a greater quantity of output, using the same amount of resources (Sriyani Dias, 1991). Therefore, productivity is correlated with output in that higher productivity means greater output. For this reason, productivity is considered to be a key determinant of output/economic growth (Schwab, 2016; OECD, 2019).

ICT is interposed in the productivity–output–employment nexus in that it increases productivity by improving efficiency. An increase in labour productivity implies that higher output is attained with the same labour input, which reduces the demand for the labour input, resulting in a decline in employment growth. At the same time, the higher output can be achieved by hiring more labour input, resulting in an increase in employment. Therefore, it is necessary to explore empirically the nexus between ICT and productivity, output and employment.

Empirically, ICT contributes to both productivity and economic growth/output through three channels. Firstly, it enhances the multifactor productivity (MFP) of the ICT-producing sector. Secondly, it contributes to capital deepening through productivity gains derived from the utilisation of ICT as a capital input in the other sectors (other sectors besides the ICT sector). Thirdly, greater utilisation of ICT throughout the economy contributes to total factor productivity (TFP) (van Ark, 2002; Piatkowski, 2004; Farooquie *et al.*, 2012; Mefteh and Benhassen, 2015). In this regard, ICT is used throughout the sectors of the economy, such that its spillover productivity gains will drive economic growth. Consequently, an industry investing highly in ICT would have higher TFP and output growth, which is an indication of a more efficient organisation of production (Kijek and Kijek, 2018). This affects employment, hence both pessimistic and optimistic views have emerged concerning the effects that ICT will have on employment. According to Schwab (2016), this is because technology exhibits two competing effects, which are the destruction and capitalisation effects.

The destruction effect occurs because the use of ICT enhances labour productivity, allowing the production of more output with less labour, resulting in jobless growth (OECD, 2016). Thus, there is a negative relation between productivity and output, and employment in that, as productivity and output rise, *ceteris paribus*, employment declines. Specifically, as labour productivity increases, higher output is attained with the same labour input, implying that the labour input is more productive (Schwab, 2016). This reduces the demand for labour, resulting in a decline in employment rates, *ceteris paribus*.[12]

The destruction effect is followed by the capitalisation effect whereby the demand for goods and services increases, leading to the generation of new occupants, and a bundle of new industries (Schwab, 2016). For instance, an increase in labour productivity could have a positive effect on employment growth through its contribution to higher output (Alexander 1993; Wakeford, 2004, cited by Tsoku and Matarise, 2014). This implies that higher output is achieved through the hiring of more labour input, giving rise to an increase in employment, *ceteris paribus*. This contention is affirmed by empirical studies that found a positive correlation between ICT and employment (Etro, 2009; Kolko, 2012; Atasoy, 2013; Pantea *et al.*, 2014; Khan *et al.*, 2017).[13]

The theoretical analysis of the nexus between ICT and productivity, output and employment calls for trend analysis of these variables concerning South Africa's agro-processing subsector. To achieve this, the annual growth rates of labour productivity, output, and employment for the period from 1994 to 2017 were calculated. The findings are presented in Table 1.2.

Table 1.2: Annual average growth rates, 1994-2017

Labour productivity (%)	Output (%)	Employment (%)
2.67	2.21	-0.79

Source: Author's calculations based on Quantec (2018a)

[12] This means that the labour force has to reallocate their skills elsewhere (Schwab, 2016). However, it should be noted that, as the labour force becomes productive, firms or industries tend to hire less productive labourers due to the higher wages associated with the more productive workers (Rankin, 2016). This leads to a trade-off between employment and productivity because, as employment increases due to an increase in the use of lower productivity workers, average productivity falls (Boulhol and Turner, 2009, in Junankar, 2013).

[13] It should be noted that other studies found no significant effect of ICT (De Stefano *et al*., 2014). Others found that the effect of ICT on employment varies according to the skill intensity (Falk and Biagi, 2017) and the type of ICT (Atasoy *et al*., 2016).

In short, both labour productivity and output increased by 2.67% and 2.21%, respectively. At the same time, employment growth declined by 0.79%. These statistics suggest a trade-off between productivity and output, and employment.

Given the above findings, two areas require investigation. The first area entails examining whether ICT investment contributed to the growth of labour productivity and output and the decline in employment growth. The second area relates to testing whether there is a causal relationship between ICT and labour productivity, output and employment. The rationale is to account for the causal relationship among these variables. By so doing, this study provides information on whether ICT is the source of productivity/output growth and the decline in employment growth. Overall, the theoretical framework signals that there exists a relationship between ICT and labour productivity, output and employment. In the meantime, the annual growth rates denote that both labour productivity and output increased, while employment declined. Hence, the need for this study to establish whether the ICT–productivity–output–employment nexus holds for the agro-processing industries, as suggested by the theoretical framework. The conceptual framework of the study is discussed in the next section.

1.6 CONCEPTUAL FRAMEWORK

The conceptual framework has been developed to present the fundamental issues under study, highlight key assumptions, and guide readers on the direction of the study. Figure 1.1 provides a schematic representation of the conceptual framework. The framework is composed of three domains: input, process and output. Entrenched in these domains are the ICT realm, the agro-processing and the outcomes domains. The ICT realm is housed in the input domain. The agro-processing realm is entrenched in the process domain, while the outcome domain is embedded in the output domain. The ICT realm is the environment under which ICT industries operate and determines the production of ICT goods and services. The agro-processing realm is the environment in which agro-processing industries operate and defines the uses of ICT goods and services. The process domain defines the interaction between the two realms – the ICT and agro-processing realms. The output domain describes the outcomes of the interaction between the two realms.

(i) The input domain

The input domain houses the ICT realm, which is defined, in this study, as the supply-side of ICT. Included in the ICT realm is the ICT-producing sector, which is responsible for the production of ICT goods and services. The ICT-producing sector is split into ICT manufacturing industries and ICT services industries. Collectively, these industries are responsible for the production and supply of ICT goods and services to other sectors of the economy. Other drivers or factors exert influence on the production and supply of ICT goods and services by the ICT manufacturing and ICT services industries. These factors include, among others, the existing policies for the regulation of the ICT sector and ensuring access to and use of ICT throughout the economy.

(ii) The process domain

The process domain houses the agro-processing realm and defines the interaction between the ICT and agro-processing realms. Included in the agro-processing realm are the 10 agro-processing industries, which are the users of ICT goods and services. The intermediate ICT inputs enter the process domain through the demand for ICTs by the agro-processing industries. Thereafter, ICT goods and services are used as intermediate inputs by the non-ICT industries, that is, agro-processing industries. For this study, the use of ICT is explained in terms of its role in the agro-processing chain.

Thus, ICT is viewed as having various roles in the production, processing, distribution and consumption of agro-processing activities, with a large number of ICTs utilised within each stage. The outcomes associated with these processes include, among others, greater level of coordination and information exchange, increased market access, reduced transportation and communication costs, effective logistics and supply chains, and reduced costs of trade. These results are expected to drive the contribution of the agro-processing industries to the economy through changes, which are explained, by the output domain.

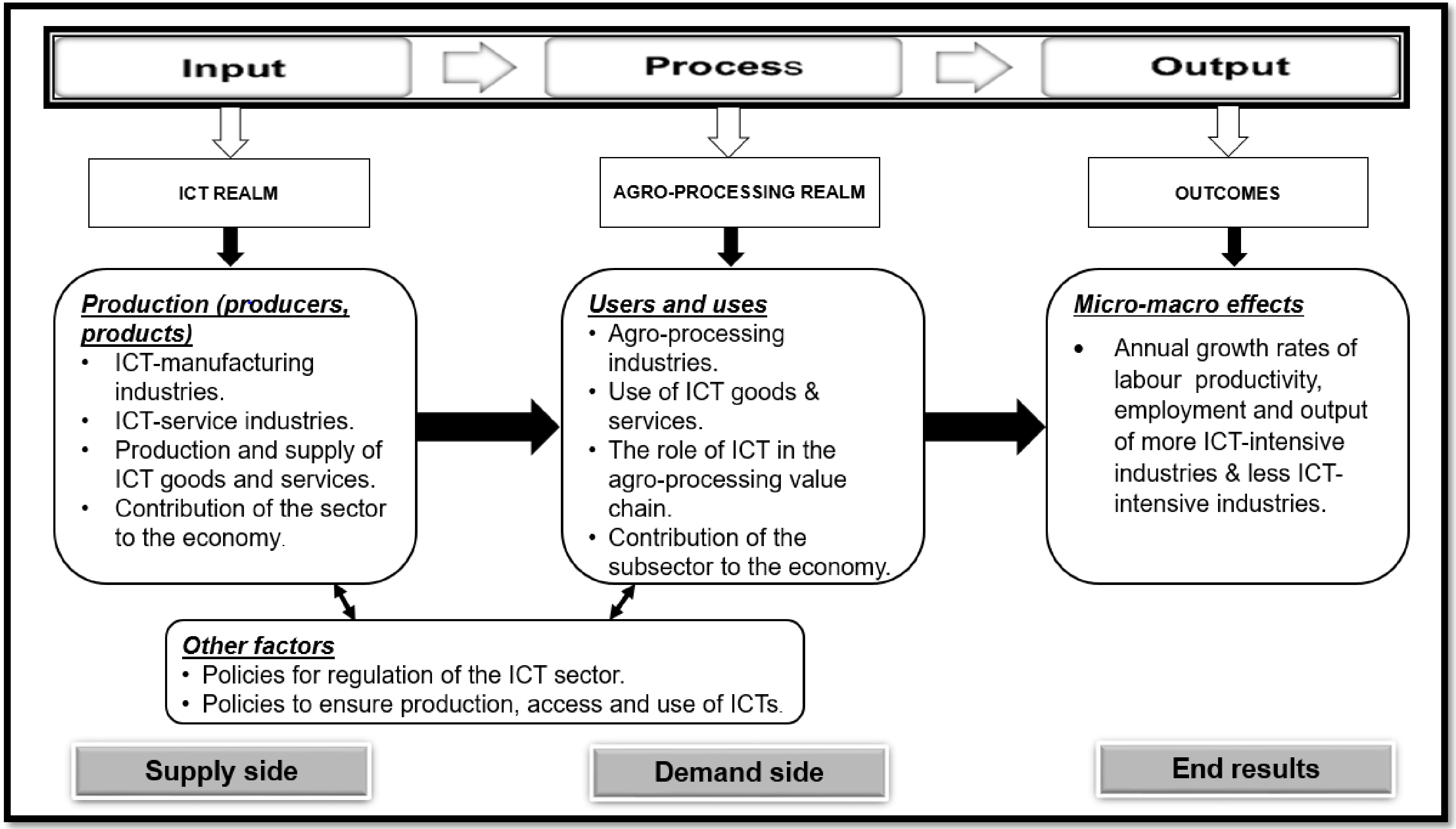

Figure 1:1 Conceptual framework of the study

(iii) Output domain

The output domain is defined as the results of the interaction between the ICT and agro-processing realms. The results are explained in terms of the outcomes of the interaction between the supply and demand for ICT. Most precisely, these interactions are defined in terms of the role of ICT in the agro-processing value chain, resulting in macro-economic effects in the form of labour productivity, output and employment. To capture these effects, the agro-processing industries were ranked into more ICT-intensive and less ICT-intensive industries.

The rationale for this approach was that the agro-processing subsector comprised of 10 industries, with varying requirements for intermediate ICT inputs, and hence varying levels of ICT investment. In this case, it is assumed that higher ICT-led growth would arise in those industries that are investing more in ICT. Therefore, it is assumed that the effects of ICT on productivity, employment and output vary across industries depending on their levels of ICT investment. To account for the varying effects of ICT investment, the study calculated the ICT intensity of industries, which measures the share of ICT investment across industries. Thereafter, the study calculated the annual growth rates of labour productivity, output and employment of industries. Ultimately, the study examined the effects of ICT intensity on the growth of labour productivity, output and employment. The contribution of the study is presented in the next section.

1.7 CONTRIBUTION OF THE STUDY TO KNOWLEDGE

The study contributes to knowledge by filling three knowledge gaps in the literature in the following sequence. Firstly, there was no information base on the ICT intensity of agro-processing industries. Accordingly, the ICT intensity index was used to calculate the ICT intensity of 10 agro-processing industries. The results from the index were used to disaggregate the industries into more ICT-intensive and less ICT-intensive industry groups. The more ICT-intensive industries are food, beverages, textile, paper and rubber industries. The less ICT-intensive industries are tobacco, wearing apparel, wood, leather and furniture industries. Therefore, the study provides an information base on which of the agro-processing industries are more ICT-intensive and which ones are less ICT-intensive. The information base on the ICT intensity of the industries is crucial as it has been established that the impact of ICT investment varies across the industries, and that higher growth would be realised by the more ICT-intensive industries.

Secondly, there is no empirical evidence on how long it would take for ICT to yield a positive and significant impact on the agro-processing industries. Accounting for this is crucial as it has been reported that the returns on ICT investment take time to materialise. Therefore, the annual growth rates of labour productivity, output and employment were calculated. The PMG estimations were applied to estimate short-and long-run effects of ICT intensity on the growth of labour productivity, output and employment. IRF and VDC analyses were conducted to account for the future effects of ICT intensity on the growth of labour productivity, output and employment. The findings from the PMG estimations and IRF and VDC analyses showed that ICT investment would yield a positive and significant impact on the agro-processing industries in the long run. Therefore, this study contributes to knowledge by answering the question of how long it would take for ICT to yield a positive and significant impact on the agro-processing industries.

Thirdly, there has been a lack of empirical evidence on which of the agro-processing industries would exhibit higher growth as a result of ICT investment. Accordingly, the analyses were performed on the more ICT-intensive and the less ICT-intensive industry groups as well as on the individual industries embedded in the industry groups. The rationale for doing this was the observation that the impact of ICT investment varied across the industries, such that higher growth would be realised by the more ICT-intensive industries.

The results showed that ICT investment would contribute more to the labour productivity, output and employment of the more ICT-intensive industry group. The results further showed that the contribution of ICT investment to the growth of labour productivity, output and employment would be higher for the more ICT-intensive industry group, an industry group that invested more in ICT. In cases where ICT investment contributed to the growth of both the more ICT-intensive and less ICT-intensive industries, higher growth would be realised by the more ICT-intensive industries. The results further showed that the contribution of ICT investment to the growth of labour productivity, output and employment varied per industry, such that the highest growth would be realised by the food industry, an industry that invested highly in ICT. In contrast, the lowest growth would be realised by the tobacco industry, an industry that invested the least in ICT. Overall, the study contributes to knowledge by establishing which industry group and which industry would realise higher growth through ICT investment. The next section provides an overview of the organisation of the thesis to guide readers on how the thesis is structured.

1.8 ORGANISATION OF THE THESIS

The remainder of the thesis is organised as follows. In chapter two, an overview of South Africa's agro-processing subsector and ICT sector is presented, while in chapter three, the contribution of ICT policies to the labour productivity growth of the agro-processing industries is examined. In chapter four, the effects of ICT intensity on the growth of labour productivity, output and employment are examined, while in chapter five, the relationship between ICT intensity and the growth of labour productivity, output and employment is estimated. In chapter six, the effects of ICT intensity on the growth of labour productivity, output and employment are forecast, while the conclusion, implications and areas for future research are presented in chapter seven.

CHAPTER 2: AN OVERVIEW OF SOUTH AFRICA'S AGRO-PROCESSING SUBSECTOR AND ICT SECTOR

2.1 INTRODUCTION

This chapter provides an insight into South Africa's agro-processing subsector to highlight the boundary between agriculture, agro-processing and the manufacturing sector. This is achieved by defining the agro-processing subsector, identifying agro-processing industries, and highlighting the scope of agro-processing and associated activities. By so doing, the chapter delineates which industries, commodities and activities are part of agro-processing and which ones are not. This is followed by the discussion of the policy plans that have been developed, since the advent of democracy in 1994, to support the growth and development of the agro-processing subsector. The rationale for discussing these policies is to underline that the agro-processing subsector has been earmarked as one of the strategic sectors to achieve, among other things, South Africa's goals of GDP growth, job creation, and poverty and inequality reduction. The discussion of the policy plans ends with an analysis of the extent to which the subsector has contributed to the objectives of the policy plans. The findings serve as a point of reference on whether there is a need for this study to examine the extent to which ICT investment could contribute to the growth of the agro-processing industries.

To highlight the potential of ICT investment, an overview of the ICT sector, which includes the definition and classification of ICT, is provided in this chapter. The aim is to delineate which industries, commodities and activities are part of ICT and which ones are not. Furthermore, reviewing the ICT policies serves the purpose of examining the extent to which the policies have ensured access to and use of ICT across the economy. The evidence from the review serves as a point of reference for discussing why the ICT policies have or have not yet contributed to the labour productivity growth of the agro-processing industries.

Thereafter, the domains of agro-processing and ICT are merged by underlining the role that ICT plays in the agro-processing value chain. The theoretical outcome of those roles includes changes in labour productivity, output and employment. It is, therefore, necessary to provide knowledge on the role of ICT in enhancing the growth performance (labour productivity, output and employment) of other sectors besides the ICT sector (i.e. agro-processing industries).

To address the chapter's above-stated aims, the rest of the chapter is organised into seven distinct sections. The definition, classification and scope of agro-processing are presented in section 2.2. The national growth and development policy plans that have identified the agro-processing subsector as one of the sectors for achieving growth and development goals are discussed in section 2.3. The contribution of the agro-processing subsector to the South African economy, including the extent to which the subsector has achieved some of the growth and development goals, is presented in section 2.4. The definition and classification of ICT are presented in section 2.5. The role of ICT in the agro-processing value chain is highlighted in section 2.6. An overview of South Africa's ICT policies is presented in section 2.7. A summary of this chapter is presented in section 2.8.

2.2 AGRO-PROCESSING: DEFINITION, CLASSIFICATION AND SCOPE

There are three commonly used conventions of defining and classifying agro-processing. The first is with respect to the input requirement. The Food and Agricultural Organisation (FAO) (1997) defines agro-processing as a subset of the manufacturing sector that processes raw materials and intermediate products derived from the agricultural sector. It is, therefore, imperative to define the boundaries between agro-processing industries and other industries, which make up the manufacturing sector given that agro-processing is a subsector of the manufacturing sector. To do so, the UN's International Standard Industrial Classification (ISIC), Revision 4 (United Nations Department of Economic and Social Affairs (UN DESA), 2008), is used to identify and separate agro-processing industries from the rest of the manufacturing industries. The detailed classification of manufacturing industries is appended in Table A.1.

Based on the ISIC (Rev.4), the key distinction between agro-processing and the rest of the manufacturing industries is that agro-processing industries are agro-based, while the rest of the manufacturing industries are not. The rest of the manufacturing industries includes mineral-based industries, information and communication-based industries, machinery and equipment based industries, metal-based industries, energy-based industries and chemical-based industries. Agro-based industries are defined as those industries that utilise products from agriculture, forestry and fisheries as their raw materials. Examples of agro-processing industries are food, beverages, tobacco, textile, wearing apparel, leather, wood, paper, rubber, plastic and furniture. Therefore, agro-processing implies the manufacturing of products originating from agriculture, forestry and fisheries. On this account, it is imperative to differentiate between activities and/or products that constitute agro-processing and those which form part of primary agriculture. The ISIC (Rev.4) is also used to delineate the boundary between primary agriculture and agro-processing. Figure A.1 demonstrates the boundary between primary agriculture and agro-processing. Based on ISIC (Rev.4), the agro-processing activities are extracted from the manufacturing activities and broken down into 10 industries, which are as follows:

(1) Food,
(2) Beverages,
(3) Tobacco,
(4) Textile,
(5) Wearing apparel,
(6) Leather and related products,
(7) Wood and wood products,
(8) Paper and paper products,
(9) Rubber products, and
(10) Furniture.

The detailed classification of agro-processing industries, as per ISIC (Rev.4), is illustrated in Table A.2. The second way of classifying agro-processing is in terms of its key characteristic, precisely, its high degree of interdependency with other sectors through upward and downward linkages. Backward linkage activities entail the initial processing of raw agricultural products. Examples include, amongst others, the manufacture of beverages from fruits and food products from grains. By contrast, forward linkage activities entail the additional processing of intermediate products in which value is added to final goods (Department of Agriculture Forestry and Fisheries (DAFF), 2013). Illustrations include, amongst others, the manufacture of furniture from wood products. The food and beverages industries are said to have a strong backward linkage with primary agriculture as they acquire their primary inputs from primary agriculture. Other industries such as furniture, textile and leather are said to have a strong forward linkage with secondary sectors, as they are involved in further processing of agricultural products (DAFF, 2013).

When defining agro-processing, it is necessary to distinguish between processing and value addition since the two terms are often used interchangeably. Processing involves transforming the original form of a product, whereas value addition means the addition of value to a product, resulting in an increase in the value of the product through higher prices in the marketplace. Value-added products are often changed from the raw state through processing; however, the value can be added without transforming or altering the form of the products. Labelling and grading, for instance, add value to products but do not require the transformation of the products. From this perspective, agro-processing includes transforming the original form of a product, incorporating all those activities such as grading and labelling that add value to products without transforming or altering the form of the products (DAFF, 2015).

The third way of classifying agro-processing is with respect to the phases of agro-processing activities: upstream/primary, secondary and downstream/advanced agro-processing. The phases of agro-processing and sequence thereof are shown in Figure A.2. Upstream processing refers to the initial transformation of agricultural products. Primary agro-processing activities are usually carried out at the farm level and involve an initial transformation of products into a slightly different form before storage and further processing. Because of this, primary agro-processing is also referred to as upstream agro-processing.

Secondary agro-processing activities are commonly carried out by medium to large corporates and involve intermediate processing of products into a considerably different form before final processing by, mostly, large multinational corporates. Downstream processing, in contrast, involves additional processing on intermediate products (FAO, 1997), to which extra value is added to produce final goods, which are then marketed via retail and whole chains and various fast-food franchises, restaurants, pubs and shebeens (DAFF, 2013). For this reason, advanced agro-processing is also known as downstream agro-processing.

In brief, the ISIC classification is adopted in this study for three reasons. Firstly, the definition is in line with that used by the South African Government. Secondly, the definition delineates which industries, commodities and activities are part of agro-processing and which ones are not. Thirdly, the definition allows for the collection and reporting of economic activities for economic analysis, policy-making and decision-making. Given that the agro-processing industries have been identified in the policy plans to drive growth and development, it is vital to provide a bird's eye view of those policies. The rationale for doing this is to provide an information base for examining the extent to which the subsector has contributed to the objectives of the policy plans. The policy plans cover macro-economic policy plans and sectoral/industrial policies.

2.3 MACRO-ECONOMIC AND SECTORAL/INDUSTRIAL POLICY PLANS

This subsection aims to provide a synopsis of the policies implemented in South Africa to support the growth and development of the agro-processing subsector. The purpose is to justify the focus on the agro-processing subsector. As stated earlier, the rationale for discussing these policies is to underline that the agro-processing subsector has been earmarked as one of the strategic sectors to achieve, among others, South Africa's goals of GDP growth, job creation, and poverty and inequality reduction. Special attention is given to policies developed post-democracy, from 1994 to 2017.

Furthermore, emphasis is given to the policies at the national level rather than other spheres of government. The rationale is that the growth and development strategies at the provincial and local levels have been developed and implemented based on the national frameworks and strategies (Small Enterprise Development Agency (SEDA), 2012). Although the focus is on national growth and development policies related to agro-processing, the subsection starts with a discussion of earlier policies to highlight historical chronology and changes in the government's priority areas.

It should be noted that, while the drawbacks of some of the preceding policies are highlighted to underscore why they were discarded as and when new ones were implemented, the purpose of the section is not to measure the performance of those policies. The analysis of performance is covered in Section 2.4 (in relation to the agro-processing subsector) – measuring the extent to which the subsector, in totality, and individual agro-processing industries, in particular, contributed to growth and employment during each policy era and across the entire policy era. The policies are grouped into two parts: macro-economic policies and sectoral/industrial policies. Figure A.3 provides a historical chronology of both the macro-economic policies and the sectoral/industrial policies.[14] These policies are discussed below to underline that the agro-processing subsector has been identified in macro-economic policies as one of the strategic sectors to achieve the macro-economic policy objectives.

(a) Macro-economic policies

The notable macro-economic policy plans that have been implemented following the inception of democracy in 1994 are the Reconstruction and Development Programme (RDP), the Growth, Employment and Redistribution (GEAR) strategy, the Accelerated and Shared Growth Initiative for South Africa (AsgiSA), the New Growth Path (NGP) and the National Development Plan (NDP). These policies are discussed below to underscore the recognition that agro-processing is one of the priority sectors for achieving South Africa's growth and development.

(i) The reconstruction and development programme (RDP)

The implementation of the macro-economic policies post-1994 started with the implementation of the RDP. The aim of the RDP was to redress the inherently gross inequalities in access to basic services, establish a more equal society and strengthen democracy for all South Africans (RDP, 1994).[15] The key point to be noted is that the RDP did not pay special attention to the agro-processing subsector but to reversing historical inequalities in access to basic services. As a result, the programme’s priorities included primary agriculture, land reform, water and sanitation, housing, energy and electrification, transport and health care.

[14] The macro-economic policies are in the bold and underlined text, while the sectoral/industrial policies are in underlined text. The specific support programmes, which are discussed after the sectoral/industrial policies, are in italicised text.

[15] The five key priority areas as identified in the RDP (1994) are: “(1) Create a strong, dynamic and balanced economy; (2) Develop human resource capacity; (3) Ensure that no one suffers racial or gender discrimination; (4) Develop a balanced regional economy in Southern Africa; and (5) Democratise the state and society.”

(ii) Growth, employment and redistribution (GEAR) strategy

Although the RDP was regarded as the cornerstone for nation building, it was unsuccessful with respect to one of its priority areas of creating a strong, dynamic and balanced economy.[16] Given this, the GEAR strategy was implemented in 1996. The GEAR was an extension of the RDP in that it contained most of the social objectives of the RDP but differed from the RDP in that it had specific targets to be achieved between 1996 and 2000. This included an average GDP growth rate of 4.2%, average inflation rate of 8.2%, average real export growth rate (manufacturing) of 10.8% and an average of 270 000 new jobs (Department of Finance, 2006). It should be noted that it was through the GEAR strategy that the manufacturing sector was identified as one of the priority sectors to achieve growth and employment.

(iii) Accelerated and Shared Growth Initiative for South Africa (AsgiSA)

While the GEAR has been and continues to be credited for achieving its targets including that of a GDP growth rate of 4.2% in 2000, the levels of unemployment and poverty skyrocketed under GEAR. Consequently, the AsgiSA was implemented in 2006 and focused on "shared growth", primarily to address the pertinent issue of how to grow the economy while reducing unemployment (to below 15% by 2014) and poverty levels.[17] Notably, the AsgiSA identified specific agro-processing industries as some of the priority industries for achieving growth and development.[18]

(iv) National Growth Path (NGP)

The NGP was launched in 2010 and replaced AsgiSA when it was realised that the recovery of economic growth from 1994 to 2008 was accompanied by high levels of unemployment, poverty and inequality. The NGP aimed to stimulate growth, create five million jobs, and reduce the unemployment rate to 15% by 2020. The NGP departed from the preceding policies in that it aimed to stimulate growth and reduce unemployment, poverty and inequality by

[16] This is credited, among other things, to fiscal constraint as a result of the poor fiscal and economic legacy inherited from years of apartheid.
[17] This phenomenon is known as jobless growth; the term is used to characterise the state in which economic growth is coupled with a high unemployment rate. It is on this account that the GEAR received strong criticism and opposition from civil society organisations, including the organised labour union, the Congress of South African Trade Unions (COSATU).
[18] These industries are clothing and textiles and wood and pulp industries. Other sectors/industries of priority included chemicals, metals beneficiation, including the capital goods sector and creative industries (crafts, film and television (TV), content and music).

creating a more labour-absorbing growth path (the Department of Trade Industry and Competition (the dtic), 2011). Akin to the AsgiSA, the NGP identified the agro-processing industries as priority drivers for growth and employment creation. To this end, the policy stipulated that, of the five million planned jobs by 2020, the agro-processing sector was expected to create 145 000 jobs. The NGP is implemented concurrently with the NDP, the country's vision for 2030.

(v) National Development Plan (NDP)

The NDP was introduced in 2011 to achieve GDP growth of at least 5.4% each year until 2030 (from 3% in 2010) and to reduce unemployment, poverty and inequality.[19] Both the NGP and the NDP are implemented concurrently. The NGP is a medium-term measure – the government's strategy in pursuit of the NDP – and the NDP a long-term measure – the country's vision for 2020 (Nkwinti, 2019). The NGP adopted employment creation as its top priority, with targets set per growth sector (for instance, 145 000 for agro-processing) and implemented tangible actions to drive a more labour-absorbing growth pattern in the selected sectors (Hendricks, 2013). The NDP, in contrast, aims to accelerate growth in order to reduce the number of households living below the poverty line to zero by 2030 and reduce income inequality from 0.7 (in 2010) to 0.6 in 2030. However, as with the NGP, agro-processing industries are among those identified by the NDP as having the potential to achieve growth, reduce unemployment, poverty rates and inequality (National Planning Commission, 2011; National Planning Commission, 2012).

The above discussion of macro-economic policies illustrates two key issues relevant to the study. Firstly, the GEAR was the first macro-economic policy to identify the manufacturing sector, a sector within which the agro-processing subsector is located, as one of the sectors with the potential to achieve its objectives. Secondly, the subsequent macro-economic policies, namely, AsgiSA, NGP and NDP, specifically identified the agro-processing industries as key industries with the potential to achieve their objectives.

[19] Specifically, the NDP aims to increase employment from 13 million (in 2010) to 24 million by 2030, and reduce poverty to zero and inequality from 0.7 (in 2010) to 0.6 in 2030 (National Planning Commission, 2011).

In the light of the aforementioned, it is imperative to focus on the agro-processing subsector. This study specifically focuses on the extent to which investment in ICT could contribute to growth. Thus, it is important to examine the extent to which investment in ICT could contribute to the growth of the agro-processing subsector as a sector identified in macro-economic policies with the capacity to achieve growth. The next section discusses the sectoral/industrial policies. The purpose of the section is to underline the fact that the agro-processing industries have been identified in sectoral/industrial policies as some of the industries to achieve sectoral/industrial policy objectives.

(b) Sectoral/industrial policies

The notable sectoral/industrial policy plans that have been implemented following democracy in 1994 are the National Industrial Policy Framework (NIPF), the Industrial Policy Action Plan (IPAP), the Nine-Point Plan (9-Point Plan), the Agricultural Policy Action Plan (APAP) and the Strategy for the development of small and medium agro-processing enterprises. It is important to note that most of the sectoral/industrial policy plans were developed as the implementation plans for the macro-economic policies. Therefore, the discussion of the sectoral/industrial policy plans also covers their relation to the macro-economic policies as highlighted in the subsequent sections.

(i) National Industrial Policy Framework (NIPF)

The NIPF, which builds on the AsgiSA in that it sought to achieve similar goals as the AsgiSA, was launched in 2007 to support industrialisation and industrial growth, especially within the manufacturing sector (the dtic, 2007).[20] As with the AsgiSA, the NIPF identified specific agro-processing industries as industries with the potential to achieve growth and development.[21]

[20] These goals include increasing GDP growth to more than 6% in 2010 and halving unemployment and poverty by 2014 (the dtic, 2007).

[21] There are four (4) groups of labour-absorbing manufacturing industries that constitute the central focus for the implementation of the NIPF. These industries are (1) Capital/transport equipment and metals; (2) Automotive assembly and components; (3) Chemicals, plastic fabrication and pharmaceuticals; and (4) Forestry, pulp and paper, and furniture (the dtic, 2007).

(ii) Industrial Policy Action Plan (IPAP)

The IPAP was developed in 2008 as the implementation plan for the NIPF to address cross-cutting and sector-specific constraints (and optimise opportunities) to put South Africa on a stronger growth path (Tsedu, 2015). The IPAP was built on previous policy plans, namely the AsgiSA and NIPF, as it mentioned the need to support specific agro-processing industries because of their labour-intensive nature, which was critical to retaining jobs.[22] While some policy plans were replaced when new ones came into effect, this did not apply to the IPAP as it is implemented concurrently with other plans, namely the NGP and NDP.

(iii) Nine Point Plan (9-Point Plan)

The 9-Point Plan was launched in 2015 to grow the economy and generate jobs once it became evident that, although the NDP aimed to achieve a GDP of 5.4% each year until 2030 in order to reduce unemployment, poverty and inequality, the economy had failed to achieve growth of more than 3.5% between 2011 and 2014. The plan consisted of nine actions to be undertaken to grow the economy and generate jobs, including the revitalisation of agriculture and the agro-processing value chain (South African Government, 2019).[23]

(iv) Agricultural Policy Action Plan

The APAP was implemented in 2015 as the strategy through which to revive agriculture and agro-processing value chains as outlined in the 9-Point Plan. Further to this, it was implemented in line with the NDP vision 2030's call for the implementation of sector-specific policies, programmes and plans to achieve specific outcomes.[24] The APAP departed from previously discussed policies in that it was value chain-based and focused on priority commodities with high-labour absorption capacity and high-growth potential for attaining the goals of the NGP, NDP and IPAP. The APAP identified nine strategic value chains (priority commodities) with the potential to attain these objectives.[25]

[22] These industries are pulp and paper, furniture, textiles, leather, clothing and footwear.
[23] The comprehensive plan is available at https://www.gov.za/issues/nine-point-plan.
[24] The outcomes include, among others, "Outcome 4: Decent Employment through Inclusive Economic Growth and Outcome 7: Comprehensive Rural Development and Food Security".
[25] These commodities are: (i) poultry/soya beans/maize integrated value chain; (ii) red meat value chain; (iii) wheat value chain; (iv) fruit and vegetables; (v) wine industry; (vi) sugar value chain; (vii) biofuels value chain; (viii) forestry; and (ix) small-scale fisheries.

(v) Strategy for the development of small and medium agro-processing enterprises

The strategy for the development of small and medium enterprises (SMEs) in agro-processing was developed in 2015 as a response to the NDP's recognition of the SME sector as a driving force for achieving its objectives of growing the economy and creating employment (SBP Alert, 2014). The strategy aimed to provide strategic direction and specific support measures to agro-processing SMEs. The strategy was developed in alignment with the NDP, IPAP and APAP and identified interventions to support and develop SMEs in the agro-processing subsector (DAFF, 2015).[26]

It is necessary to underscore that sectoral/industrial policies, namely, the IPAP, the Nine-Point Plan, the APAP and the strategy for the development of agro-processing SMEs, were implemented in support of macro-economic policies, the NIPF, NGP and NDP. Figure A.4 shows the progression of the policy plans from the earlier policies, namely, the RDP, the GEAR and AsgiSA, to the current policy plans, which are the NGP, NDP, 9-Point Plan, IPAP, APAP and the strategy for the development of agro-processing (SMEs). The aim is to provide a summary of all the policy plans discussed so far to highlight the relationship among them as well as the overarching goal (s) of each policy plan.

The current national policy plans that identify agro-processing as one of the priority sectors for achieving South Africa's desired growth and development are highlighted in Figure A.5. These policies or plans are the NGP, NDP, 9-Point Plan, IPAP, APAP and the strategy for the development of small and medium agro-processing enterprises. Overall, these policy plans have identified the agro-processing subsector as one of the sectors to achieve the policy objectives of growing the economy, creating jobs and reducing poverty and inequality. Accordingly, various industry-specific support programmes were developed from 1994 to 2017 to capacitate the industries to achieve the objectives of the macro-economic and sectoral/industrial policy plans. Table 2.1 describes the support programmes, their accompanying objectives and the beneficiary industries.[27]

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[26] The support is in the form of Entrepreneurial support, Enterprise development, Access to finance, Market access, Incubation, Industry research and transfer of technology, and Infrastructure investment.

[27] The support programmes have been included in Figure A.3 to provide a historical chronology of the macro-economic policies, the sectoral/industrial policies and the support programmes. The macro-economic policy plans

Table 2.1: Industry-specific support programmes

Support programme	Objective (s)	Beneficiary sector/industry
Workplace Challenge Programme (WPC), 1997	Support and encourage negotiated workplace change to enhance productivity, best-operating practices, world-class competitiveness, lean manufacturing, continuous improvement, while ensuring job creation (the dtic, 2019a)	Agriculture, agro-processing, manufacturing, and mining and beneficiation businesses (the dtic, 2019a)
Seda Technology Programme (STP), 2006	Stimulate economic growth and development through the promotion of technological innovation (the dtic, 2019b)	Small enterprises, women-owned enterprises (the dtic, 2019b)
Sector Specific Assistance Scheme (SSAS), 2009	"Develop an industry sector as a whole; Develop new export markets; Stimulate job creation; Broaden the export base; Propose solutions to factors constraining export growth; Promote broader participation of black-owned and SMME's to the economy" (the dtic, 2019c)	Joint Action Groups, Industry Associations and Export Councils involved in the development of emerging exporters (the dtic, 2019c)
Clothing and Textiles Competitiveness Programme (CTCP), 2010	"Assist the industry in upgrading products and people, process, equipment, and re-positioning South Africa to compete effectively against other low cost producing countries, and create sustainable capabilities and employment in these industries" (the dtic, 2019d)	Textiles, Clothing, Leather & Leather Goods & Footwear industries (the dtic, 2019d)
The Manufacturing Competitiveness Enhancement Programme (MCEP), 2012	"To support enterprises in the production sectors of the economy soon after the onset of the global economic recession to weather very adverse market conditions, secure higher levels of investment, raise competitiveness and retain employment" (the dtic, 2019e)	Enterprises in the production sectors (the dtic, 2019e)
Aquaculture Development and Enhancement Programme (ADEP), 2013	"To stimulate investment in the aquaculture sector to: develop emerging agriculture farmers; increase production; and sustain and create jobs" (the dtic, 2019f)	Fish hatcheries and fish farms involved in the production, processing and preserving of aquaculture fish (the dtic, 2019f)

are highlighted by the bold and underlined text, sectoral/ industrial policies are highlighted by the underlined text, while the support programmes are highlighted by the italicized text.

Table 2.1 continued

Critical Infrastructure Programme (CIP), 2015.	To stimulate investment growth according to the NIPF and IPAP through infrastructure development (the dtic, 2019g)	Registered legal entity including small enterprises, “distressed municipalities and state-owned industrial parks, agro-processing and state-owned Aerospace and Defence National Strategic Testing Facilities” (the dtic, 2019g)
Support Programme for Industrial Innovation (SPII), 2016	“To promote technology development in the industries through the provision of financial assistance for the development of innovative products and/or processes” (the dtic, 2019h)	Small, very small and micro-enterprises and individual and all enterprises (the dtic, 2019h)
Technology and Human Resource for Industry Programme (THRIP), 2016	To support industries through research and technology development (the dtic, 2019i).	“All companies undertaking science, engineering and technology (SET) research, in collaboration with educational institutions, and to address the participating firms' technology needs” (the dtic, 2019i).
The Agro-Processing Support Scheme (APSS), 2017.	To stimulate investment by agro-processing or beneficiation (agri-business) enterprises (the dtic, 2019j).	Agro-processing and agri-business enterprises (the dtic, 2019j).
Black Industrialists Scheme, 2017	“To promote industrialization, sustainable economic growth and transformation through the support of black-owned entities in the manufacturing sector” (the dtic, 2019k).	Black-owned enterprises in the manufacturing sector, particularly in “the Ocean Economy, Oil and gas, clean technology and energy, mineral beneficiation, Aerospace, Rail and Automotive Components, Industrial Infrastructure, ICTs, Agro-processing, Clothing, Textiles/leather and footwear, Pulp, Paper and Furniture, Chemicals, Pharmaceuticals and Plastics, Nuclear, Manufacturing-related logistics” (the dtic, 2019k).

Source: Author based on the dtic (2019a–2019k)

The industry-specific programmes were aimed at supporting specific industries including the agro-processing industries. Specifically, the clothing and textiles competitiveness programme (CTCP), which aims to increase competitiveness and employment, have identified the textile, wearing apparel (clothing, footwear) and leather industries as some of the beneficiary industries. Also, the cluster development programme (CDP), which aims to promote sustainable economic growth, industrialisation and job creation, have identified the rubber (plastics), paper, textile, wearing apparel (clothing, footwear), furniture and leather industries. These industries have also been identified as some of the beneficiary industries by the black industrialists scheme, which aims to promote industrialisation, sustainable economic growth and transformation through the support of black-owned entities in the manufacturing sector.

The key point to note in relation to the industry-specific programmes is that they were developed to capacitate the agro-processing industries to contribute towards the macro-economic and sectoral/industrial policy objectives of growing the economy and creating employment. From this perspective, the next section serves to determine the extent to which the agro-processing subsector contributed to these policy objectives. As mentioned earlier, this enables the study to ascertain the justification for considering ICT investment as one of the potential drivers of growth of the agro-processing industries.

2.4 CONTRIBUTION OF THE AGRO-PROCESSING SUBSECTOR TO THE SOUTH AFRICAN ECONOMY

This section aims to provide statistical evidence of the extent to which the agro-processing subsector contributed towards the attainment of policy objectives as embedded in the policy plans that have been discussed in the preceding section. To provide this statistical evidence, the contribution of the subsector and individual industries to output growth and employment was examined. The output was then used as a proxy for GDP in that GDP is defined as the gross value of output produced within a country. The rationale for focusing on output and employment is that higher GDP could be increased by hiring more labour to produce more output. The period of the analysis is composed of three periods: the past policy era (1994–2007), the current policy era (2008–2017) and the entire policy era (1997–2017).

The entire policy era covers all the policies that have been implemented from 1994 to 2017.[28] This holistic approach enables the chapter to provide an insight into the extent to which the

[28] The rationale for ending with 2017 is that the analyses were conducted in 2018, with 2017 being the last year in which data used in this study was available. The NIPF, which was implemented in 2007, has been left out as it

agro-processing industries have contributed to output and employment throughout the years. The past policy era covers the policy plans that are no longer in effect such as the RDP, GEAR and AsgiSA, while the current policy plans cover the plans that are in effect, at the time of writing, such as the IPAP, NGP, 9-Point Plan, APAP and the strategy for agro-processing SMEs. The rationale for disaggregating the policy era in this manner is that the current policy plans were implemented to address the jobless growth associated with the past policy plans. Therefore, the focus is on comparative analysis of the past and current policy eras in terms of growth of output and employment. By so doing, this chapter provides an insight into whether the agro-processing industries contributed more or less to growth during the past or current policy era. The analysis also included the industries' share of output and employment of the agro-processing subsector to determine which industry contributed more or less to the total output and employment.

The analyses were limited to output and employment due to insufficient data on the contribution of the agro-processing industries to poverty and inequality.[29] The study calculated, in particular, the annual average growth rates of output and employment for all the policy eras.[30] The presentation of the results starts with the agro-processing subsector in its totality, followed by the individual agro-processing industries. Table 2.2 shows the annual average growth of output and employment of the agro-processing subsector for all the policy eras.

Table 2.2: Output and employment growth of the agro-processing subsector per policy era

Variable	Past policy era (%)	Current policy era (%)	Entire policy era (%)
Output growth	3.67	0.16	2.21
Employment growth	-0.64	-1.01	-0.79

Source: Author's own compilation

Table 2.2 demonstrates that the subsector in its entirety performed fairly well for the entire policy era as evidenced by the positive average output growth of 2.21%. However, results also indicate that the subsector experienced the highest output growth during the past policy era and

is implemented through the IPAP. Furthermore, the APAP was published in 2014, with 2015 being the first year of its implementation.

[29] The output is used as a proxy for GDP.

[30] The raw data consisted of output, value-added and employment from 1993 to 2017 to cover the annual growth rates from 1994 to 2017.

the lowest growth during the current policy era. The higher growths were achieved during the GEAR and AsgiSA policy eras, which have been credited with achieving South Africa's highest GDP growth. Therefore, the GEAR and AsgiSA policy plans could have contributed to the higher output growth of the agro-processing subsector.

However, the study observes that despite the above-noted higher output growths achieved during the cited policy eras, the opposite results were found in terms of employment growth. In this regard, the subsector had underperformed over the entire policy era as evidenced by the negative average employment growth of 0.79%. Moreover, the subsector had experienced negative average employment growth of 0.64% during the past policy era. While this decline is lower than that of the current period, it is at variance with the highest and positive average output growth experienced over the same period. In other words, while the agro-processing subsector had experienced the highest and positive average output growth during the past policy era, it had experienced negative average employment growth during the same era. This suggests that there was a trade-off between output growth and employment.

The aforementioned finding is in line with the observation that although South Africa's highest GDP growth of 5.6% was attained during the past policy era, the levels of unemployment also increased (between 1996 to 2006). For instance, the unemployment rate increased to 27.8% in 2002, the highest since 1994 and up until 2017. This phenomenon is known as jobless growth, the state in which economic growth is coupled with a high unemployment rate. It was based on the realisation that GDP growth was accompanied by high levels of unemployment that the current policy plans were implemented. However, the agro-processing sector experienced negative average employment growth of 0.79% during the current policy era, which is higher than a negative average growth of 0.64% for the past policy era. Therefore, while employment had declined during the past policy era, it has declined further under the current policy era.

Overall, three observations can be made from the findings on the output and employment growth of the agro-processing subsector. Firstly, the past policy plans could have contributed to the higher output growth of the agro-processing subsector. Secondly, the same plans could have stimulated output growth while reducing employment growth. Finally, the agro-processing subsector, as a whole, performed better in terms of growth of output and employment growth during the past policy era relative to the current policy era.

It is noted that although the subsector in its totality experienced positive output growth and negative employment growth, it consists of 10 industries with varying output and employment growth. Therefore, some industries could have experienced higher growth than others could. Given this, the study calculated the output and employment growth of individual agro-processing industries. The presentation and discussion of the results start with the output growth, followed by employment growth. Table 2.3 shows the output growth of the agro-processing industries.

Table 2.3: Output growth of the agro-processing industries per policy era

Industry	Past policy era (%)	Current policy era (%)	Entire policy era (%)
Food	3.56	0.10	2.12
Beverages	1.35	0.28	0.91
Tobacco	4.25	0.13	2.53
Textile	2.05	0.24	1.30
Wearing apparel	1.07	1.16	1.11
Leather	6.56	0.79	4.16
Wood	5.02	1.05	3.36
Paper	4.50	-0.06	2.60
Rubber	2.98	-0.49	1.53
Furniture	5.37	-1.65	2.44

Source: Author's own compilation

In respect of the output growth of the agro-processing industries, the study found that all the industries had performed fairly well for the entire policy era as evidenced by their positive average annual growths as shown in Table 2.3. This observation is consistent with that of the agro-processing subsector in its totality in which positive average growth was observable. The leather industry experienced the highest output average growth over the entire policy era when compared with the tobacco industry, which experienced the lowest average output growth.

The comparative analysis of the past and current policy eras shows that the individual industries performed better during the past policy era. These findings are consistently in line with those for the agro-processing subsector as a whole, which achieved the highest output growth during the past era in comparison with the current era. Although most of the industries had experienced positive growth during both the past and current policy eras, their growth declined during the current policy era. These industries are food, beverages, tobacco, textile, wearing apparel and leather. However, the leather industry had experienced the highest growth during the past period, whereas the wearing apparel industry experienced its highest growth during the current policy era.

Whereas the paper, rubber and furniture industries had experienced positive output growth during the past policy era, they experienced negative output growth during the current policy era. Furthermore, the furniture industry experienced its highest negative output growth during the current period. The overall finding is that, while the agro-processing industries had performed well during the entire period, in terms of output growth, they had performed better during the past policy era than during the current policy era. Therefore, the implication is that past policy plans such as GEAR and AsgiSA could have been more effective in driving the output growth of the agro-processing industries than the current policies such as the IPAP, NGP, 9-Point Plan, APAP and the strategy for agro-processing SMEs.

Given that the same plans could have stimulated the output growth of the agro-processing subsector while reducing employment growth, it is, therefore, imperative to examine whether this suggestion holds for the individual industries. To ascertain this, the employment growth of the individual industries was calculated. The results are presented in Table 2.4.

Table 2.4: Employment growth of the agro-processing industries per policy era

Industry	**Past policy era (%)**	**Current policy era (%)**	**Entire policy era (%)**
Food	-0.97	-0.12	1.06
Beverages	-2.29	-0.77	1.37
Tobacco	-2.10	-0.64	1.41
Textile	-1.32	-2.04	-3.05
Wearing apparel	0.20	-2.52	-6.32
Leather	-2.10	-1.31	-0.21
Wood	3.10	1.04	-1.84
Paper	0.48	1.89	3.86
Rubber	-1.65	-1.60	-1.53
Furniture	0.28	-1.88	-4.91

Source: *Author's own compilation*

The findings for employment growth demonstrate that, whereas the subsector as a whole had experienced negative employment growth over the entire policy era, some industries performed better than others did during specific policy eras. The food, beverages, tobacco and paper industries, in particular, experienced positive average employment growth over the entire period, whereas the remaining industries had experienced negative average growth. This means that, over the entire policy era, the policies have been effective in driving employment growth in some industries (food, beverages, tobacco and paper industries) but not in all industries. Moreover, the paper industry had experienced the highest and positive average growth in employment of 3.86%, whereas the wearing apparel industry had experienced the lowest and negative average growth of 6.32%.

Comparative analysis of the past and current policy plans demonstrates that more industries experienced negative average growth in employment during the current policy era than during the past policy era. The study observes that 6 out of 10 industries had experienced negative average growth in employment during the past policy era, whereas 4 out of 10 industries had experienced positive average growth. In contrast, 8 out of 10 industries had experienced negative average growth in employment during the current policy era, whereas 2 out of 10 industries had experienced positive average growth. These findings are in line with the finding for the agro-processing subsector, in which higher and negative average growth in employment was observed during the current policy era. Therefore, although the current policy plans were implemented to achieve GDP growth and simultaneously increase employment, these findings suggest that the current policy plans could have been ineffective in achieving both objectives. This assertion is supported by the finding that most industries experienced a negative average employment growth during the current policy plans.

Given that some industries experienced their highest output growth and lower employment growth during the same policy era, it is necessary to examine whether there has been a trade-off between output and employment in those industries. The observation is that the leather industry has experienced a positive average output growth and negative average employment growth throughout all policy eras. Similarly, the wearing apparel industry has experienced the highest positive average output growth and the highest negative average employment growth during the current policy era.

Further to the aforementioned, the paper industry has experienced a negative average output growth and positive average employment growth during the current policy era. These findings collectively suggest that there is a trade-off between output growth and employment. The trade-off is consistent with that observed for the agro-processing subsector as a whole. The implication is that, whereas the past policy plans could have been more effective in driving the output growth of the industries than the current policy plans, such growth led to a decline in employment. From this perspective, it is necessary to examine whether the labour productivity-output and employment nexus discussed in the theoretical framework of the study holds for the agro-processing industries.

Following Schwab (2016) and OECD (2019), productivity is considered a key determinant of output growth. This is because productivity refers to the efficient use of inputs in the production of goods and services (Prokopenko, 1987). According to this definition, higher productivity is achievable through the production of a greater quantity of output, using the same amount of resources. Therefore, productivity is correlative to output in that higher productivity means greater output. Thus, improvement in labour productivity implies, *ceteris paribus*, the production of more output using the same amount of labour input. This has an implication for employment in that lower labour input will be required to produce more output.

Consequently, an increase in labour productivity is expected to increase output and decrease employment, *ceteris paribus*.[31] Given this, the average annual growth of labour productivity of the agro-processing subsector and individual industries was calculated. Table 2.5 shows the annual average growth rates of labour productivity in the agro-processing subsector. The results also include the average growth rates of output and employment as presented in Table 2.2.

[31] However, this does not mean that higher output cannot be attained by hiring more labour input, *ceteris paribus*.

Table 2.5: **Growth rates for the agro-processing subsector per policy era**

Growth rate	Past policy era (%)	Current policy era (%)	Entire policy era (%)
Labour productivity	4.07	2.30	2.67
Output growth	3.67	0.16	2.21
Employment growth	-0.64	-1.01	-0.79

Source: *Author's own compilation*

Table 2.5 shows that, whereas the agro-processing subsector had experienced positive average labour productivity growth throughout all the policy eras, the highest growth was observable during the past policy era. Moreover, a comparative analysis of the growth in output and employment shows that the agro-processing subsector had experienced the highest and positive average output growth and the lowest negative average employment growth during the past policy era, suggesting a trade-off between the growth of output and employment. This further suggests that increased output growth was achieved through higher labour productivity, giving rise to a decline in employment growth. Given that trade-off between the growth of output and employment was also observable in the case of some of the industries, the study further calculated the annual average growth of labour productivity for the individual industries. The findings are presented in Table 2.6.

Table 2.6: **Growth rates for agro-processing industries per policy period**

Industry	Past policy era (%)	Current policy (%)	Entire era (%)
Food	4.96	1.40	-3.58
Beverages	2.35	-3.58	0.03
Tobacco	10.20	-2.85	5.09
Textile	3.71	2.77	3.35
Wearing apparel	1.87	11.49	5.63
Leather	8.17	9.53	8.70
Wood	-0.27	3.77	1.31
Paper	3.25	-3.25	0.71
Rubber	3.35	0.65	2.29
Furniture	3.15	3.12	3.14

Source: Author's own compilation

A summary of the findings for the average growth of output and employment is provided before the presentation of labour productivity results to link the findings with those for labour productivity. Accordingly, it was observed that most of the industries had experienced positive average output growth during the past policy era relative to the current era. Similarly, the findings from Table 2.6 show that most industries had experienced positive average labour productivity growth during the past policy era relative to the current era. This suggests that for most industries, higher output growth was achieved through higher labour productivity growth.

In terms of the output-employment nexus, it was observed that the leather industry had experienced positive average output growth and negative average growth in employment throughout all policy eras. The findings from Table 2.6 show that the industry had also experienced positive average labour productivity growth throughout all the policy eras. Therefore, this suggests that an increase in output growth of the leather industry has been achieved through higher labour productivity, giving rise to a decline in employment growth. Moreover, the wearing apparel industry experienced the highest and positive average output growth and negative average employment growth during the current policy era. The findings from Table 2.6 show that the wearing apparel industry experienced the highest average labour productivity growth during the current era. Similar to the case of the leather industry, this suggests that an increase in output growth was achieved through higher labour productivity, giving rise to a decline in employment growth.

The findings for the paper industry show that the industry experienced a negative average output growth and positive average employment growth during the current policy era, suggesting a trade-off. The findings from Table 2.6 show that the paper industry experienced negative average growth in labour productivity during the current policy era. This suggests that the higher employment growth of the paper industry was achieved through a decline in labour productivity because a decline in labour productivity implies that less output is produced with more labour input, resulting in an increase in employment.

The key point that has emerged from the analysis of the output–employment nexus is that labour productivity growth could be one of the determinants of the trade-off between the growth of output and employment in the agro-processing subsector. In the case of the subsector as a whole and the individual industries, the higher output growth observed during the past policy era was achieved through higher labour productivity, giving rise to a decline in employment growth.

Two main implications emerge from the analysis of growth and the output-employment nexus in the agro-processing subsector as a whole and its individual industries. Firstly, it is notable that the agro-processing subsector, as a whole and on an individual industry basis, had performed better in terms of growth of output during the past policy era relative to the current policy era. The implication is that past policy plans such as GEAR and AsgiSA could have been more effective in driving the output growth than the current policies such as the IPAP, NGP, 9-Point Plan, APAP and the strategy for agro-processing SMEs. However, the past policy plans could have stimulated output growth while reducing employment growth, as evidenced by the negative average employment growth. Although the current policy plans were implemented to mitigate such a situation, these findings suggest that the current policy plans could have been ineffective in achieving their target, as evidenced by higher negative employment growth during the current policy era.

Secondly, another implication is that, whereas the past policy plans could have been effective in driving the output growth than the current policy plans, such growth led to a decline in employment. The analysis of the labour productivity-output nexus shows that the higher output growth observed during the past policy era was achieved through higher labour productivity, giving rise to a decline in employment growth. As a whole, these results show the extent to which the agro-processing subsector and its industries have performed in terms of growth of output and employment during each policy era.

In brief, the contribution of the agro-processing industries to employment growth varied according to the policy period, with the result that higher contributions were observed for the past period relative to the current policy era. Therefore, although the current policy plans were implemented to address the jobless GDP growth associated with past policies, the current policies have not been effective in achieving this objective. The finding that most industries have experienced a negative average employment growth during the current policy plans supports this assertion.

The analyses also included each industry's share of output and employment in the agro-processing subsector to determine which industry contributed more or less to output and employment. The results varied in relation to the previous ones for growth in that they measured the contribution of the industries to the total output and employment. Each industry's share of output is presented in Table 2.7.

Table 2.7: Share of output for agro-processing industries per policy era

Industry	Past policy era (%)	Current policy era (%)	Entire policy era (%)
Food	43.7	46.6	45.1
Beverages	15.3	13.7	14.6
Tobacco	3.0	2.5	2.8
Textile	5.6	5.0	5.3
Wearing apparel	4.0	3.7	3.8
Leather	1.0	1.1	1.1
Wood	6.7	7.2	6.9
Paper	13.0	13.2	13.1
Rubber	3.5	3.1	3.3
Furniture	4.2	3.8	4.0

Source: Author's own compilation

The overall findings are that, while the results for the growth indicate that industries had contributed more to growth during the past era than the current era, the results show that there was no significant change in the industries' contribution to the total output. This implies that the contribution of the industries to total output had remained relatively stable. It is further notable that more industries had contributed more to the total output during the past policy era relative to the current policy era. However, the food industry had contributed the most to the total output of the agro-processing subsector throughout the policy eras, whereas the leather industry had contributed the least. Although the leather industry had experienced a higher average output growth throughout the policy eras, it is worth noting that it had contributed the least to the total output of the subsector. Moreover, the wearing apparel industry experienced the highest average output growth during the current period, but its contribution to total output was lower than that of the food industry.

The study further calculated the industries' share of employment to determine which industry contributed more or less to the total employment of the agro-processing subsector. The findings are presented in Table 2.8.

Table 2.8: Share of employment for agro-processing industries per policy era

Industry	Past policy era (%)	Current policy era (%)	Entire policy era (%)
Food	38.5	42.0	39.9
Beverages	7.2	8.0	7.5
Tobacco	0.6	0.7	0.7
Textile	9.8	7.5	8.9
Wearing apparel	16.2	11.1	14.2
Leather	1.2	1.1	1.2
Wood	9.8	11.4	10.5
Paper	4.7	8.2	6.1
Rubber	3.4	2.8	3.2
Furniture	8.5	7.0	8.0

Source: *Author's own compilation*

The overall findings indicate that industries' contribution to total employment was higher during the current policy era relative to the past era. These findings varied from the previous findings in which industries contributed more to employment growth during the past policy era than the current era. The implication is that, while the current policy plans have been less effective in achieving employment growth, as evidenced by the negative average employment growth, they have contributed more to the total employment during the current period relative to the past period. Comparatively, the food industry contributed the most to total employment of the agro-processing subsector throughout the policy eras, whereas the tobacco industry contributed the least. Suffice to state once again that, while the paper industry had experienced higher employment growth, its contribution to total employment was lower than that of the food industry. Overall, industries that had experienced a higher average growth of output and employment contributed less to the output and employment of the subsector.

Three main conclusions can be derived from the findings of the growth of output and employment and industries' share of output and employment of the agro-processing subsector. Firstly, the agro-processing subsector in its totality and on an individual industry basis contributed more to output growth during the past policy era relative to the current era. The implication is that past policy plans could have been more effective in driving the output growth of the agro-processing subsector in its totality and on an individual industry basis than the current plans, as evidenced by higher average output growth during the past policy era relative to the current era.

Secondly, agro-processing industries contributed more to the employment growth of the agro-processing subsector during the past period relative to the current period. This implies that, while the current policy plans were implemented to address the jobless GDP growth associated with the past policies, the current policies have been ineffective in achieving this objective. Thirdly, the food industry contributed more to the total output and total employment of the agro-processing subsector. This implies that industries that have experienced a higher average growth of output and employment have contributed less to total output and employment of the subsector. In brief, although the agro-processing subsector was earmarked as one of the sectors with the potential to stimulate GDP growth and generate employment, the findings of this chapter show that the subsector has been less effective in achieving this.

Given the aforementioned, it is imperative to examine the extent to which ICT could contribute to the growth of the agro-processing industries. The rationale is to capture the network effects of technology, which are defined as growth effects arising from the use of ICT in other sectors besides the ICT sector (Stiroh, 2002a; van Ark, 2014). By so doing, this study provides knowledge on the role of ICT in enhancing the growth performance of the other sectors besides the ICT sector. The subsequent sections serve to determine this by defining the ICT sector, reviewing the ICT policies, and examining the role of ICT in agro-processing value chains. As stated earlier in the chapter, this enables the study to provide an insight into the contribution that ICT play in driving the growth of the agro-processing industries. The next section aims to provide the definition and classification of ICT to delineate which industries, commodities and activities are part of ICT and which ones are not.

2.5 ICTS IN SOUTH AFRICA: DEFINITION AND CLASSIFICATION

Information and Communication Technology (ICT) is a complex sector, which is difficult to distinguish as a technology and as a sector because of its universal, multi-disciplinary and cross-industry nature. As stated by DTPS (2015), the complexity surrounding the ICT concept is reflected in the various ways in which it is defined and used. It is, therefore, crucial to draw a clear distinction between ICT as a technology and as a sector. Given the complexity and contradictions surrounding the concept of ICT, the OECD published the guidelines for measuring the information economy in 2007 (OECD, 2007). The OECD guidelines were not mandatory, and therefore each country had to develop its definition and classification of ICT.

Subsequently, Stats SA, the national statistical agency of South Africa, initiated a process of developing the first satellite account for South Africa's ICT sector in 2005, using the guidelines proposed by the OECD (Stats SA, 2015). The ICT inter-institutional working group was then established by Stats SA with the support of the then Department of Communications.

According to Stats SA (2012), the ICT inter-institutional working group used other countries' best practices with respect to ICT indicators and the classification of ICT industries as benchmarks in the development of the ICT satellite account. Canada's practice, in particular, was used because its national classification standard of ICT industries is perceived to be very close in scope to the ISIC classification (Stats SA, 2012). In addition, Mauritius' experience was also useful as it had a broad range of databases on ICT indicators including, among others, imports and exports of ICT products, value-added in the sector, and usage of ICT by businesses and households (Stats SA, 2012).

Three discussion documents were subsequently published by the Stats SA (March 2011, 2012 and 2013), highlighting the processes and progress undertaken in the development of the ICT satellite account (Stats SA, 2015). The documents contained, among other things, the definition and classification of ICT industries, sources of data for the satellite account and ICT indicators. Ultimately, the first ICT satellite account was published in 2013 for the year 2005 (Stats SA, 2013). To date, Stats SA has published ICT satellite accounts for the years 2005 to 2014, with 2017 being the latest publication (Stats SA, 2017b). In these accounts, Stats SA adopted the OECD's guideline for delineating ICT as a sector and its economic activities, based on ISIC (Rev.4), as follows (Stats SA, 2015, p.73):

- "ICT products must primarily be intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display;
- For the ICT sector, the production (goods and services) of a candidate industry must primarily be intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display; and
- For the 'content and media' sector, the production (goods and services) of a candidate industry must primarily be intended to inform, educate and/or entertain humans through mass communication media."

The advantage of the ICT satellite account is that it clarifies the complexity surrounding the ICT concept by isolating the demand for and supply of ICT among various industries (Stats SA, 2015). This study, therefore, defines ICT in line with the Stats SA (2015), as any technology used to process, store, distribute and communicate information. The justification for this is that the definition delineates which industries, commodities and activities are part of ICT and which ones are not. Moreover, the definition and classification of ICT by Stats SA is according to the standards and principles set by the UN's international standards for the industrial classification of economic activities. Thus, using this definition provides a statistical basis for evaluating ICT in an internationally comparable way. Accordingly, the ICT sector is classified into ICT manufacturing industries, ICT trade industries and ICT service industries (Stats SA, 2012). The detailed classification of ICT economic activities is presented in Table A.3. The subsequent section discusses the role that ICT plays in agro-processing value chains to highlight the interaction between ICT and agro-processing.

2.6 THE ROLE OF ICT IN AGRO-PROCESSING VALUE CHAIN

In this study, ICT is viewed as having various roles in various stages of the agro-processing value chain. The main stages are production, processing, marketing, distribution and consumption. Accordingly, a large number of ICTs are utilised within each stage and between these stages. Figure 2.1 shows the interaction between ICT and the main stages of the agro-processing value chain.

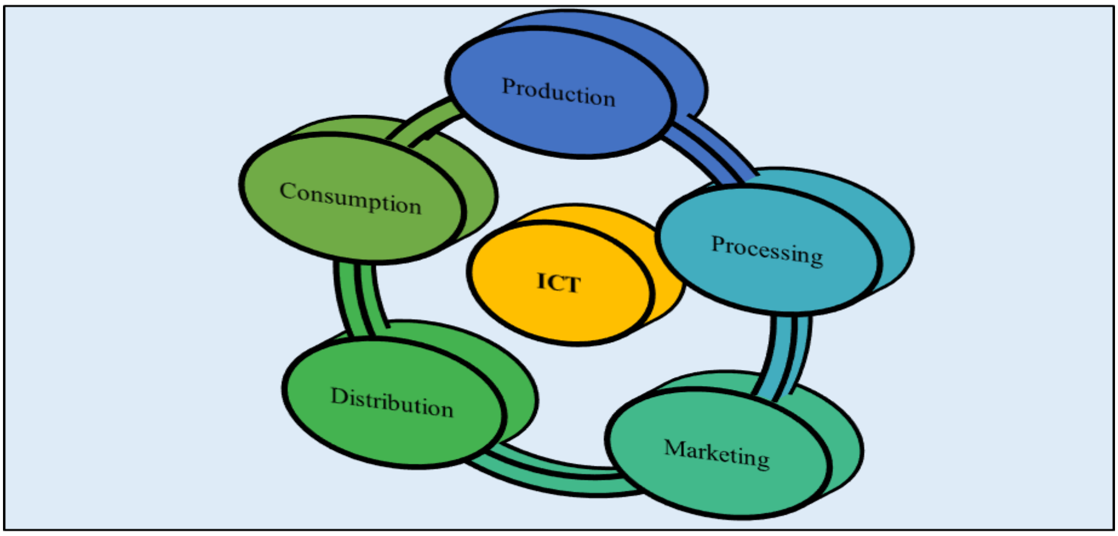

Figure 2.1: Interaction between ICT and agro-processing value chain
Source: Adapted from Berti and Mulligan (2015)

Production and processing: The application of ICTs at the production and processing stages entails the use of ICTs and related activities between farmers and agro-producers. At the production phase, examples would be the use of mobile phones, tablets and associated applications (APPs) to provide timely and precise information on input use, weather forecasts and production methods for farmers. ICT application enhances the production decisions of farmers, facilitates the adoption of improved inputs and, in so doing, improves productivity (IICD, 2012; Deichmanna, Goyalb and Mishrac, 2016). Another example would be the use of mobile phones to communicate with agents and traders (Reardon, Chen, Minten and Adriano (2012). This results in a greater level of coordination and information exchange between farmers and agro-processors, thereby maintaining a more dynamic and responsive set of relationships among supply chain actors.

Marketing: Examples encompass the advertisement and promotion of products through both the broadcast (radio and TV) and print (newspapers, magazines, brochures, posters, flyers, etc.) media. Advertisement and promotion induce the demand for products by creating awareness and enticing potential customers to use the product. An increase in demand will reduce unemployment, as more labour input will be required to produce more output to meet the increased demand, *ceteris paribus*. According to Barnichon (2018), this will, in turn, lead to an increase in labour productivity, temporarily, as firms seek to increase labour effort to meet the demand in the short run, *ceteris paribus*. Therefore, advertisement and promotion of products stimulate the demand, giving rise to higher growth in output, employment and labour productivity.

Distribution: Examples include the distribution of products through postal and courier services. This protects the inventory against demand spikes and supply disruptions and ensures that the products are delivered to the point of requirement (Wang, 2018; Naway and Rahmat, 2019).

Consumption: the use of ICTs includes the online ordering of agro-processing products. Online ordering results in the saving of time and effort required to buy directly from the retailers. Another example involves the use of the internet, which allows consumers to search for various products without being constrained by geographic location (Berti and Mulligan, 2015). This provides consumers with more options with respect to the variety of agro-processing products they have access to through local or regional supply chains. Another example involves the use of e-business (buying and selling through the internet and related services). This eliminates barriers to trade, which allows parties to trade worldwide without being constrained by time and geographic barriers.

Overall, the consequences associated with using ICT across the various stages of the agro-processing value chain include, among others, a greater level of coordination and information exchange, increased market access, reduced transportation and communication costs, effective logistics and supply chains, and reduced costs of trade. These outcomes create opportunities for opening new markets and therefore drive economic growth (Berti and Mulligan, 2015). This is because ICTs are considered flexible inputs that allow industries to reorganise the production and distribution of goods and services in order to improve efficiency, thereby reducing transaction costs while improving the industries' information flows both internally and externally (i.e. with customers/suppliers), possibly leading to higher labour productivity (Brynjolfsson and Hitt, 2000).

All these consequences have implications for employment in that higher labour productivity implies the attainment of more output, using the same labour input. However, higher labour productivity could have a positive effect on employment growth through its contribution to higher output (which means higher labour demand) (Alexander, 1993; Wakeford, 2004, cited in Tsoku and Matarise, 2014). Hence, the need for this study to examine the effects that ICT would have on labour productivity, output and employment of the agro-processing industries. The subsequent section reviews the ICT policies.

2.7 REVIEW OF SOUTH AFRICA'S ICT POLICIES

This section aims to review the ICT policies that have been implemented in South Africa since 1994. The rationale for reviewing policies is that the overall objective of ICT policies is to ensure access to and usage of ICT throughout the economy. Moreover, given that the first objective of the study was to determine whether ICT policies contributed to the growth of labour productivity of the agro-processing industries, it is necessary to review these policies. The results from the review serve as a source of reference for explaining why ICT policies have contributed or are yet to contribute to the labour productivity growth of the agro-processing industries. Consequently, it is imperative to examine the extent to which ICT policies have ensured access to and usage of ICT in the non-ICT sectors, particularly in the agro-processing subsector. The study achieved this by assessing the objectives of each policy and the outcomes associated with the overall policies. Table A.4 presents the key ICT policy frameworks and their objectives.

Three key points of note have been derived from the identified policies. Firstly, most of the policies are legislative frameworks for the establishment and governance of agencies in the ICT sector as well as for the regulation of the telecommunication, broadcasting and postal sectors. Secondly, the identified policy frameworks are silent on the issue of ensuring access to and use of ICT in the non-ICT sector. For instance, the National Integrated ICT Policy (2014) focuses on a proposal to streamline the roles and responsibilities of various state-owned agencies, and on the introduction of new state-owned agencies and dismantlement of others (Oguz, 2017; Pater and Hurst, 2017; Mzekandaba, 2018). Therefore, as with most policies, the National Integrated ICT Policy is focused on governance and regulation of the state-owned agencies in the ICT sector.

In addition to the above, the ICT SMME Development Strategy (2017) is focused on creating business opportunities and creating an enabling administrative and business environment for SMMEs in the ICT sector. The policies related to skills development are focused on the skills in the ICT sector. This focus demonstrates that the existing ICT policies are yet to focus on ensuring access to and the use of ICT in the non-ICT sector.

Thirdly, although most of the ICT policies are silent on the issues of growth and development, it is important to note that ICT has been identified in some macro-economic and sectoral/industrial policies as having the potential to boost South Africa's growth and development. It is also significant that ICT has been conceptualised within the context of ICT infrastructure, particularly broadband infrastructure. This conceptualisation is further borne out by the development plans, namely, the NDP, the NGP and the 9-Point Plan, in which ICT is only conceived in terms of economic infrastructure (Gillwald *et al.*, 2012; USAASA, 2017).[32] Specifically, in the NGP and 9-Point Plan, ICT is limited to the rapid deployment of ICT infrastructure and rollout of broadband to stimulate growth and vibrant knowledge society (USAASA, 2017). The 9-Point Plan has further identified ICT infrastructure and broadband rollout as one of the nine plans to boost economic growth and create jobs.

Overall, while the policy plans such as the NGP, NDP, 9-Point Plan have identified ICT infrastructure (broadband) as one of the drivers of economic growth, Gillwald *et al.* (2012) have observed that they lack coherence and a clear direction in terms of how ICT can be utilised to drive South Africa's growth and development. For ICT to drive overall growth, ICT policies have to align with the macro-economic and industrial policies (Herman, 2012). While this has been achieved through the National Integrated ICT Policy, the study noted that such integration is silent in terms of ensuring access to and use of ICT in other sectors of the economy. For instance, the agro-processing subsector has been identified in the macro-economic and industrial policy plans as having the potential to stimulate growth and generate jobs. At the same time, policy plans have further identified ICT infrastructure and broadband rollout as one of the measures to boost economic growth and create jobs. From this perspective, there is a need to align the ICT with the agro-processing subsector to examine the extent to which ICT could contribute to the growth and employment of the subsector. Doing so would, it is assumed, enhance the subsector’s productive capacity and drive growth and employment.

Although the biggest drawback of the identified policies is that they are yet to ensure access to and use of ICT in other sectors of the economy, the ICT sector has nonetheless achieved three outcomes, which could be attributed to ICT policies. The first outcome is the establishment of institutions to govern the ICT sector (Gillwald *et al.*, 2012). The institutions, as well as their governing Acts and legislative mandates, are shown in Table 2.9. All these agencies are 100% state-owned apart from Telkom, which was semi-privatised (39% state-owned) in 1997 (Burger, 2002).

[32] In line with the NDP, the National Broadband Policy was established in 2013 to deliver high-speed broadband (i.e. download speed of at least 256 kbps) to 100% of the population by 2030 and ensure 100% broadband connectivity for all health, schools and government facilities by 2020 (DTPS, 2015).

Table 2.9: Institutions, governing Acts and legislative mandates

Institution	Governing Act (s)/Policy	Legislative mandate
Telkom	Telecommunications Act, 1996 and Electronic Communications Act, 2005.	Provide local exchange telecommunication services using radio-local-loop and fixed radio facilities
South African Broadcasting Corporation (SABC)	Broadcasting Act, 1999	Provide television and radio broadcasting services
SENTECH	Sentech Act, 1996 and Electronic Communications Act, 2005	Distribution of broadcasting signal to licensed radio and television operators
Universal Service and Access Agency of South Africa (USAASA)	Telecommunications Act, 1996	Initiate, advocate, and oversee all matters related to universal access and service within the ICT sector
State Information Technology Agency (SITA)	State Information Technology Agency Act, 1998	"Provide information technology, information systems and services to, or on behalf of participating Departments and, act as an agent of the South African Government" (DTPS, 2015)
Independent Communications Authority of South Africa (ICASA)	Broadcasting Act, 1999; Telecommunications Act, 1996; Postal Service Act, 1998; ICASA Act, 2000; Electronic Communications Act, 2005	Regulate the communications, broadcasting and postal sector
. Zadna	Electronic Communications and Transactions Act, 2002	Administer, regulate and issue licenses
Broadband Infraco	Broadband Infraco Act, 2007	Broaden the availability and affordability of access to national and international wholesale broadband connectivity
SA Post office (SAPO)	South African Post Office SOC Ltd Act, 2011	Ensure universal and affordable provision of a wide range of innovative postal services
National Electronic Media Institute of South Africa (Nemisa)	The National e-Skills Plan of Action 2012	"Provides skills training at an advanced level for the broadcasting industry (i.e. TV and radio production, and creative multimedia)" (DTPS, 2015)

Source: Author based on DTPS (2015) and DTPS (2019)

The second outcome is the positioning of South Africa's ICT sector as one of the largest in Africa, among the leading African economies. The leading African economies by GDP as per the International Monetary Fund (IMF) (2017) were Nigeria (17.17%), South Africa (15.94%), Egypt (10.81%) and Algeria (8.13%). Table 2.10 shows the selected ICT indicators for these economies for the year 2017.

The study further observes that South Africa had the highest percentage of persons using the internet, mobile-cellular subscriptions and percentage of persons with access to the internet at home. The country had the highest number of internet users (56%), followed by Algeria (48%), Egypt (45%), Nigeria (28%) and Angola (14%). South Africa also had the highest percentage of households with access to the internet at home (60.7%), followed by Egypt (49.2%), Algeria (40.3%), Nigeria (17.8%) and Angola (11.3%). With regard to mobile-cellular subscriptions, South Africa was shown to have the highest number of subscribers, leading with 156.03 subscriptions per 100 people, followed by Algeria (110.96), Egypt (105.54), Nigeria (75.92) and Angola (44.73).

Table 2.10: Selected ICT indicators for the leading African economies (2017)

Leading African Economies	**ICT indicators**						
	% of internet users	Mobile-cellular subscriptions/100 people	Fixed-Telephone subscriptions/ 100 people	Fixed (wired)-broadband/ 100 people	Mobile-broadband subscriptions/100 people	Households with a computer (%)	Households with internet access at home (%)
Nigeria	28	75.92	0.07	0	19.9	8.1	17.8
South Africa	56	156.03	8.48	3.1	70	21.9	60.7
Egypt	45	105.54	6.77	3.3	50.1	58	49.2
Algeria	48	110.96	9.93	4.1	111	41.3	40.3
Angola	14	44.73	0.54	0.3	14.6	11.9	11.3

Source: (International Trade Union (ITU), 2018)

In the case of fixed-telephone subscriptions, South Africa was ranked the second-largest subscriber with 8.48 subscriptions per 100 people, following Algeria (9.93 subscriptions per 100 people), and followed by Egypt (6.77), Angola (0.54) and Nigeria (0.07). South Africa was also ranked the second-largest subscriber of mobile broadband with 70 subscriptions per 100 people, following Algeria with 111 subscriptions. The country was ranked third with respect to fixed (wired)-broadband subscriptions, with 3.1 subscriptions per 100 people following Algeria (4.1) and Egypt (3.3). The country was also ranked third with respect to the percentage of households with access to computers at home (21.9%) after Egypt (58) and Algeria (41.3). These statistics confirm that the South African ICT sector is one of the largest among the leading African economies.

The third outcome arising from the policies is in terms of the contribution of the ICT sector to the South African economy. This is evident through its contribution to GDP growth, imports, exports and household expenditure. Table 2.11 shows the contribution of the ICT sector to the economy over the period 2005 to 2014. The data were sourced from the ICT satellite accounts, compiled and published by the Stats SA for the years 2005 to 2014. The choice of the period was based entirely on data availability.[33]

Table 2.11: Contribution of the ICT sector to the economy

Period	ICT contribution to GDP (%)	ICT contribution to total imports (%)	ICT contribution to total exports (%)	Household expenditure as a share of total expenditure (%)
2005	4.3	10.9	3.0	4.3
2006	4.0	10.0	2.9	4.5
2007	3.7	9.7	2.6	4.5
2008	3.3	9.4	2.4	4.4
2009	3.2	9.4	2.4	4.0
2010	3.2	10.0	2.6	3.9
2011	3.2	7.1	2.4	3.7
2012	2.9	10.4	2.8	4.6
2013	3.1	10.5	2.7	4.6
2014	3.0	10.4	2.8	4.6
Average	**3.3**	**9.7**	**2.6**	**4.3**

Source: Author based on Quantec (2018a) and Stats SA (2014, 2015, 2017)

From Table 2.11, it is observed that the ICT sector contributed 3.3%, on average, to the total GDP from 2005 to 2014. In the same period, the sector imported more than it exported, as evidenced by its average contribution of 9.7% to the total imports, relative to its contribution of 2.6% to the total exports. These statistics illustrate that the ICT sector imported more than it exported. This means that South Africa relies on other countries for the provision of ICT equipment like computers, smartphones, tablets, and servers (Stats SA, 2017b). In terms of expenditure, the sector contributed 4.3% on average to total household expenditure. These

[33] The contribution of the sector to the economy is based on the available data. For this reason, the contribution might be higher or lower, if data for other periods were to be taken into account.

statistics signify the contribution of the ICT sector to the South African economy in terms of GDP, imports, exports and household expenditure.

Given that ICT has been identified in the NGP, NDP and 9-Point Plan policy plans as one of the drivers of economic growth and job creation, it is of interest to determine the extent to which the subsector has contributed to GDP growth and employment. However, due to a lack of data on employment, the focus is on the contribution of the ICT sector to GDP. To achieve this, the study compared the ICT sector's contribution to GDP against the contribution of the agro-processing subsector.[34] By so doing, this chapter provides an insight into which of these sectors contributes more or less to South Africa's GDP growth. The period of the analysis is from 2005 to 2014 given the absence of data on the contribution of the ICT sector to GDP in other periods. Moreover, the focus is on GDP due to the absence of data on employment in the ICT sector.[35] Table 2.12 shows the contribution of the ICT sector and agro-processing subsector to GDP growth from 2005 to 2014.

Table 2.12: Contribution of the ICT sector and agro-processing subsector to GDP growth

Period	ICT contribution to GDP growth (%)	Agro-processing contribution to GDP (%)
2005	3.3	1.2
2006	4.0	0.4
2007	3.7	0.8
2008	3.3	1.7
2009	3.2	4.1
2010	3.2	0.9
2011	3.2	-0.3
2012	2.9	0.6
2013	3.1	-0.1
2014	3.0	0.5
Average	**3.3**	**1.0**

Source: Author's own compilation

The findings indicate that the ICT sector contributed more than the agro-processing subsector to GDP growth, as evidenced by its average contribution of 3.3% relative to the agro-

[34] The data for ICT contribution to GDP growth was sourced from the ICT satellite accounts, compiled and published by the Stats SA for the years 2005 to 2014. Data for the contribution of the agro-processing subsector to GDP growth were sourced from Quantec (2018).

[35] The ICT satellite accounts, which provide data on the contribution of the ICT sector to the South African economy, include data on the compensation of employees in the ICT sector, instead of the number of persons employed in the sector.

processing subsector's average contribution of 1.0%. Therefore, given that the ICT sector contributed more to GDP growth than the agro-processing subsector, it is justifiable to examine the extent to which ICT could contribute to the growth of the agro-processing subsector.

2.8 CHAPTER SUMMARY

An overview of South Africa's agro-processing subsector was presented in this chapter to distinguish between agriculture, agro-processing and the manufacturing sector. The UN's ISIC (Rev.4) was used to identify and separate agro-processing industries from the rest of the manufacturing industries. The agro-processing industries, according to ISIC (Rev.4) are food; beverages; tobacco; textile; wearing apparel; leather and related products; wood and wood products; paper and paper products; rubber and plastic products; and furniture. Accordingly, the key distinction between agro-processing and other industries is that agro-processing industries are agro-based, whereas the rest of the manufacturing industries are not.

After the classification of agro-processing industries, the macro-economic and sectoral or industrial policy plans were discussed to underline the strategic importance of the agro-processing subsector in the policy plans in terms of its potential to achieve GDP growth, job creation, and poverty and inequality reduction. Thereafter, the average growths of output and employment were calculated to examine the extent to which the agro-processing subsector as a whole and its individual industries have contributed to the policy objectives.

The findings showed that the agro-processing subsector and individual industries had performed better in terms of growth of output and employment during the past policy era relative to the current policy era. The findings suggest that the agro-processing industries have been ineffective in achieving the policy objectives of driving growth and creating employment. The chapter also reviewed the ICT policies to examine the extent to which the policies have ensured access to and usage of ICT in the non-ICT sectors. The key observation is that the reviewed policies are yet to focus on ensuring access to and usage of ICT in the non-ICT sector.

A comparative analysis of the contribution of the ICT sector and the agro-processing subsector to GDP growth showed that the ICT sector contributed more to GDP than the agro-processing subsector. This observation justifies the need for this study to examine the extent to which ICT could contribute to the growth of the agro-processing subsector. Accordingly, the next chapter examines whether ICT policies contributed to labour productivity growth of the agro-processing industries.

CHAPTER 3: CONTRIBUTION OF ICT POLICIES TO THE GROWTH OF THE AGRO-PROCESSING INDUSTRIES

3.1 INTRODUCTION

This chapter examines the contribution of South Africa's ICT policies to labour productivity growth of the agro-processing industries. The analyses were conducted within the manufacturing sector setting for three reasons. The first is that empirical evidence by Rankin (2016) indicated that labour productivity in South Africa's manufacturing sector increased post-1994. Hence, it is imperative to examine whether the growth in labour productivity in the manufacturing sector is attributable to ICT use.

The second rationale is to separate the growth of ICT-producing industries (ICT manufacturing industries) from that of the non-ICT manufacturing industries (manufacturing industries excluding the ICT manufacturing industries). This process serves to prove whether the ICT-producing industries contributed more or less to labour productivity growth, relative to other industries excluding the ICT industries. Comparing the ICT manufacturing industries against the non-ICT manufacturing industries is important given that the initial productivity effects are realised by a few industries, particularly producers of new technologies in the ICT sector, before the effect becomes noticeable in other industries (van Ark, 2014).

The third rationale is to isolate the labour productivity growth of the agro-processing industries. By so doing, this chapter addresses the first objective of examining whether ICT policies contributed to the labour productivity growth of the agro-processing industries. The manufacturing industries were disaggregated into three groups: Category A, Category B and Category C. Category A encompassed all the manufacturing industries, Category B comprised of agro-processing industries, and Category C consisted of the manufacturing industries to the exclusion of the ICT manufacturing industries. The analyses were conducted for the period 1970–2016 (entire period) and sub-periods 1970–1995 (pre-policy era) and 1996–2016 (post-policy era). The industries embedded in each category were disaggregated into two groups: more ICT-intensive and less ICT-intensive industries. The rationale for disaggregating industries is that the degree of ICT usage, and hence productivity growth differs a great deal across industries. Therefore, it is important to disaggregate the industries in order to identify which group of industries (between the more ICT-intensive and less ICT-intensive) contributed more or less to labour productivity growth. The chapter begins with a general overview of studies on the link between ICT and productivity. This is done to provide a theoretical basis for examining the effects of ICT on the productivity of industries. Thereafter, the literature on the impact of ICT on productivity is reviewed to compare productivity gains of ICT use between the developed and developing countries.

The review is extended to the case of South Africa to underscore gaps in the literature and the justification for carrying out the analysis. Thereafter, the research methods are described, including the measurement and definition of productivity and the classification of industries according to the ICT intensity index. The research methods section also describes the source of data, empirical models used for the analysis, as well as the parameters of estimates and variables contained in the models. Thereafter, the findings of both the descriptive and empirical analyses are discussed. The chapter ends with a summary of key findings and the implications thereof, and an explanation of the link between this chapter and the other chapters of the thesis.

3.2 BACKGROUND

South Africa has been experiencing several economic challenges such as low economic growth (GDP) and high rates of unemployment. Yet, as stated in chapter one, investment in ICT has been identified by international development organisations, such as the United Nations (UN) and the World Bank, as one of the drivers to stimulate growth and achieve development. The UN specifically views supporting technology development and increasing access to ICT as among the key strategies to boost productivity and development in developing countries (UNDP, 2016). Similarly, the World Bank holds the optimistic view that ICTs have the potential to create jobs, enhance productivity and economic growth in developing countries (World Bank, 2012; World Bank, 2017).

Despite the optimism of the World Bank, aggregate-level studies have generally found a negative or zero impact of ICT on productivity growth. Previous researchers have provided three reasons for this finding of aggregate-level studies. Firstly, Stiroh (2002a) argued that the standard growth accounting model used in the aggregate-level studies does not indicate which part of productivity growth is due to the network effects of technology. The network effects of technology are defined by van Ark (2014) as productivity effects generated from the use of ICT in the non-ICT sectors (i.e. sectors other than the ICT sector). Secondly, some scholars such as Stiroh (2002b) and Engelbrecht and Xayavong (2006) have contended that the neoclassical assumptions, namely, constant returns to scale and competitive markets, underlying the growth accounting model do not hold. As a result, the growth accounting model provides poor estimates of the ICT–productivity relationship (Stiroh, 2002b; Engelbrecht and Xayavong, 2006). Thirdly, Stiroh (2002a) maintains that the growth accounting model does not consider the variations in ICT intensity across industries. Accounting for such variations is necessary as variations in ICT use, and hence productivity growth would vary across industries. In the case of South Africa, it is noted that the existing empirical studies did not investigate the productivity gains that might be generated from ICT use in the manufacturing sector.

However, a study by Rankin (2016) showed that labour productivity had increased post-1994 in South Africa's manufacturing sector. Against this backdrop, this chapter aims to test empirically whether the observed growth in labour productivity in South Africa's manufacturing sector is associated with ICT use. The rationale is that since the advent of democracy in 1994, several ICT policy frameworks have been developed to ensure the usage of ICTs and achieve development (DTPS, 2015). The main ICT policy frameworks are presented in Table A.6.[36] In the light of these policy frameworks, empirical evidence on whether the ICT policies, as presented in Table A.6, have contributed to the labour productivity growth of the manufacturing sector and agro-processing industries, is provided in this chapter. For this reason, it is important to explain ways in which ICT contributes to productivity.

Empirically, ICT contributes to productivity growth through three channels. According to scholars such as van Ark (2003), Piatkowski (2004), Farooquie, Gani, Zuberi and Hashemi (2012) and Mefteh and Benhassen (2015), the key contributions are as follows: Firstly, it increases labour and capital productivity (multifactor productivity) in the ICT-producing sector. Secondly, it contributes to productivity gains in the non-ICT sectors by using ICT as capital input (capital deepening). Thirdly, it contributes to total factor productivity (TFP) through greater use of ICT in the overall economy.

[36] The policies include key publicly available ICT frameworks and exclude specific ICT projects.

Overall, based on Abri and Mahmoudzadeh (2015), ICT contributes directly to productivity growth in the ICT sector (ICT-producing industries) and indirectly to the growth of the non-ICT industries. This chapter, therefore, analyses the contribution of ICT policies to the labour productivity of the manufacturing sector, providing empirical evidence on the contribution of ICT policies to the labour productivity growth of the non-ICT industries. To this end, the variations in ICT intensity across the industries, in line with previous researchers (Stiroh, 2002a; van Ark, Inklaar and McGuckin, 2002; Engelbrecht and Xayavong, 2006; Abri and Mahmoudzadeh, 2015) are accounted for to address the problems associated with the aggregate-level studies. This is achieved by disaggregating the industries into ICT intensity clusters (i.e. less ICT-intensive and more ICT-intensive industries) by employing the ICT intensity index. By disaggregating the industries into ICT intensity clusters, the variations in ICT use, and hence productivity growth across the industries, were accounted for in this chapter.

3.3 REVIEW OF RELATED LITERATURE

Despite the anecdotal productivity gains that might be accrued through ICT use, some empirical studies have found no evidence of a positive link between ICT and productivity growth. Solow (1987) described the lack of evidence on the positive link between ICT and productivity growth as a "productivity paradox". The term was coined to clarify why researchers found no evidence of a positive link between ICT and productivity growth in the US between the 1970s and 1980s.

Following the proliferation of the perception of productivity paradox, various studies have explained the reasons for the productivity paradox at the different levels of analysis (i.e. firm level, aggregate level and industrial level). Overall, several earlier firm-level studies have detected either no significant impact or a negative impact of ICT on productivity growth (Loveman, 1994; Berndt and Morrison, 1995; Kılıçaslan, Sickles, Kayış, and Gürel, 2015). Based on Kijek and Kijek (2018), this finding is due to focusing on the direct effects of ICT on productivity growth, neglecting the indirect effects of ICT.

Analogous to firm-level studies, the aggregate-level studies have detected no significant impact of ICT (Oliner and Sichel, 1994; Jorgenson and Stiroh, 1995, 1999; Mačiulytė-Šniukienėa and

Gaile-Sarkane, 2014; Edquist and Henrekson, 2017). This finding has been attributed to the aggregation in the analysis of industries that are more ICT-intensive with those that are less ICT-intensive (Stiroh, 2002a). In contrast, the industry-level studies have shown a positive and significant effect of ICT on productivity growth for industries that are either using or producing ICT most intensively (McGuckin and Stiroh, 2001; Stiroh, 2002a; Engelbrecht and Xayavong, 2006; Kuppusamy *et al.*, 2009; Abri and Mahmoudzadeh, 2015; Niebel *et al.*, 2016; Corrado *et al.*, 2017). The disaggregation of industries with respect to ICT intensity ultimately allows researchers to unlock the differential effect of ICT across industries with different intensities of ICT use (Chen, Niebel and Saam, 2016).

Therefore, the disaggregation of industries in relation to their ICT intensity is crucial in identifying which group of industries, between the more ICT-intensive and less ICT-intensive industry groups, contributed more or less to productivity growth. However, Stiroh (2002a) cautioned that ICT by itself is not the main driver of the variations in productivity growth across industries. This is because productivity gains accrued from ICT use can only be fully generated through ICT-complementary factors, such as the ability of industries to use ICT effectively, the adaptation of workers' skills, and a favourable regulatory environment (Edquist, 2005; Yousefi, 2011; World Bank, 2016).

In brief, the empirical studies have shown the positive and significant effects of ICT when industries were disaggregated. As stated in chapter 1, the focus of the study is on manufacturing industries for both economic and technical justifications. Economically, South Africa's labour market has been characterised by high rates of unemployment. On this account, the NDP was developed to achieve GDP growth of 5% per year in order to increase employment from 13 million in 2010 to 24 million by 2030 (National Planning Commission, 2011).[37] Consequently, the manufacturing sector has been earmarked as being among the strategic sectors with the potential to achieve this aim.[38] Despite this, Bhorat and Rooney (2017) posited that the manufacturing sector had failed to achieve this potential as evidenced by its poor contribution

[37] The manufacturing sector has also been identified in other growth and development policies such as the GEAR, AsgiSA, the NGP, the NIFP, the IPAP, the NGP, the NDP and the 9-Point Plan.
[38] The manufacturing sector has been chosen given its labour-intensive nature and strong backward and forward linkages with other sectors.

to growth in both GDP and employment. Hence, it is imperative to test empirically the productivity gains that might accrue to the manufacturing industries through ICT use.

In terms of the technical justification, focusing on the manufacturing industries helps to explain the network effects of ICT (Stiroh 2002a; van Ark, 2014). In line with Szewczyk (2009), it is assumed that, depending on the levels of investment in ICT (expenditure), developments in ICT at the national level would spill over to the manufacturing industries. As such, the industries that have invested highly in ICT are expected to benefit the most. It is further assumed that the higher labour productivity growth effects of ICT would be realised by the manufacturing industries that have invested more in ICT.

However, the above assumptions do not negate the point that various factors could impact the results of this chapter as follows. While several ICT policy frameworks have been developed post-1996 to increase access to ICT, Gillwald *et al.* (2012) observed that they lacked coherence and a clear direction in terms of how ICT could be utilised to drive South Africa's growth and development. Although there is no evidence to support the view that these policies have failed to drive growth and development, this chapter examines the extent to which the ICT policies implemented post-1994 have contributed to the labour productivity growth of manufacturing industries. By so doing, the extent to which ICT policies have contributed to labour productivity growth of South Africa's manufacturing industries is explored in this chapter. Moreover, the contribution of ICT to the productivity growth performance of manufacturing industries, including the agro-processing industries, is provided in this chapter.

3.4 RESEARCH METHODS

3.4.1 Productivity: Definition and measurement

According to Prokopenko (1987), productivity is commonly defined as the relationship between the input used to produce the output by a service or production system. Consequently, productivity is described as the efficient utilisation of resources – for instance, capital, labour, land, information, materials, energy in the production of different goods and services. For this reason, an industry can attain higher productivity by producing more output (quantity) using the same quantity of resources.

Mathematically, productivity is measured as the ratio of output produced to all inputs used in the production system as described in Equation (3.1): as follows:

$$P = \frac{Y}{X} \tag{3.1}$$

where P represents productivity, Y is the output and X represents the inputs. There are three types of productivity: (1) labour productivity (i.e. productivity with respect to labour, (2) capital productivity (i.e. productivity with respect to capital), and (3) TFP (i.e. productivity with respect to all inputs). TFP is the accurate measure of productivity in that it considers all inputs that affect productivity. However, using TFP poses an economic problem of calculating weights reflecting prices of all inputs. In light of this, statisticians have opted to use the term "MFP", which is the output per weighted average of labour and capital inputs, instead of "TFP", considering that not all inputs are usually included in calculating TFP (Sriyani Dias, 1991). For this study, labour productivity was used, instead of MFP and TFP for both technical and economic reasons.

Technically, the study used labour productivity based on a neoclassical viewpoint, which states that the ICT impacts on labour productivity growth through the traditional capital deepening effects (Baily and Gordon, 1998; Stiroh, 1998; Jorgenson and Stiroh, 1999, cited by Stiroh, 2002a). Therefore, ICT is considered an intermediate input that firms invest in to enhance labour productivity. In turn, investment in ICT affects productivity growth through traditional capital deepening in the ICT-using sector and the "embodied technological change" in the ICT-producing sector. However, distinguishing between traditional capital deepening and the embodied technological change is complex and susceptible to potentially serious measurement problems. Therefore, using labour productivity allows for the examination of the effect of ICT on productivity without having to deal with the problem of distinguishing between traditional capital deepening and embodied technological change. In addition, the data required for the measurement of labour productivity growth and other measures of labour input were more available than data required to accurately measure TFP.

Economically, reasons for using labour productivity are based on the observation that the labour productivity growth of the manufacturing industries could drive South Africa's GDP growth. This is because a highly productive economy implies that the same level of output is produced using fewer resources or more quantities of outputs are produced using the same amount of resources. From this perspective, an increase in labour productivity is, therefore, related to increases in worker's real wages (Krueger, 1993; Freeman, 2002; Rankin, 2016). As such, workers would benefit if an increase in productivity results in higher wages. In addition, an increase in labour productivity stimulates investment and generates higher profits for industries. In the longer term, increased productivity increases employment. In return, increased employment benefits government through higher tax revenues for the government (International Labour Organization (ILO), 2016).

Theoretically and empirically, labour productivity can be estimated using data on either value-added or gross output. For this study, data on gross output, rather than value-added, were used. According to Stiroh (2002a), this choice is in line with other empirical studies that showed that value-added data led to biased estimates and, hence incorrect inferences about production parameters (Basu and Fernald 1995, 1997a, 1997b). Therefore, gross output was used as a measure of labour productivity, which is defined, in this study, as gross output per hours worked. Since the focus of this chapter is to examine which industry group (i.e. between the more ICT-intensive and less ICT-intensive industry groups) contributes more to labour productivity growth, the next section presents the classification of industries into more ICT-intensive and less ICT-intensive industry groups.

3.4.2 Classification of industries by ICT intensity

The three most common indexes are used to disaggregate industries into less ICT-intensive and more ICT-intensive industry groups. The first index entails the disaggregation of industries according to their share of ICT capital services (Stiroh, 2002a). The second index disaggregates industries according to their direct requirement for intermediate ICT inputs (Engelbrecht and Xayavong 2006). The third index disaggregates industries based on their investment in ICT (Abri and Mahmoudzadeh, 2015). In all cases, an industry with an ICT intensity index value of greater than the median value of the index is ranked as "more ICT-intensive", whereas an industry with values less than the median value is “less ICT-intensive".

According to Chen *et al.* (2016), none of the indexes is superior to the others. However, ICT intensity indexes by Stiroh (2002a) and Abri and Mahmoudzadeh (2015) are not suitable for the current analysis as they are based on ICT capital stock, which is unavailable for the current analysis. Consequently, the index described by Engelbrecht and Xayavong (2006) was used in this study because it is based on the I-O data, which are readily available for ranking industries into "less ICT-intensive" and "more ICT-intensive" industry groups based on their direct requirements for intermediate ICT inputs. The justification is that I-O data capture the nature of ICT goods and services produced by the ICT sector and used by other industries. For this reason, using I-O data allows for the disaggregation of the industries into "ICT-using" and "ICT-producing" groupings.

Accordingly, it is assumed that innovation initially occurs in the ICT-producing sector and thereafter spreads to the ICT-using sectors. Consequently, productivity effects are initially experienced by a few industries in the ICT sector and, more specifically, producers of new technologies. Thereafter, productivity effects are realised by other industries when innovations spread across the economy (van Ark, 2014). Against this backdrop, following Engelbrecht and Xayavong (2006), the ICT intensity index was used to calculate the ICT intensity of 23 manufacturing industries, using I-O data for the year 1996. Based on Engelbrecht and Xayavong (2006), the ICT intensity index of an industry (I_j) is defined as industry j's direct requirements for intermediate ICT inputs relative to the total requirements for ICT inputs by other industries, described as follows:

$$I_j = \left(\frac{\sum_{j=1}^{n} ict^* j}{Tj} \right) X\,100 \qquad (3.2)$$

where I_j is the ICT intensity index for industry j's, $\sum_{j=1}^{n} ict * j$ is industry j's direct requirements for intermediate ICT inputs, and T_{aj} is the total requirements for intermediate ICT inputs by all the industries. The results from the ICT intensity index were then used to disaggregate the industries into less ICT-intensive and more ICT-intensive industry groups. Since an examination of whether ICT policies contributed to the labour productivity growth of the manufacturing industries is the main focus of this chapter, the models used to achieve this are described in the next section.

3.4.3 Description of empirical models

The difference-in-differences (DD) technique was applied to achieve the first objective (of the study) of examining whether ICT policies contributed to the labour productivity growth of the agro-processing industries. By its nature, the DD is used to measure the effect of a given policy by comparing the changes in the outcomes of the policy between the control group and treatment group (Wooldridge, 2013). On this account, the DD was employed to estimate the effects of ICT policies on the labour productivity growth of industries. This was achieved by comparing the changes in labour productivity growth, over time, between the less ICT-intensive and more ICT-intensive industries.[39]

The rationale for using the DD is that it has been widely utilised by empirical studies to compare productivity growth over time between the less ICT-intensive and the more ICT-intensive industry groups (McGuckin and Stiroh, 2001; Stiroh, 2002a; Engelbrecht and Xayavong, 2006; Corrado, Haskel, Jona-Lasinio and Iommi 2013; Chen *et al.*, 2016; Corrado *et al.*, 2017). It is acknowledged that an alternative technique to the DD is the traditional growth accounting model. However, the DD technique is preferred over the traditional growth accounting model as it accounts for variations in ICT use across industries. The DD is also preferred due to its ability to control for "time-invariant unobserved heterogeneity", which is impossible to control using cross-sectional data.

In brief, the DD technique was used to estimate the effect of ICT on labour productivity growth outcomes by contrasting the average change over time in the labour productivity growth of the more ICT-intensive industries compared to that of the less ICT-intensive industries. Data on labour productivity of the industries pre-and post-ICT policy eras are required for DD estimation. Given this, data on labour productivity for the 23 manufacturing industries for the period 1970–2016 were used. Data were divided into two sub-periods: 1970–1995 and 1996–2016. The first sub-period represents the pre-policy era, while the second represents the post-policy era.

[39] The less ICT-intensive industries are assumed to be the control group, while the more ICT-intensive industries are the treatment group.

The justification for segregating the eras as outlined is that ICT policy frameworks in South Africa were developed in the second half of the 1990s, in particular from 1996 after the advent of democratic governance in 1994. In line with Engelbrecht and Xayavong (2006), the mean growth rates of labour productivity for each policy era and industry group were calculated. Thereafter, the DD was used to examine whether ICT policies contributed to the labour productivity growth of the manufacturing industries.

In applying the DD, four dummy variable regression models were estimated as expressed in Equations (3.3) to (3.6). Equation (3.3) was used to estimate the growth rate of labour productivity of all industries pre-and post-1996. Equation (3.4) was used to determine the growth rate of labour productivity for the less ICT-intensive industries, pre-and post-1996. Equation (3.5) was used to determine the growth rate of labour productivity for the more ICT-intensive industries, pre-and post-1996. Equation (3.6) was used to test whether the difference in labour productivity growth between the less ICT-intensive and more ICT-intensive industries, pre-and post-1996, is due to ICT. The empirical models are as described below (Engelbrecht and Xayavong, 2006):[40]

$$dLnP_{i,t} = \alpha_0 + \alpha_1 D + \varepsilon_{i,t} \tag{3.3}$$

$$dLnP_{i,t} = \beta_{L0} + \beta L_1 ICT_L + \varepsilon_{i,t} \tag{3.4}$$

$$dLnP_{i,t} = \beta_{M0} + \beta_{M1} ICT_M + \varepsilon_{i,t} \tag{3.5}$$

$$dLnP_{i,t} = \delta_0 + \delta_1 D + \delta_2 ICT + \delta_3 D.ICT + X's + \varepsilon_{i,t} \tag{3.6}$$

The variables in Equations (3.3)–(3.6) are defined as follows:

i, t	i = 1 – 23 industries; t = 1– 46 annual observations for the period 1970–2016
dlnPi,t	an annual growth rate of labour productivity for industry i.
D	Dummy variable wherein D is 1 for t ≥1996, and D is 0 otherwise.
ICT_L	ICT intensity for the industries that are less ICT-intensive.
ICT_M	ICT intensity for the industries that are more ICT-intensive.
ICT	Dummy variable = 1 if an industry is more ICT-intensive, 0 otherwise.
α_0	Mean growth rate of labour productivity, pre-1996.
$\alpha_0 + \alpha_1$	Mean growth rate of labour productivity, post-1996.
α_1	Change in the mean growth rate of labour productivity post-1996.

[40] The equations and the description of parameters and variables were adapted from Engelbrecht and Xayavong (2006).

βL_0	Mean growth rate of labour productivity of less ICT-intensive industries (pre-1996).
$\beta L_0 + \beta L_1$	Mean growth rate of labour productivity for less ICT-intensive industries (post-1996).
βL_1	Change in the mean growth rate of labour productivity for less ICT-intensive industries (post-1996).
BM_0	Mean growth rate of labour productivity for more ICT-intensive industries (pre-1996).
$\beta M_0 + \beta M_1$	Mean growth rate of labour productivity for more ICT-intensive industries (post-1996).
βM_1	Change in the mean growth rate of labour productivity for more ICT-intensive industries (post-1996).
δ_0	Mean growth rate of labour productivity for less ICT-intensive industries (pre-1996).
$\delta_0 + \delta_1$	Mean growth rate of labour productivity for less ICT-intensive industries (post-1996).
δ_1	Acceleration of labour productivity for less ICT-intensive industries (post-1996).
$\delta_0+\delta_2$	Mean growth rate of labour productivity for more ICT-intensive industries (pre-1996)
$\delta_0+\delta_2+\delta_1+\delta_3$	Mean growth rate of labour productivity for more ICT-intensive industries (post-1996).
$\delta_1 + \delta_3$	Acceleration in labour productivity for more ICT-intensive industries (post-1996).
δ_3	Difference-in-differences (differential acceleration) in labour productivity growth rate for more ICT-intensive industries relative to the less ICT-intensive industries.
X's	Explanatory variables, which are the unit cost of labour, employment, remuneration and capital-labour ratio.
$\varepsilon_{i,t}$	Error term.

Although a similar approach to that described by Engelbrecht and Xayavong (2006) was used in the analysis, the approach used deviates from their study in that it accounts for other variables that might influence labour productivity growth, besides ICT. The rationale is that excluding other variables gives rise to omitted variable bias, which results in inconsistent and biased coefficients of estimates (Wooldridge, 2013). To avoid omitted variable bias, four (4) controls (i.e. explanatory variables), which account for labour productivity growth excluding ICT were included in the analysis. These control variables are the unit cost of labour, employment, remuneration and capital-labour ratio.

Empirical evidence on the relationship between the controls and productivity is based on several case studies. A study by the Statistics Netherlands (2006) found a positive correlation between the unit cost of labour and labour productivity. Furthermore, in terms of remuneration, a large number of studies has also found a correlation between labour productivity and wages (remuneration) (Krueger, 1993; Freeman, 2002; Nikulin, 2015; Yildirim, 2013; and Rankin, 2016). Studies on employment have found a negative and statistically significant association between employment growth and productivity growth (Muscatelli and Tirelli, 2001; Junankar, 2013; Gallegati, Gallegati, Ramsey and Semmler, 2014). Moreover, in terms of capital-labour ratio, studies have found a correlation between productivity and capital intensity of industries (Datta, Guthrie and Wright, 2005; Mason and Osborne, 2007; Lannelongue, Gonzalez-Benito, and Quiroz, 2017). The decision about the choice of the explanatory variables is based on data availability, as in reality; other variables might influence labour productivity growth of the manufacturing industries.

The Chow test was performed, before DD estimation, to test for the presence of structural break. In particular, the test was performed to examine whether there was a difference in the labour productivity growth of the industries pre-and post-policy eras. There are two methods of detecting structural break, that is, exogenous detection (when the breakpoint period is known) and endogenous detection (when the breakpoint period is unknown). For this chapter, the exogenous detection method was applied with 1996 as the breakpoint year. In this context, the Chow test was performed by using the same data for the labour productivity of industries from 1970 to 2016.

The rationale for using the Chow test is based on the assumption that the breakpoint period is known, that is, 1996 in the case of this chapter. Accordingly, the periods prior to 1996 account for the pre-policy era, while the periods from 1996 to 2016 account for the post-policy era. This was achieved by testing for the null hypothesis of the absence of structural break against an alternative hypothesis of the presence of structural break.

Following Chow (1960), this was achieved through the following procedures:

1. Running an initial regression for the entire data set (i.e. the “pooled regression”), that is, from 1970 to 2016. The initial regression can be described as follows:

$$LP = \beta_0 + \beta_1 X's + \varepsilon_t \quad (3.7)$$

2. Creating a dummy variable, D_t, for all the regressors wherein $D_t = 0$ pre-policy era and $D_t = 1$ post-policy era. The second regression can be described as follows:[41]

$$LP = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \gamma_0 D_t + \gamma_1 X_1 D_t + \gamma_2 X_2 D_t + \gamma_3 X_3 D_t + \gamma_4 X_4 D_t + \varepsilon_t \quad (3.8)$$

3. Running the second regression with all the regressors and the newly generated series of the dummy variable and the interaction terms, in other words, running the regression as described in (3.8).
4. Calculating the Chow F-statistic by using the Error Sum of Squares (SSE) from each regression. The formula for the Chow test is described as follows:

$$Chow = \frac{(RSS_p - RSS_1 - RSS_2)/k}{(RSS_1 + RSS_2)/(N_1 + N_2 - 2k)} \quad (3.9)$$

   where: RSS_p = the residual sum of squares (RSS) for the pooled regression; RSS_1 = RSS for the pre-policy era; RSS_2 = RSS for the post-policy era; K = number of parameters; $N_1+N_2=N$, where N_1 = the sample size for the pre-policy era; N_2 = sample size for the post-policy era; and N = the full sample size.
5. Testing the sum of squared residuals from (3.7) against (3.8), that is, H_0: $\gamma_0=\gamma_1=\gamma_2=\gamma_3=\gamma_4=0$ against H_1: $\gamma_0\neq\gamma_1\neq\gamma_2\neq\gamma_3\neq\gamma_4\neq 0$. In this regard, if the coefficients are statistically different, it signifies the presence of a structural break and vice versa. The sources of data for the analyses are described in the next section.

3.4.4 Description of data sources

I-O data were used to calculate the ICT intensity industries for the year 1996. However, I-O data for the year 1996 were unavailable as the National Statistical Agency of South Africa (Stats SA) started publishing the ICT satellite accounts, containing I-O tables, annually from 2009–2014, with 2014 being the last year of publication (Parry, 2018). As such, there were missing data for some periods including 1996 (1994–1997, 2001, 2003–2004, 2006 and 2008). Consequently, I-O data for the year 1996 were obtained from the South African Standardised Industry Indicator Database. The database is owned, managed and collected by Quantec. The justification for sourcing I-O data from Quantec is that the database is composed of data on 46 industries and segregates the economy into three key sectors: primary, secondary and tertiary

[41] X's are the explanatory variables, whereby X_1 = unit cost of labour, X_2 = remuneration, X_3 = employment and X_4 = capital to labour ratio.

sectors. Moreover, data from the Central Bank, the South African Reserve Bank (SARB), are used as a benchmark for compiling the data. Thus, Quantec's industry database is consistent with South Africa's public sector accounts, the balance of payments account, and the national accounts of SA. The data are, therefore, compiled using the comprehensive set of industry indicators and national accounts. This results in a consistent input-output framework, and systematic and up-to-date, and set of standardised industry time-series data for South Africa (Quantec, 2018c).

The framework used by Quantec to classify industries in the I-O tables is analogous to that used by the Stats SA. The classification of both the manufacturing industries and ICT used in this chapter is based on the UN's ISIC (Rev.4), which is used by both Quantec and Stats SA (Quantec, 2018c; Stats SA, 2015). Moreover, the industry classification follows a 3-digit ISIC system used by Stats SA. Thus, Quantec's I-O data are based on the last full release and estimates of the dataset by Stats SA. At the time of writing, the Quantec database has been widely used in empirical studies on both financial and economic analyses of the South African economy (Altman, van der Heijden, Mayer and Lewis, 2005; Laubscher, 2011; Burrows and Botha, 2013; Quantec Research, 2016; Mukandla, 2016). The explanatory and their units of measurement are presented in Table 3.1.

Table 3.1: Units of measurement for the explanatory variables

Explanatory variable	**Unit of measurement**
Unit cost of labour	Index of the total wages and salaries paid out by industry or sector divided by the net output (value-added) of that industry and multiplied by 100.
Remuneration	The total amount paid to employees in money or in kind and includes salaries and wages, bonuses and employers' contributions to pension and provident funds.
Employment	The total number of employees in an industry, including formal and informal employment (taking into account both casual and permanent employees).
Capital to labour ratio	An index of the capital stock divided by an index of the number of employees, times 100.

Source: Quantec (2018c)

Data on labour productivity and the explanatory variables (i.e. unit cost of labour, employment, remuneration and capital-labour ratio) were sourced from Quantec's Trend Tables of the South African Standardised Industry Indicator Database (Quantec, 2018c) as Stats SA lacked up-to-date and comprehensive data on the explanatory variables. Specifically, data on labour productivity and the explanatory variables for all the 23 manufacturing industries were extracted from the Quantec database.

3.5 DESCRIPTIVE RESULTS

3.5.1 ICT intensity results for manufacturing industries

The descriptive results of the ICT intensity index and the mean growth rates of labour productivity are provided in this section. As previously stated, an ICT intensity index was used to calculate the ICT intensity of 23 manufacturing industries. In accordance with previous studies (Stiroh, 2002a; Engelbrecht and Xayavong, 2006), the median value of the index was used as a benchmark for disaggregating the industries into less ICT-intensive and more ICT-intensive industry groups.[42] Precisely, the less ICT-intensive industries were industries with index values of less than the median value of the index, while more ICT-intensive were industries with ICT index values of greater than the median value of the index. The ICT intensity results are presented in Table 3.2.[43]

Columns 2 to 5 of Table 3.2 describe the classifications of the corresponding industries in Column 1 as described by previous studies. Column 6 presents the classification of the industries as found in this chapter, while Column 7 provides the results for the ICT intensity index values as found in this study.

[42] The median value is defined, in this study, as the middle value of the index, obtained from a sequence of ICT intensity values ranging from the highest value to the lowest value of the index.

[43] It should be noted that, from Table 3.2, "More/Less" implies that other parts of the industry are categorised as more ICT-intensive, while others are less ICT-intensive. "More" implies that the industry is more ICT-intensive, while "Less" implies that the industry is less ICT-intensive. "N/A" implies that the industry was not included in the study under review.

Table 3.2: ICT intensity of manufacturing industries

Industry	ICT intensity of the industry					ICT intensity index (%)
	Stiroh (2002a)	Ark, Inklaar, and McGuckin (2002)	Engelbrecht and Xayavong (2006)	Abri and Mahmoudzadeh (2015)	This study	
Agro-processing industries						
1. Food	More/Less	Less	Less	Less	More	2.51
2. Beverages	More/Less	Less	Less	Less	More	1.98
3. Tobacco	More/Less	Less	Less	Less	Less	0.21
4. Textile	More/Less	More/Less	Less	More	Less	0.16
5. Wearing apparel	More/Less	More/Less	Less	More	More	1.69
6. Leather & leather products	More/Less	More/Less	Less	More	Less	0.02
7. Wood & wood products	Less	Less	Less	Less	More	0.46
8. Paper & paper products	Less	Less	Less	Less	Less	0.14
9. Rubber products	Less	Less	Less	N/A	Less	0.14
10. Furniture	More/Less	More/Less	Less	Less	Less	0.41
ICT manufacturing industries						
11. Printing, publishing & recorded media	More	More	More	More	More	8.44
12. Radio, TV instruments, watches & clocks	N/A	N/A	N/A	More	More	37.69
13. TV, radio, communication equipment	N/A	N/A	N/A	More	More	35.86
Rest of the manufacturing industries						
14. Coke & Refined petroleum	Less	Less	Less	Less	Less	0.11
15. Basic chemicals	Less	Less	More	More	Less	0.34
16. Other chemicals & man-made fibres	N/A	N/A	More	N/A	More	1.08
17. Other non-metallic products	N/A	N/A	N/A	Less	Less	0.27
18. Glass & glass products	N/A	N/A	N/A	N/A	Less	0.04
19. Non-metallic mineral products	Less	Less	Less	Less	Less	0.23

Table 3.2 continued

20. Machinery & equipment	More	More	More	N/A	More	2.12
21. Electrical machinery & apparatus	N/A	N/A	N/A	More	More	3.40
22. Transport equipment	More/Less	Less	More	Less	More	1.92
23.Motor vehicles, parts & accessories	N/A	Less	N/A	Less	More	0.80

Source: Author's classification based on previous studies

The findings presented in Table 3.2 show that 52% of the manufacturing industries (i.e. more than half of the industries) were categorised as more ICT-intensive, while the remaining 48% were less ICT-intensive. In the case of the agro-processing industries, four industries (food, beverages, wood and wearing apparel) were ranked as more ICT-intensive industries. This means that these four industries had the highest share of direct requirements for intermediate ICT inputs. In contrast, the other six industries (textile, paper, furniture, leather, tobacco and rubber) were less ICT-intensive. This implies that these industries had the lowest share of direct requirements for intermediate ICT inputs. In terms of the rest of the manufacturing industries, four industries (“manufacture of other chemicals, machinery and equipment, electrical machinery equipment, and transport equipment and motor vehicles”) were ranked as more ICT-intensive, while the remaining manufacturing industries were less ICT-intensive.

Overall, the ICT manufacturing industries had the highest share of ICT intensity. Specifically, of the 23 manufacturing industries, the ICT industries accounted for 82% of the share of direct requirements for intermediate ICT inputs. These findings are in accordance with the observation that the ICT sector is the most intensive user of ICT goods and services (OECED, 2016). However, it should be noted that most of the intermediate ICT inputs originate from imports in that the ICT sector in South Africa relies on imports from other countries for the provision of ICT. This is evident through the ICT trade deficit, which grew from R42 billion in 2011 to R97 billion in 2014 (Stats SA, 2017).

In brief, the findings from the ICT intensity index were used to categorise the manufacturing industries into more ICT-intensive and less ICT-intensive industry groups. Given that part of the chapter includes determining which industry group contributed more or less to labour productivity growth, the labour productivity growth rates of the industries were calculated. The findings are presented in the next section.

3.5.2 Labour productivity growth rates of industries

Before discussing the labour productivity growth results, it should be noted that one of the rationales for focusing on the manufacturing sector is that it is a sector that has been identified in the growth and development policy plans as one of the sectors with the potential to drive South Africa's GDP growth and create employment. In the light of this, it is of interest to highlight those policies and discuss the results with respect to the labour productivity growth pre and post the growth and development policies. The growth and development policies are, sequentially, the GEAR, AsgiSA, the NGP, the NIFP, the IPAP, the NGP, the NDP and the 9-Point Plan.[44]

A critical observation derived from these policies is that the first policy, the GEAR, was implemented in 1996 at the same time as the first ICT policy after the advent of democratic governance, which was implemented in 1996. It is on this basis that the pre-ICT policy era is defined as being from 1970 to 1995, whereas the post-ICT era is from 1996 to 2016. Equally important, it is on this premise that both the pre-policy era and post-policy era are also adopted for the growth and development policy plans. Accordingly, the discussion of the labour productivity growth results includes the difference in labour productivity growth pre and post the growth and development policies. The labour productivity growth rates for the manufacturing industries for the entire period (1970–2016) and sub-periods (1970–1995 and 1996–2016) are presented in Table 3.3.

[44] These policies have been discussed in detail in section 2.3 of chapter 2. The GEAR and AsgiSA are no longer in effect. The policies that are in effect, at the time of writing, are the NGP, the NIFP, the IPAP, the NGP, the NDP and the 9-Point Plan.

Table 3.3: Labour productivity growth rates of industries

Annual growth rate (%)					
Industry	1970-2016	1970-1995	1996-2016	Acceleration [(1996-2016)-(1970-1995)]	Is there an acceleration in labour productivity?
Agro-processing industries					
Food	2.56	1.62	4.01	2.39	Yes
Beverages	1.25	3.38	-1.51	-4.89	No
Tobacco	1.24	3.38	-1.51	-4.89	No
Textile	1.20	0.92	2.63	1.71	Yes
Wearing apparel	1.28	0.42	5.31	4.89	Yes
Leather	1.27	1.14	1.09	-0.05	No
Wood	0.52	0.08	1.42	1.34	Yes
Paper	1.04	1.11	1.31	0.2	Yes
Rubber	1.04	1.11	1.31	0.2	Yes
Furniture	1.85	0.67	3.74	3.07	Yes
ICT manufacturing industries					
Printing	-0.49	-1.03	0.10	1.13	Yes
Radio, TV instruments	1.26	0.12	0.93	0.81	Yes
TV, radio, communication equipment	1.92	0.25	1.50	1.25	Yes
Rest of the manufacturing industries					
Coke and Refined petroleum	1.37	1.44	1.22	-0.22	No
Basic chemicals	2.92	2.15	3.60	1.45	Yes
Other chemicals	2.09	3.13	0.60	-2.53	No
Other non-metallic products	1.58	-0.39	4.33	4.72	Yes
Glass and Glass Products	3.24	2.96	3.96	1	Yes
Non-metallic mineral products	1.32	-0.80	4.23	5.03	Yes
Machinery and Equipment	0.83	0.12	1.61	1.49	Yes
Electrical machinery and Equipment	1.95	1.85	2.97	1.12	Yes
Transport equipment	1.08	-0.90	3.66	4.56	Yes
Motor vehicle parts	2.28	1.09	4.22	3.13	Yes

Source: Author's calculations based on Engelbrecht and Xayavong (2006)

The findings show that 78.2% of the manufacturing industries (i.e. most of the industries) exhibited positive growth in labour productivity across all periods. In particular, 86.9% of the industries (i.e. 20 out of 23) showed an acceleration in labour productivity growth.[45] In the context of the agro-processing industries, 80% of the industries demonstrated an acceleration in labour productivity growth.

To identify the industry group exhibiting more growth, the industries were categorised into two groups, namely Category A and Category B. Category A is for all the manufacturing industries as shown in Table 3.3. Category B is for the agro-processing industries. In each category, the labour productivity growth rates of both the less ICT-intensive industry group and the more ICT-intensive industries were calculated. This allowed the industry contributing more to labour productivity growth to be identified. The findings for the labour productivity growth rates for the two categories for the periods under study are presented in Table 3.4.

Table 3.4: Labour productivity growth rates, categories

Annual growth rate (%)				
	1970-2016	1970-1995	**1996-2016**	**Acceleration [(1996-2016)-(1970-1995)]**
Category A[46]				
Mean growth rate for more ICT-intensive industries	1.61	0.76	3.00	2.24
Mean growth rate for less ICT-intensive industries	2.46	1.68	3.65	1.97
Total	**4.07**	**2.44**	**6.65**	**4.21**
Category B[47]				
Mean growth rate for more ICT-intensive industries	1.89	1.24	3.00	1.76
Mean growth rate for less ICT-intensive industries	2.39	2.08	3.00	0.92
Total	**4.28**	**3.3.2**	**6.00**	**2.68**
Category C[48]				
Mean growth rate for more ICT-intensive industries	1.89	1.28	2.90	1.62
Mean growth rate for less ICT-intensive industries	2.46	1.68	3.65	1.97
Total	**4.35**	**2.96**	**6.55**	**3.59**

Source: Author's calculations based on Engelbrecht and Xayavong (2006)

[45] Acceleration means that the mean growth of labour productivity increased over time, and vice versa for deceleration.
[46] Category A = All the 23 industries.
[47] Category B = Agro-processing industries.
[48] Category C = All industries in Category A, excluding the ICT manufacturing industries.

The results for Category A (i.e. all manufacturing industries) show that labour productivity growth rates for the post-policy era in the case of both the less and more ICT-intensive industries were higher than those for the pre-policy era. Specifically, the labour productivity growth rate for the manufacturing industries post-1996 was 6.65%, whereas that for the pre-policy era was 2.44%. This suggests that the labour productivity of the manufacturing industries increased post the growth and development policies era and post the ICT policies era.

The findings for labour productivity growth rates in Category B industries (i.e. agro-processing industries) indicate that labour productivity growth in the post-policy era, in the case of both the more and less ICT-intensive industries, was higher than that in the pre-policy era. Specifically, the labour productivity growth rate for the agro-processing industries in the post-policy era was 6.00% compared to 3.32% in the pre-policy era. This suggests that the labour productivity of the agro-processing industries increased post the growth and development policies era and post the ICT policies era. In terms of acceleration in Category A industries, both the less and more ICT-intensive industries exhibited an acceleration in labour productivity growth. However, the labour productivity growth rates of the less ICT-intensive industries were slightly lower than that of the more ICT-intensive industries (i.e. 1.97% compared to 2.24%), as shown in Figure 3.1.

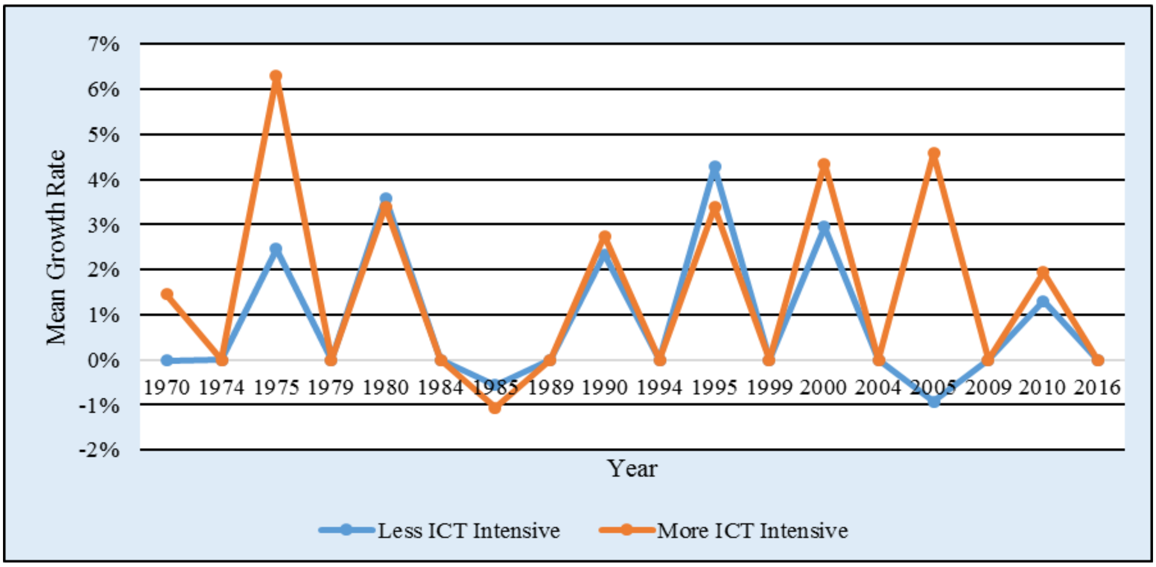

Figure 3.1: Mean growth rates of industries, Category A
Source: Author based on Quantec (2018b)

In particular, the more ICT-intensive industries displayed an upward and downward trend in labour productivity growth over the entire period, whereas the less ICT-intensive industries displayed a positive but stagnant trend. Overall, the more ICT-intensive manufacturing industries exhibited higher acceleration (an increase over time) than the less ICT-intensive industries.

The findings for Category B (agro-processing industries) are that both the less and more ICT-intensive industries exhibited an acceleration in labour productivity growth. However, the less ICT-intensive industries experienced a slightly lower acceleration in labour productivity growth than the more ICT-intensive industries (0.92% compared to 1.76%), as presented in Figure 3.2. This means that the more ICT-intensive agro-processing industries exhibited higher acceleration (an increase over time) than the less ICT-intensive industries.

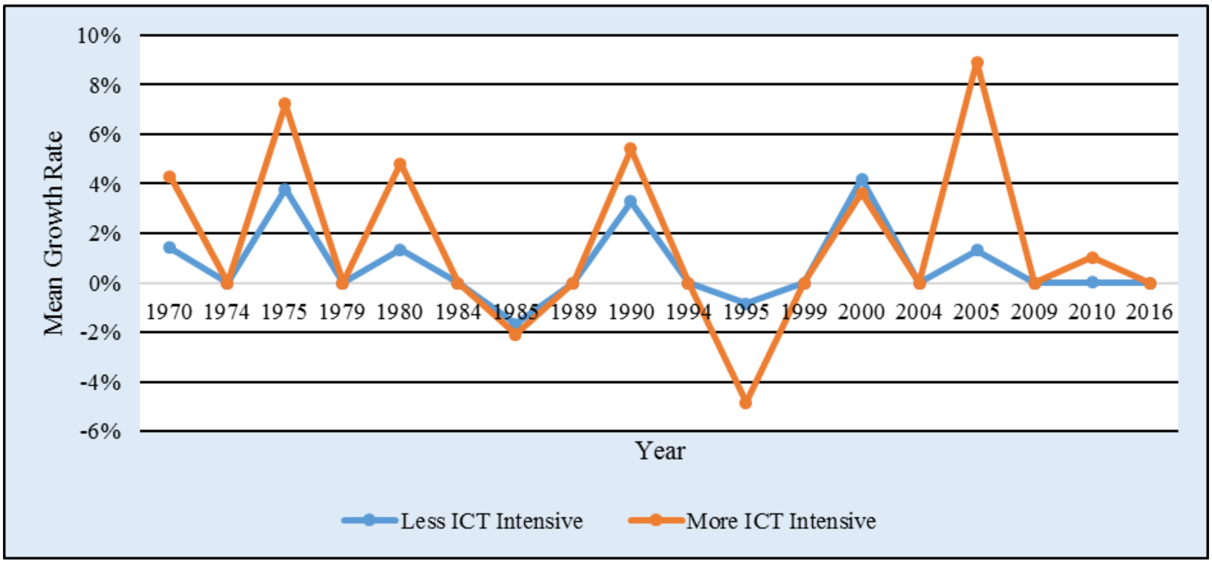

Figure 3.2: Mean growth rates of industries, Category B
Source: Author, based on Quantec (2018b)

In general, the findings show that the more ICT-intensive industries outperformed their counterparts with respect to labour productivity growth regardless of the category. This means that the more ICT-intensive industries contributed more to the labour productivity growth of the manufacturing industries. These findings are in accordance with those of other countries reported in previous studies. For instance, in New Zealand, Engelbrecht and Xayavong (2006) found that labour productivity growth was higher for the more ICT-intensive industries compared to the less ICT-intensive industries. In Iran, Abri and Mahmoudzadeh (2015) found that although ICT had a positive and significant effect on the productivity of all the manufacturing industries, effects were higher for the more ICT-intensive industries relative to other industries.

However, Engelbrecht and Xayavong (2006) noted that there were conflicting international findings on whether the ICT-producing industries contributed more or less to labour productivity growth relative to the ICT-using industries. In support of this, a study by van Ark *et al.* (2002) revealed that the US's ICT-using industries (i.e. retail and wholesale industries) displayed higher productivity growth in the late 1990s, whereas the ICT sector (telecommunications) exhibited lower growth.

Contrary to van Ark *et al.* (2002), Engelbrecht and Xayavong (2006) found that the wholesale and retail industries (ICT-using industries) in New Zealand exhibited lower labour productivity growth, whereas the communication industries (ICT industries) displayed higher growth. In the case of Iran, a study by Abri and Mahmoudzadeh (2015) detected that there was no significant difference in terms of labour productivity growth between the ICT-using and ICT-producing industries. Given this conflicting evidence, the three ICT manufacturing industries were removed from Category A. Thereafter, the growth rates of labour productivity of the manufacturing industries, excluding the ICT manufacturing industries were calculated.[49] The industries excluding the ICT manufacturing industries were then defined as Category C. The results are included in Table 3.4.

The findings for the labour productivity growth of the manufacturing industries, excluding the ICT manufacturing industries, show that the labour productivity in the post-policy era, in the case of both the less and more ICT-intensive industries was higher than that in the pre-policy era. Specifically, the labour productivity growth of the industries in the post-policy era was 6.55% and 2.96% in the pre-policy era. This suggests that the labour productivity of the manufacturing industries increased post the growth and development policies era and post the ICT policies era.

[49] ICT-producing industries comprise the manufacture of printing, publishing and recorded media; the manufacture of radio, TV and instruments; and the manufacture of TV, radio, and communication equipment.

The findings further show that there was a decline in labour productivity growth of the more ICT-intensive industries (i.e. from 2.24% to 1.62%), when the ICT industries were excluded from the analysis. Further to this, with the exclusion of the ICT manufacturing industries, the less ICT-intensive industries experienced a higher acceleration in labour productivity growth than the more ICT-intensive industries (1.97% compared to 1.62%). This finding suggests that the labour productivity growth rate of the more ICT-intensive industries is driven by the ICT-producing manufacturing industries. This conclusion is logical given that ICT industries registered higher labour productivity growth rates. More particularly, the manufacture of the printing, publishing and recorded media industry group registered the highest labour productivity growth rate among all the 23 industries. Since most of the intermediate ICT inputs originate from imports (Stats SA 2017); this finding suggests that ICT imports could have driven the labour productivity growth of the ICT manufacturing industries.

Overall, the findings for the growth rates show that the labour productivity of the industries increased post-1996. The findings also show that labour productivity growth rates for the more ICT-intensive industries, in each category, were higher than those for the less ICT-intensive industries. On this basis, the next section serves to test whether the difference in labour productivity growth between the more and less ICT-intensive industries is due to ICT policies.

3.6 EMPIRICAL RESULTS

The descriptive results show that growth rates of labour productivity of the more ICT-intensive industries were higher than those of the less ICT-intensive industries. Moreover, the results suggest that the ICT manufacturing industries contributed more to the labour productivity growth of the more ICT-intensive industries. Therefore, this section provides evidence on whether the differences in the growth rates of labour productivity between the industry groups are statistically significant. In particular, the section provides empirical evidence on whether the differences in growth rates of labour productivity between the industry groups are attributable to ICT. Equations (3.3)–(3.5) were used to analyse data for all the Categories (A, B and C). The findings are presented in Table 3.5.

Table 3.5: Estimates of the relationship between labour productivity growth and ICT intensity: Equations (3.3)–(3.5)

Eq. (3.3)	**Category A**		**Category B**		**Category C**	
α_0	0.173 (0.004)	Pr(T<t) = 0.997	0.022 (0.006)	Pr(T<t) = 0.832	0.019 (0.004)	Pr(T<t) =0.987
$\alpha_0 + \alpha_1$	0.359*** (0.007)	Pr(T>t) = 0.003	0.033 (0.011)	Pr(T>t) = 0.168	0.036** (0.006)	Pr(T>t) = 0.014
α_1	0.187*** (0.007)	$Pr(\lvert T\rvert>\lvert t\rvert)$ = 0.005	0.012 (0.119)	$Pr(\lvert T\rvert>\lvert t\rvert)$ = 0.335	0.016** (0.007)	$Pr(\lvert T\rvert>\lvert t\rvert)$ =0.027
T-statistic	2.776		0.9642		2214	
No of Obs	1058		460		920	
Eq. (3.4)						
βL_0	0.208 (0.006)	Pr(T<t) = 0.962	0.023 (0.082)	Pr(T<t) = 0.755		
$\beta L_0 + \beta L_1$	0.411** (0.103)	Pr(T>t) = 0.030	0.035 (0.016)	Pr(T>t) = 0.245		
βL_1	0.203* (0.114)	$Pr(\lvert T\rvert>\lvert t\rvert)$ = 0.070	0.012 (0.017)	$Pr(\lvert T\rvert>\lvert t\rvert)$ = 0.489		
T-statistic	1.776		0.692			
No of Obs	506		276			
Eq. (3.5)						
β_0	0.014 (0.005)	Pr(T<t) = 0.989	0.020 (0.020)	Pr(T<t) = 0.764	0.018 (0.006)	Pr(T<t) = 0.908
$\beta_0 + \beta M_1$	0.312** (0.006)	Pr(T>t) = 0.011	0.031 (0.031)	Pr(T>t) = 0.237	0.030* (0.007)	Pr(T>t) = 0.091
βM_1	0.017** (0.008)	$Pr(\lvert T\rvert>\lvert t\rvert)$ = 0.023	0.011 (0.015)	$Pr(\lvert T\rvert>\lvert t\rvert)$ = 0.473	0.012 (0.009)	$Pr(\lvert T\rvert>\lvert t\rvert)$ = 0.1829
T-statistic	2.285		0.7193		1.334	
No of Obs	552		184		414	

Source: Author's own compilation

Notes: The dependent variable = Annual growth rate of labour productivity. Figures in parenthesis are standard errors. * P < 0.01, ** P < 0.05, *** P < 0.001. Pr (T<t), Pr (T>t), Pr (|T|>|t|) are the P-values for the pre-1996, post-1996 and post-1996 minus pre-1996, respectively. No. of Obs= Number of observations.

Before discussing the results, it must be noted that Category A consisted of all the 23 industries, whereas Category B consisted of the agro-processing industries. Category C consisted of all the manufacturing industries excluding the ICT manufacturing industries. The descriptive results show that the ICT manufacturing industries were ranked as more ICT-intensive based on the descriptive statistics. From this perspective, there were no results for Category C (Equation 3.4), as Equation (3.4) was for the less ICT-intensive industries.

The findings for Category A (all manufacturing industries) revealed that the estimate for labour productivity growth in the industries pre-1996 era was insignificant, while the estimate for the post-1996 era was significant (i.e. Category A, Equation (3.3)). Moreover, the post-1996 estimate was higher than the pre-1996 recorded estimate. The implication is that the labour productivity growth of the manufacturing industries accelerated more post-1996 than pre-1996. Most importantly, the DD estimator (α_1) was significant, which indicates that the labour productivity of the manufacturing industries increased post-1996. These results conform to those of Rankin (2016) who established that the labour productivity of South Africa's manufacturing sector increased after 1994.

A Chow test was conducted to validate whether the coefficients for the pre-and post-policy eras were statistically different. This was achieved by testing for the structural breaks in the data in 1996. The results of the Chow test are presented in Table 3.6.

Table 3.6: Chow test results

F-statistics	92.83	Prob. (5, 35)	0.000
Log-likelihood ratio	82.93	Prob. Chi-Square	0.000
Wald statistics	280.15	Prob. Chi-Square	0.000
Chow breakpoint test: 1996, Equation Sample: 1970 – 2016			

Source: Author, based on Quantec (2018a)

The findings indicate that there was evidence of a structural break in the period 1996. This is because the probability values of the F-statistics, Log-likelihood ratio and Wald statistics were significant at 1% level of significance. This confirms that the labour productivity of the manufacturing industries increased from 1996. The findings for the less ICT-intensive manufacturing industries show that the labour productivity growth estimate for the pre-1996 era was insignificant, whereas that for the post-1996 era was significant (Category A, Equation (3.4)). This means that there is no statistically significant increase in the labour productivity growth estimate for the pre-1996 era. These findings imply that labour productivity growth of the less ICT-intensive industries accelerated more post-1996 than pre-1996. It is important to note that the estimator for the DD (βL_1) was significant, suggesting that labour productivity for less ICT-intensive industries increased post-1996.

Similar to the findings for the less ICT-intensive industries, the labour productivity growth for more ICT-intensive industries accelerated more post-1996 than pre-1996. Moreover, the estimator (βM_1) was significant, validating that labour productivity growth for the more ICT-intensive industries increased post-1996 (i.e. Category A, Equation (3.5)). However, it is important to note that this applies only when ICT manufacturing industries are included in the analysis, as the estimator (βM_1) was insignificant when the ICT manufacturing industries were excluded (i.e. Category C, Equation (3.5)). The findings show that the ICT manufacturing industries contributed more to the labour productivity growth of the more ICT-intensive industries. These results conform to the empirical study by Engelbrecht and Xayavong (2006), which showed that ICT manufacturing industries are the key driver of labour productivity growth.

The analyses were extended to Category B by estimating Equations (3.3) to (3.5) to examine the contribution of ICT to the labour productivity growth of the agro-processing industries. According to Abri and Mahmoudzadeh (2015), the justification for doing so is that ICT contributes directly to the growth of ICT-producing industries and indirectly to the productivity growth of ICT-using industries. Following van Ark (2014), it is assumed that the labour productivity effects of ICT are initially experienced in the ICT sector (i.e. ICT-producing industries) and thereafter in other sectors (ICT-using industries, including the agro-processing industries) as technology spreads across the economy. Hence, the analyses were extended to the agro-processing industries.

The findings show that estimates for both the pre-1996 and post-1996 were insignificant. The same was true for the DD estimators in the case of the less ICT-intensive industries (βL_1), the more ICT-intensive industries (βM_1) and the agro-processing industries in totality (α_1). The implication is that there was no acceleration in labour productivity growth of the agro-processing industries pre-and post-1996. This applies to both the more ICT-intensive and less ICT-intensive industry groups. In general, the findings show that the more ICT-intensive industries contributed more to labour productivity growth than the less ICT-intensive industries.

From this perspective, Equation (3.6) was estimated to validate whether the difference in labour productivity growth between the less and more ICT-intensive industries pre-and post-1996 could be attributed to ICT. To this end, Equation (3.6) was estimated for Categories A, B and C, with and without the explanatory variables. Accordingly, Equation (3.6) was isolated into two wherein Equation (3.6a) excluded the explanatory variables, while Equation (3.6b) included the explanatory variables. Consequently, the variance inflation factor (VIF) analysis was conducted before estimating Equation (3.6b) to avoid multicollinearity among the explanatory variables.[50] The VIF results are as presented in Table 3.7.

Table 3.7: VIF results

Variable	**VIF value**
ICT	1.02
Unit cost	5.59
Capital-labour ratio	1.27
Remuneration	1.62
Employment	1.01

Source: Author, based on Quantec (2018a)

The VIF results show that there was no collinearity problem for three variables, which are capital-labour ratio, remuneration and employment, as they have VIF values of less than 5.[51] This implies that there was sufficient evidence to justify the integration of these explanatory variables in the analysis. However, this is distinct from the unit cost of labour variable, which has a VIF value of 5.59, suggesting the existence of a moderate correlation. Consequently, the unit cost of labour variable was deleted from the analysis to avoid multicollinearity. Ultimately, (3.6a) and (3.6b) were estimated, respectively. The results are presented in Table 3.8.

The findings demonstrate that the DD estimator (δ_3) for Equation (3.6b) was slightly larger than that for Equation (3.6a), regardless of category group. In other words, the estimator was higher with the inclusion of the explanatory variables than with the exclusion of the explanatory variables. In particular, the derived estimator shows that the more ICT-intensive industries contributed 7% more to labour productivity growth when the explanatory variables were included in the analysis and 5% when the explanatory variables were excluded. These findings

[50] VIF analysis was used as it detects multicollinearity better than correlation coefficients, which are univariate.
[51] The VIF value of less than 5 indicates that there is no collinearity, whereas that of more than 5 signifies the presence of collinearity.

imply that, with the exclusion of the explanatory variables, the contribution of the more ICT-intensive industries to labour productivity growth was underestimated, as evidenced by a higher DD estimator when the explanatory variables were included. This finding justifies the inclusion of other variables, besides ICT, that influence the labour productivity growth of industries. Hence, Equation (3.6b) was estimated to find out the effect of three explanatory variables, namely, employment, remuneration and capital-labour ratio, on labour productivity. The findings are presented in Table 3.8.

Table 3.8: Estimates of the relationship between labour productivity growth and ICT intensity: Equation (3.6)

Eq. (3.3)	**Category A**		**Category B**		**Category C**	
α_0	0.173 (0.004)	Pr(T<t) = 0.997	0.022 (0.006)	Pr(T<t) = 0.832	0.019 (0.004)	Pr(T<t) = 0.987
$\alpha_0 + \alpha_1$	0.359*** (0.007)	Pr(T>t) = 0.003	0.033 (0.011)	Pr(T>t) = 0.168	0.036** (0.006)	Pr(T>t) = 0.014
α_1	0.187*** (0.007)	Pr(|T|>|t|) = 0.005	0.012 (0.119)	Pr(|T|>|t|) = 0.335	0.016** (0.007)	Pr(|T|>|t|) = 0.027
T-statistic	2.776		0.9642		2214	
No of Obs	1058		460		920	
Eq. (3.4)						
βL_0	0.208 (0.006)	Pr(T<t) = 0.962	0.023 (0.082)	Pr(T<t) = 0.755		
$\beta L_0 + \beta L_1$	0.411** (0.103)	Pr(T>t) = 0.030	0.035 (0.016)	Pr(T>t) = 0.245		
βL_1	0.203* (0.114)	Pr(|T|>|t|) = 0.070	0.012 (0.017)	Pr(|T|>|t|) = 0.489		
T-statistic	1.776		0.692			
No of Obs	506		276			
Eq. (3.5)						
β_0	0.014 (0.005)	Pr(T<t) = 0.989	0.020 (0.020)	Pr(T<t) = 0.764	0.018 (0.006)	Pr(T<t) = 0.908
$\beta_0 + \beta M_1$	0.312** (0.006)	Pr(T>t) = 0.011	0.031 (0.031)	Pr(T>t) = 0.237	0.030* (0.007)	Pr(T>t) = 0.091
βM_1	0.017** (0.008)	Pr(|T|>|t|) = 0.023	0.011 (0.015)	Pr(|T|>|t|) = 0.473	0.012 (0.009)	Pr(|T|>|t|) = 0.1829
T-statistic	2.285		0.7193		1.334	
No of Obs	552		184		414	

Source: Author's own compilation

Notes: The dependent variable = Annual growth rate of labour productivity. Figures in parenthesis are standard errors. * P < 0.01, ** P < 0.05, *** P < 0.001. Pr (T<t), Pr (T>t), Pr (|T|>|t|) are the P-values for the pre-1996, post-1996 and post-1996 minus pre-1996, respectively. No. of Obs = Number of observations

The findings show that, regardless of the category, both capital-labour ratio and remuneration had a positive effect on labour productivity growth, whereas employment had a negative effect. However, of the three explanatory variables, only remuneration was significant. These findings for remuneration imply that labour productivity of the manufacturing industries, including the agro-processing industries, would increase as remuneration increases. These findings are in line with those of previous studies, which found a positive correlation between labour productivity (i.e. greater hours worked) and higher wages (Krueger, 1993; Freeman, 2002; Nikulin, 2015). The findings are also in line with those found in South Africa by Rankin (2016), who found that manufacturing industries with higher labour productivity had the highest average wage. Overall, the findings for remuneration imply that workers would benefit from being productive through higher wages if an increase in labour productivity leads to higher wages. In addition, employees would benefit if an increase in labour productivity leads to higher profit through the sale of higher output.

After testing for the effect of the explanatory variables on labour productivity growth, the study tested whether the observed difference in the growth rates of labour productivity between the less and more ICT-intensive industries can be attributed to ICT. The findings show the DD estimators were not statistically significant, regardless of the category, and with and without controls. The implication is that, overall, regardless of the industry category, the difference in the growth rates of labour productivity between the less and more ICT-intensive industry groups cannot be attributed to ICT. These findings contrast with the findings of other studies, which have established a significant and positive effect of ICT on the productivity of the more ICT-intensive manufacturing industries (Lee *et al.*, 2005; Abri and Mahmoudzadeh, 2015; Niebel *et al.*, 2016). However, the findings conform to the observation by Joseph (2002) and Niebel (2018) that ICT-led productivity growth has been confined to developed countries. This finding has two implications for South Africa. The first implication is that the ICT policies that have been implemented post-1994 are yet to contribute to the labour productivity growth of the manufacturing industries. The second implication is that the non-ICT industries are yet to experience productivity gains from ICT use.

The derived DD estimator for Category B was also insignificant. This implies that the difference in the growth rates of labour productivity between the less and more ICT-intensive industries of the agro-processing subsector cannot be attributed to ICT use. This finding implies that the contribution of ICT to the labour productivity growth of the agro-processing industries is not observable, implying also that ICT policies are yet to contribute to the labour productivity growth of the agro-processing industries. The finding further implies that the agro-processing industries are yet to benefit from ICT policies that have been implemented post-1994. This reasoning is similar to that of Kuppusamy *et al.* (2009), who assert that Malaysia's agriculture had not gained from technological advancement at the national level because of the insignificant findings regarding the elasticity of ICT with respect to agriculture's contribution to GDP in Malaysia.

The insignificant findings for the agro-processing industries, though unexpected, are logical in that they can be attributed to three factors. The first factor is that South Africa's ICT policies have not focused on ensuring access to and usage of ICT goods and services in the non-ICT industries. However, comparatively, other empirical studies have detected significant findings for non-ICT industries that are more ICT-intensive (Jorgenson and Stiroh, 2000; Stiroh, 2002a; O'Mahony and van Ark, 2003). The findings from these studies departed from this present study in that these empirical studies did not exclusively focus on the agro-processing industries. The second factor is that the main assumption of the present study is that industries that have invested more in ICT (i.e. more ICT-intensive industries) would experience higher growth in labour productivity than those that have invested less (i.e. less ICT-intensive industries). However, the study established that the agro-processing industries had invested less in ICT, as they accounted for only 7.72% of the direct requirements for intermediate ICT inputs. This is because most agro-processing industries are resource-based and not information-intensive (Kuppusamy *et al.*, 2009; Shyam, 2011; Campana and Cimatti, 2015).

The third factor is that gains in labour productivity from ICT use are observable over a longer period, which calls for forecasting. However, the DD technique does not consider the future potential contribution of ICT to the labour productivity growth of the industries over a long period. For this reason, the insignificant findings derived from the agro-processing industries are not conclusive. In other words, the insignificant findings do not imply that ICT use does not affect labour productivity growth of the agro-processing industries. Instead, they suggest that the effect of ICT on labour productivity growth of the agro-processing industries might be notable over a longer period.

This chapter effectively tested whether ICT policies contributed to the labour productivity growth of the industries. The findings indicated that the contribution of ICT policies to the labour productivity growth of the industries is unobservable. A summary of the findings is provided in the next section.

3.7 CHAPTER SUMMARY

This chapter provided empirical evidence on whether ICT policies contributed to the growth in labour productivity of the agro-processing industries. The ICT intensity index was used to rank manufacturing industries into two industry groups: less ICT-intensive industry group and more ICT-intensive industry group. The disaggregation of the industries into the two industry groups was imperative in that, in reality, the extent of ICT use varies across the industries. As such, the labour productivity effects of ICT would vary across the industries. Thus, the disaggregation of the industries was needed to identify the industries contributing more to labour productivity growth rates. In particular, the link between the growth rates of labour productivity in manufacturing industries and ICT intensity was examined in this chapter.

The analyses were for the period (1970–2016) and two sub-periods (1970–1995) and 1996–2016), where the 1970–1995 sub-period represented the pre-policy era and the 1996–2016 sub-period represented the post-policy era. The analyses provide an insight into whether labour productivity growth in South Africa's manufacturing sector post-1994 was attributable to ICT use. This was achieved by comparing the changes in labour productivity growth over time between the less ICT-intensive and more ICT-intensive industries, pre-and post-1996.

The findings of this chapter can be summarised in three points. Firstly, the results showed that labour productivity growth of the manufacturing industries accelerated (increased over time) post-1996 in the case of both the less and more ICT-intensive industry groups. This applied to all the manufacturing industries (Category A), agro-processing industries (Category B) and the manufacturing industries excluding the ICT manufacturing industries (Category C). However, regardless of category, the derived DD estimators for the more ICT-intensive industries were greater than those for the less ICT-intensive industries. This implies that the more ICT-intensive industry group contributed more to growth in labour productivity of the manufacturing industries, including the agro-processing industries.

Secondly, the derived DD estimator (δ_3) for the more ICT-intensive industry group was significant only when the ICT manufacturing industries were included in the analysis. The implication is that the ICT manufacturing industries contributed more to growth in the labour productivity of more ICT-intensive industries. This reasoning is logical because the ICT manufacturing industries accounted for the largest share of the direct requirements for intermediate ICT inputs.

Thirdly, although the more ICT-intensive industry group contributed more to labour productivity growth than the less ICT-intensive industry group, the difference in the growth rates of labour productivity between the two groups cannot be attributed to ICT use. The reason for this is that the derived DD estimator (δ_3) was insignificant. In addition, the difference in the growth rates of labour productivity between the less ICT-intensive and more ICT-intensive agro-processing industries cannot be attributed to ICT use. The implication is that the ICT policies have not yet contributed to the labour productivity growth of the agro-processing industries. Thus, in this chapter, the first objective of the study to examine whether ICT policies contributed to the labour productivity growth of the agro-processing industries has been achieved.

Five delimitations that could have contributed to the findings reported in this chapter have been identified. The first delimitation is that the trend in ICT use over the years has not been accounted for as only I-O data for the year 1996 was used in ranking the industries into less and more ICT-intensive industry groups. As such, some industries might have used ICT more or less intensively pre-and post-1996. The second delimitation is that the DD technique does not account for the causal relationship between the labour productivity growth of industries and ICT use. The third delimitation is that the DD technique does not capture (quantify) how long it would take for industries to experience gains from ICT investment. This delimitation is based on Becchetti *et al*. (2003)'s assertion that the returns on ICT investment take time to materialise.

The fourth limitation is that the focus was on intermediate ICT inputs from the manufacturing industries given that the focus was on the manufacturing sector. From this perspective, contrary results could be obtained if intermediate ICT inputs from other ICT industries such as the ICT service industries were to be included in the analysis. The fifth delimitation is that the study examined the contribution of ICT to the growth of labour productivity only. However, according to the theoretical framework of the study, which was presented in Section 1.5 of chapter 1, there exists a relationship between ICT and labour productivity, output and employment. It is, therefore, appropriate to examine whether ICT would contribute to the growth of not only labour productivity but also output and employment.

The remaining chapters serve to address the delimitations that have been identified in this chapter. Specifically, the delimitations are addressed in the following chapters as follows. The ICT intensity index is used to calculate the ICT intensity of industries using all intermediate ICT inputs, instead of only those from the ICT manufacturing industries. The data used for calculating the ICT intensity of the industries are from 1994 to 2017, instead of only 1996. In addition to this, the annual growth rates of output and employment are calculated for the period 1994–2017, including those of labour productivity. The information from the ICT intensity and annual growth rates are used to address the remaining objectives of the study (objectives (2)–(4)) as follows. In chapter 4, the effects of ICT intensity on growth of labour productivity, output and employment are estimated, while the causal relationship between ICT intensity and growth of labour productivity, output and employment is examined in chapter 5, and the potential effects of ICT intensity on growth of labour productivity, output and employment are forecast in chapter 6.

CHAPTER 4: ESTIMATING EFFECTS OF ICT INTENSITY ON PRODUCTIVITY, OUTPUT AND EMPLOYMENT IN SOUTH AFRICA: AN INDUSTRY-LEVEL ANALYSIS

4.1 INTRODUCTION

This chapter serves to estimate the effects of ICT intensity on productivity, output and employment in agro-processing industries. The chapter begins with a summary of the lessons derived from the preceding chapter to set out the logical basis for conducting the current analysis. This is followed by a review of the literature on the effects of ICT on output/GDP, labour productivity and employment. Thereafter, the sources of data, variables and econometric approaches used to estimate the effects of ICT intensity on the productivity, output and employment of agro-processing industries are discussed. This is followed by the discussion of both the descriptive and empirical results. The chapter is concluded with a summary of key findings and their implications.

4.2 BACKGROUND AND RATIONALE

In chapter three, it was established that, in the case of agro-processing industries, both the less and more ICT-intensive industry groups exhibited higher acceleration (an increase over time) in labour productivity growth although, in total, the more ICT-intensive industry group experienced greater growth in labour productivity (1.76%) than the less ICT-intensive industry group (0.92%). At the same time, the difference in labour productivity growth between the two industry groups, derived through DD estimations, cannot be attributed to ICT investment. For this reason, four delimitations, which could have influenced the result, were identified. Firstly, in calculating the ICT intensity index of industries, data for the year 1996 were used. However, some industries could have used ICT more or less intensively pre-and post-1996. In other words, the trends in ICT use over the years were not considered. To cater for ICT use over time, data from 1994 to 2017 are employed in this chapter to calculate the ICT intensity of industries.

Secondly, in chapter three, the focus was on manufacturing industries. As such, the intermediate ICT inputs considered were confined to the ICT manufacturing industries. In this regard, different results could be derived if other intermediate ICT inputs are considered.

Hence, all the intermediate ICT inputs used over the period from 1994 to 2017 are considered in this chapter. Thirdly, in chapter three, the focus was on whether ICT contributed to the growth of labour productivity. However, as per the theoretical framework of the study, there is a nexus between ICT and labour productivity, output and employment. Accordingly, in this chapter, consideration is given to the question of whether ICT would contribute not only to labour productivity growth but also to output and employment.

Lastly, the DD technique does not capture the short-and long-run effects of ICT. For this reason, the pooled mean group estimation technique is applied in this chapter to account for the short-and long-run effects of ICT on the growth of the agro-processing industries. The rationale for estimating the effects of the short-and long-run effects is to determine the extent to which ICT intensity would contribute to the productivity, output and employment of industries. The effects are explained in terms of the extent to which ICT impacts on industries (i.e. positive or negative) and by how much (in percentage point form). The focus is on the effects in both the short run and long run given that the returns on ICT investment take time to materialise (Becchetti *et al.*, 2003; Engelbrecht and Xayavong, 2006). This focus provides an insight into how long it would take for ICT to yield positive effects on the growth of labour productivity, output and employment in the industries. A review of literature on the effects of ICT investment on output, labour productivity and employment is presented in the next section.

4.3 REVIEW OF RELATED LITERATURE

A broad range of studies has investigated the effects of ICT investment on economic growth and other measures of development using varied data sources, analytical approaches, and diverse periods. In this chapter, the review focuses on the effects of ICT on GDP/output, productivity and employment. Further to this, special attention is given to cross-country analytical studies and studies at both the aggregate and disaggregate levels.

The first group of studies consists of studies that evaluated the effects of ICT on GDP/output growth at the aggregate level. It is important to note that much of the earliest research work found zero or negative effects of ICT on countries' growth. For instance, Oliner and Sichel (1994) investigated the contribution of computers to output growth in the US from 1970 to 1992. They found that the computer hardware contributed less to the growth of gross output

(0.16 annual percentage point). The reason for the lower contribution of computers to output growth is that ICT accounted for only a small share of investment as a proportion of the total capital stock, such that it had a low effect on aggregate output.

In a related study focusing on household and business sectors, Jorgenson and Stiroh (1999) applied the growth accounting framework to examine the effects of computers on TFP growth from 1948 to 1996. They found that computers had an effect on capital deepening, but no effect on TFP. Another aggregate-level study by Khan and Santos (2002) applied the standard growth accounting model and found that there was zero acceleration in the effect of ICT use on growth of output in Canada in the late 1990s.

In the light of the above findings, various authors have advanced reasons why aggregate-level studies that have employed the growth accounting model found a negative or zero impact of ICT. The first reason put forward is that the disaggregate-level studies cannot establish sources of growth in productivity (i.e. which industry group between the less and more ICT-intensive industry groups would exhibit higher growth due to ICT investment). The second reason is that aggregate-level studies do not take into account the variations in ICT intensity across industries (i.e. do not rank industry into less and more ICT-intensive industry groups). According to van Ark *et al.* (2002), the consequence of aggregating industries is that the lower growth contribution of the less ICT-intensive industries outweighs the relatively higher growth contribution of the more ICT-intensive industries.

The second group of studies includes those that focused on comparing the effects of ICT investment between countries (i.e. cross-country studies). The main point made by these studies is that the impact of ICT varies according to the extent of investment, such that countries investing highly in ICT experience higher growth compared to those that invest less. For example, van Ark *et al.* (2008) investigated the source of the growth performance gap between the US and the EU between 1980 and 2006. They found that the US's GDP was nearly 1% higher than that of the EU between 1995 and 2006. The gap in GDP growth performance between the US and the EU was attributed to the slower emergence of ICT and lower share of investment in ICT in Europe compared to the US.

Despite the aforementioned, empirical evidence from Colecchia and Schreyer (2002) has shown that the US was not alone in benefiting from the positive effects of ICT investment. Specifically, Colecchia and Schreyer (2002) compared the impact of ICT capital accumulation on the output growth of nine OECD countries in the 1990s.[52] The results indicated that the contribution of ICT to economic growth varied per country (i.e. between 0.2 and 0.5 percentage points per year). During the late 1990s, the contribution increased from 0.3 to 0.9 percentage points per year. This result revealed that the positive effects of ICT capital investment were not confined to the US, and that the US was not the only country to experience acceleration in output growth. Thus, overall, Colecchia and Schreyer (2002) found a positive and significant effect of ICT investment on economic growth in OECD countries, not only in the US.

However, as with van Ark *et al.* (2008), empirical findings by Bloom *et al.* (2012) have shown that the US experienced higher growth than comparable countries due to its higher levels of ICT investment. Bloom *et al.* (2012) specifically applied the fixed effects within the standard production function framework to compare the effects of ICT on the productivity growth of Europe against US multinational firms over the period 1980 to 2005. The results showed that productivity growth in the US accelerated after 1995 compared to Europe, especially in highly ICT-intensive sectors. Thus, overall, comparative aggregate-level studies have shown that the impact of ICT investment varies from country to country, such that countries investing highly in ICT experienced higher growth than those that invested the least.

The third group of studies covers those that examined the effects of ICT investment at the disaggregated level. The key point derived from the disaggregate studies is that the impact of ICT varies according to the intensity of usage, such that the more ICT-intensive industries exhibit higher growth compared to the less ICT-intensive industries. By way of illustration, Stiroh (2002a) examined the link between ICT and the resurgence in productivity of the US industries in the late 1990s using several econometric tests. The findings showed that most ICT-intensive industries experienced significantly higher productivity growth relative to other industries. The implication is that the upsurge in productivity originated in those industries that produced and used ICT most intensively.

[52] The OECD countries are the United States, Australia, Finland, Canada, France, Italy, Germany, United Kingdom and Japan.

In another study, Engelbrecht and Xayavong (2006) used the differences-in-difference (DD) technique to estimate the effects of ICT intensity on the labour productivity growth of New Zealand's manufacturing industries from 1988 to 2003. The findings from the DD estimation indicated that labour productivity growth was higher in the case of the more ICT-intensive industries relative to the less ICT-intensive industries.

In a similar study focusing on Iran, Abri and Mahmoudzadeh (2015) investigated the effect of ICT on the productivity of 23 manufacturing industries from 2002 to 2006 using the Extended Cobb-Douglas function, data envelopment analysis (DEA) and Panel regression models. Results obtained from the analysis demonstrated that ICT had a positive and significant effect on the productivity of all the manufacturing industries (i.e. both the high and less IT-intensive industries). However, effects were higher for the high ICT-intensive industries relative to other industries. These findings confirmed that the effects of ICT vary according to the industry concerned, such that higher productivity was experienced by the more ICT-intensive industries compared to the less ICT-intensive industries.

In the case of Canada, Moshiri (2016) investigated the impact of ICT and its spillovers on the productivity of Canada's industries for the period 1981–2008 using the growth model. The findings demonstrated that, although ICT had a positive impact on labour productivity, the effects differed significantly across industries. Specifically, the industry-level findings showed that the more ICT-intensive industries (services and manufacturing industries) gained more from ICT investment than the less ICT-intensive industries (primary sector industries). These findings suggest that industries that invest more in ICT have higher growth rates than those that invest less.

In the context of the European countries, Niebel *et al.* (2016) examined the contribution of ICT (intangible assets) to growth in the labour productivity of 10 European Union (EU) countries from 1995 to 2007.[53] Data were analysed using the production function and growth accounting frameworks. The findings showed that the contribution of ICT to labour productivity was highest for the more ICT-intensive industries (i.e. finance and manufacturing industries). These

[53] The 10 EU member states are Austria, Czech Republic, Denmark, Spain, Finland, France, Germany, Italy, Netherlands and United Kingdom.

findings prove that the contribution of ICT intangible assets to labour productivity differs according to the industry, with the contribution higher for the more ICT-intensive industries than for the less ICT-intensive industries.

In another European case, Corrado *et al.* (2017) assessed the returns on a country's investments in the case of 10 EU member states from 1998 to 2007 using the production function framework.[54] They found that the returns on investment in intangible capital were stronger in the industries that were more ICT-intensive. This result suggests that the output elasticity of intangible capital varies according to ICT intensity, such that the returns were higher for those industries that invested highly in ICT.

The fourth group of studies comprises those that evaluated the effects of ICT on employment. It is notable that, while ICT is generally promoted due to its proven record of enhancing productivity and boosting GDP growth, contrary arguments have emerged for employment. The key argument is that the use of ICT increases labour productivity thereby enabling the production of more output with less labour and giving rise to jobless growth (OECD, 2016). Therefore, it is important to review the empirical findings on the effects of ICT on employment.

In general, despite the pessimistic views regarding the effects that ICT would have on employment, empirical findings have tended to find a positive correlation between ICT and employment. For instance, empirical findings by Etro (2009) revealed that the adoption of cloud computing had a positive effect on employment in European economies. In the case of the US, Crandall and Singer (2010) found that increasing broadband investments would result in increased employment. In another study focusing on the US, Atasoy (2013) found a positive significant correlation between broadband access and an increase in the employment rate over the period 1999 to 2007. Using similar data for the period up to 2006, Kolko (2012) also found a positive significant correlation. Jayakar and Park (2013) disaggregated the same data and found a positive significant correlation between broadband expansion and employment growth.

[54] The 10 EU countries covered were Austria, Finland, Denmark, France, Italy, Germany, Spain, Netherlands, the United Kingdom and Sweden.

In the case of Germany, the 2013 report on digitisation by the World Economic Forum forecast that a 10% increase in digitisation would bring about a 1.02% decline in the unemployment rate. In the case of other European countries, Pantea, Biagi and Sabadash (2014) assessed whether ICT was replacing workers and reducing the demand for workers among seven European countries.[55] The authors found no evidence of a negative relationship between employment growth and the intensity of ICT use. These results serve to dispel the notion that ICT use would reduce the demand for labour among ICT-using firms.

In the case of Africa, Khan, Lilenstein, Oosthuizen and Rooney (2017) studied the correlation between ICT and employment in the case of 12 Sub-Saharan African countries. In general, the study found that ICT had positive effects on employment. Specifically, the study estimated that higher employment effects were more likely to occur in the case of older people, males and those living in an urban area. In conclusion, studies with a focus on employment found a positive significant correlation between ICT and employment growth. Further to this, some studies found no evidence of a negative relationship between employment growth and the intensity of ICT use.

In short, aggregate-level studies that employed the standard growth accounting model found zero effects of ICT investment, which is attributable to several factors, the most important being the aggregation of the industries. At the same time, the comparative aggregate-level studies showed that the impact of ICT varies from country to country, such that countries investing highly in ICT experience higher growth than those that invest the least. In terms of employment, empirical studies have found a positive correlation between ICT and employment, notwithstanding the pessimistic on the correlation between ICT and employment.

Given the above empirical findings and to avoid problems associated with aggregate studies, agro-processing industries were ranked according to their ICT intensity (i.e. less ICT-intensive and more ICT-intensive industry groups), using the ICT intensity index. The disaggregation of industries was imperative, as the agro-processing subsector comprises various industries, with varying intensities of ICT investment. For this reason, it is assumed that the impact of ICT

[55] The seven European countries are France, Finland, the Netherlands, the United Kingdom, Sweden, Norway and Poland.

varies according to the intensity of usage, such that the more ICT-intensive industries would experience higher growth than the less ICT-intensive industries.

After calculating the ICT intensity of industries, the annual growth rates of labour productivity, output and employment were calculated. Ultimately, analytical techniques, which account for heterogeneity across industries in a multivariate setting, were applied. This approach avoids the econometric problem of omitted variable bias, while unlocking multiple causality channels, which are undetectable under the bivariate setting.

Based on the above background, this chapter aims to examine the effects of ICT on the growth of the agro-processing industries. The specific objective is to estimate the short-and long-run effects of ICT intensity on the growth of labour productivity, output and employment of agro-processing industries. The next section sets out the research methods adopted, including the description of data sources and variables, as well as the model used for data analysis.

4.4 RESEARCH METHODS

4.4.1 Description of data sources

The I-O data from 1994 to 2017 were used to calculate the ICT intensity of industries, in line with previous studies (Engelbrecht and Xayavong, 2006, Vu, 2013; Lefophane and Kalaba, 2020). Specifically, the I-O time-series data for 10 agro-processing industries were sourced from Stats SA. However, it was established in chapter three that Stats SA started publishing the ICT satellite accounts containing I-O tables, annually from 2009–2014, with 2014 being the last year of publication (Parry, 2018). As such, data were missing for some periods including 1996 (1994–1997, 2001, 2003–2004, 2006 and 2008). Consequently, I-O data for the missing years were extracted from the Quantec database. The justifications for sourcing I-O data from Quantec and the description of the database were outlined in chapter three (section 3.4.4).

Data on the growth variables, namely, labour productivity, output and employment, were also extracted from the Quantec database, as up-to-date and comprehensive data on these variables are not available from Stats SA. The variables used, in this chapter (i.e. ICT intensity, labour productivity, output and employment), are described in the next section.

4.4.2 Description of variables

In this study, ICT intensity is defined, in line with Vu (2013), as an industry's share of its expenditure on, or its purchase of, intermediate ICT inputs relative to the total share by all the agro-processing industries. For this reason, in line with previous studies (Vu, 2013; Engelbrecht and Xayavong, 2006), ICT intensity was used as a proxy for the share of industries' investment in ICT. The ICT intensity index, adapted from Engelbrecht and Xayavong (2006) and described in chapter three, was applied to calculate the ICT intensity of 10 agro-processing industries. The reasons for using an index similar to that of Engelbrecht and Xayavong (2006) are as described in section 3.4.2 of chapter three. Similarly, the equation and description of the ICT intensity index are as described in section 3.4.2 of chapter three. The differences are that chapter three used I-O data for manufacturing industries for the year 1996 in calculating the ICT intensity of industries, whereas in this chapter I-O data for agro-processing industries from 1994–2017 are utilised. The justification for using the I-O data are outlined in section 3.4.2 of chapter three.

The growth variables used in this chapter are defined as follows: labour productivity is the gross output per hours worked; employment is the total number of employees in an industry, including formal and informal employment (taking into account both casual and permanent employees); and real output is the value of goods or services produced in a particular industry, measured in millions of rands (Quantec, 2018c). As in previous studies, the raw data for the labour productivity, real output and employment were transformed into mean growth rates (i.e. annual growth rates) (Engelbrecht and Xayavong, 2006; Lovrić; 2012; Vu, 2013). The focus is on labour productivity, output and employment because the theoretical framework of the study showed that there is a nexus between ICT and labour productivity, output and employment. Accordingly, in this chapter, the effects of ICT intensity on the growth of labour productivity, output and employment, are examined.

In brief, panel data are used in this chapter, that is, time series on ICT intensity, labour productivity, output and employment for the period 1994–2017 for cross-sections of 10 agro-processing industries.[56] There are three justifications for using the Panel approach for this chapter. Firstly, the chapter focuses on estimating the effects of ICT intensity for groups in the sample (i.e. less ICT-intensive and more ICT-intensive industries), with heterogeneities with respect to labour productivity, output and employment. According to Lee *et al.* (2005), using the Panel approach allows the study to take account of the heterogeneity across groups in the sample, which improves the accuracy of the findings.

Secondly, panel data analyses allow for a detailed understanding of the impact of ICT along the continuum of ICT investment (Lucas, 1993, cited by Lee *et al.*, 2005). Thirdly, the use of panel data allows researchers to account for the lag effects of technology and avoid the "productivity paradox" phenomenon (Brynjolfsson and Hitt, 1996; Lee and Barua, 1996; Peffers and Dos Sontos, 1996; Devaraj and Kohli, 2000, cited by Lee *et al.*, 2005). For this reason, the analysis in this chapter uses panel data. In particular, data on ICT intensity, labour productivity, output and employment from 1994 to 2017 are used. However, it is acknowledged that the sample size (i.e. the period from 1994 to 2017) is small to conduct the econometric analysis. It is for this reason that the econometric models, which produce consistent and efficient estimates even in the case of small sample size, are used in this chapter. A description of these econometric models is provided in the next section.

4.4.3 The model

The pooled mean group estimation approach of the autoregressive distributed lag (ARDL) technique, developed by Pesaran and Shin (1999), is used to address the second objective of the study (i.e. estimate short-run and long-run effects of ICT intensity on the growth of labour productivity, output and employment). The use of ARDL is preferable for three reasons. Firstly, unlike techniques such as those of Engle and Granger (1987), Johansen and Juselius (1990), Johansen (1988, 1991) and Phillips and Ouliaris (1990), the ARDL can be applied in the presence of mixed order of integration. This is because the ARDL technique is unrestrictive. This implies that it does not require all variables to be integrated of the same order; hence, it is applied regardless of whether variables are $I(1)$ or $I(0)$. Secondly, the ARDL framework allows

[56] The choice of the period is based on data availability. It is acknowledged that the period is very short to conduct the analysis. For this reason, panel data are used to conduct the analysis as they allow a greater degree of freedom than the use of either time-series or cross-sectional data.

each variable to have its optimal lag, which is impractical with the traditional cointegration techniques. Lastly, the framework produces consistent and efficient estimates even in the case of small sample studies (Pesaran and Shin, 1999), as is the case in this chapter (i.e. the period from 1994 to 2017). The basic ARDL (p, q) model is as follows:

$$Y_t = a_0 + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{i=1}^{q} \delta_i X_{t-i} + \varepsilon_{it} \tag{4.1}$$

where: Y_t is a vector, implying that all the variables in the model are used as endogenous variables. X_t represents the exogenous variables that can be purely $I(0)$ or $I(1)$. p is the optimal lag for the endogenous variable, while q is the optimal lag for the exogenous variables. i represents the number of variables in the model, hence i,….,k implies that i can range from 1 to k. α_0 is the intercept or the constant. β and δ are the coefficients for the endogenous and exogenous variables, respectively. ε_{it} is the vector of the error terms.

For this chapter, the analyses were conducted in a multivariate setting involving ICT intensity (ICT_t), labour productivity (LP_t), employment (EMP_t) and real output (RO_t). Consequently, the basic ARDL (p, q) model was transformed into specific ARDL (p, q, r, s) model as follows:

$$\Delta ICT_t = \alpha_{01} + \sum_{i=1}^{p} \alpha_{1i} \Delta ICT_{t-i} + \sum_{i=1}^{q} \alpha_{2i} \Delta LP_{t-i} + \sum_{i=1}^{r} \alpha_{3i} \Delta \mathrm{EMP}_{t-i} + \sum_{i=1}^{s} \alpha_{4i} \Delta RO_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EMP}_{t-1} + \lambda_4 RO_{t-1} + \varepsilon_{1it} \tag{4.2}$$

$$\Delta LP_t = \alpha_{02} + \sum_{i=1}^{q} \alpha_{1i} \Delta LP_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta ICT_{t-i} + \sum_{i=1}^{r} \alpha_{3i} \Delta \mathrm{EMP}_{t-i} + \sum_{i=1}^{s} \alpha_{4i} \Delta RO_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EMP}_{t-1} + \lambda_4 RO_{t-1} + \varepsilon_{2it} \tag{4.3}$$

$$\Delta \mathrm{EMP}_t = \alpha_{03} + \sum_{i=1}^{r} \alpha_{1i} \Delta \mathrm{EMP}_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta ICT_{t-i} + \sum_{i=1}^{q} \alpha_{3i} \Delta LP_{t-i} + \sum_{i=1}^{s} \alpha_{4i} \Delta RO_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EMP}_{t-1} + \lambda_4 RO_{t-1} + \varepsilon_{3it} \tag{4.4}$$

$$\Delta RO_t = \alpha_{04} + \sum_{i=1}^{s} \alpha_{1i} \Delta RO_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta ICT_{t-i} + \sum_{i=1}^{q} \alpha_{3i} \Delta LP_{t-i} + \sum_{i=1}^{r} \alpha_{4i} \Delta \mathrm{EMP}_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EMP}_{t-1} + \lambda_4 RO_{t-1} + \varepsilon_{4it} \tag{4.5}$$

where: ICT_t, EMP_t, LP_t and RO_t are growth rates of ICT intensity (%), employment (%), labour productivity (%) and output (%), respectively. All the variables are expressed in percentages; hence, the equations are not in log forms. Each endogenous variable (ICTt, EMPt, LPt and Rot) is explained by its lagged values and the lagged values of the exogenous variables. Δ represents the difference operator. p, q, r and s are the optimal lags for ICT_t, EMP_t, LP_t and RO_t, respectively. $\alpha_{01,}$ $\alpha_{02,}$ α_{03} and α_{04} are the intercepts for Equations (4.2)–(4.5). a_1, a_2, a_3 and a_4 are the short-run coefficients for ICT_t, EMP_t, LP_t and RO_t, respectively. λ_1, + λ_2, λ_3 and λ_4 are the long-run coefficients for ICT_t, EMP_t, LP_t and RO_t, respectively. ε_{1t}, ε_{2t}, ε_{3t} and ε_{4t} are error terms for Equations (4.2)–(4.5), respectively. The ARDL framework requires each variable (ICT_t, EMP_t, LP_t and RO_t) to have its optimal lag. Therefore, the next section presents the criteria for determining the optimal lags.

4.4.3.1 Determining the optimal lags

The ARDL framework allows each variable to have its optimal lag. Given this, two criteria were used to determine the orders of the lags in the ARDL model: The Akaike information criterion (AIC) and the Schwartz Bayesian criterion (SBC). The lag order that gave the lowest value of either the AIC or the SBC was chosen as the optimal lag. For annual data, as is the case in this chapter, Pesaran and Shin (1999) recommend 1 to 2 lags. The rationale for using lags is to account for the lag effects of technology. This is because the beneficial effects of ICT intensity on the growth of productivity, output and employment are likely to be experienced with a lag. This assertion is validated by previous studies, suggesting that ICT-led growth does not manifest in the same period in which the investment took place due to lags (Brynjolfsson and Hitt, 2000; Leung, 2004a, 2004b; Lee *et al.*, 2005; Kuppusamy *et al.*, 2009). These lags are associated with ICT-complementary factors such as skills training that usually have to be undertaken for ICT to be effective (Brynjolfsson and Hitt, 1996, cited in Lee *et al.*, 2005). The next step after the determination of the optimal lag is diagnostic testing. The diagnostic testing procedure is explained in the next section.

4.4.3.2 Diagnostic testing

The next step after determining the optimal ARDL model involved conducting diagnostic testing to examine the robustness of the model (Kuppusamy *et al*., 2009). Specifically, the diagnostic tests for normality of error terms, the functional form of the model, serial correlation and heteroscedasticity were performed to prove the robustness of the ARDL model. The Jarque-Bera test was performed to examine whether the error terms were normally distributed. The Ramsey regression specification error test (RESET) was conducted to test for the functional form of the model. The Autoregressive Conditional Heteroscedastic (ARCH) test was undertaken to test for heteroscedasticity. Finally, the Lagrange multiplier (LM) test was performed to test for the existence of serial correlation.

The ARDL technique is unrestrictive in that it is applied regardless of whether variables are *I*(1) or *I*(0). Therefore, Panel unit root testing (PURT) was conducted to test whether the variables are integrated of order *I*(1) or *I*(0), as described in the next section.

4.4.3.3 Panel unit root testing

The Im-Pesaran-Shin (IPS) unit root test, developed by Im, Pesaran and Shin (2003), was applied to verify the order of integration among variables. The rationale behind the use of this test is to ensure that variables are stationary to avoid spurious regression and generate results that are applicable in other periods, which validates forecasting. As indicated by Lee *et al.* (2005), the test allows the contribution of ICT to be more accurately forecast into the future.

Alternative unit root tests to the IPS include, among others, the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979), ADF-GLS test (or DF-GLS test) (Elliott, Rothenberg and Stock, 1996), Phillips and Perron (PP) test (Phillips and Perron, 1988) and Ng-Perron test (Ng and Perron, 1995, 2001). The IPS is preferable over these tests as it tests for stationarity in Panel that combines information from the cross-section dimension with that from the time-series dimension so that fewer time observations are required for the test to have power (Im *et al.*, 2003). The IPS was applied by averaging individual ADF t-statistics across cross-section units. A separate ADF regression is, therefore, specified for each cross-section with individual effects and no time trend as follows (Im *et al.*, 2003):

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \quad (4.6)$$

where Y_{it} is the series for industry i in the Panel over period t; pi is the number of lags chosen for the ADF regression; Δ is the first difference filter (I_L), and ε_{it} refers to endogenously and normally distributed random variables for all i and t with zero means and finite heterogeneous variances. After estimating the separate ADF regressions, the average of the t-statistics for the individual ADF regressions is as follows:

$$\bar{t}_{NT} = \frac{1}{N}\sum_{i=1}^{N} t_{iT}(p_i \beta_i) \tag{4.7}$$

It has been proven that the standardised t-bar statistic converges to the standard normal distribution as N and T. As stated in Im *et al.* (2003), the t-bar test has better performance when N and T are small, which confirms that the test has enough power to test for stationarity (Hassan, Bakar, and Abdullah, 2014).

The PMG estimation was used to estimate the short-and long-run effects of ICT on the growth of labour productivity output and employment. Therefore, cointegration testing was required to test whether the long-run relation existed among the variables (ICT_t, EMP_t, LP_t and RO_t). The next section describes the cointegration test used in this chapter.

4.4.3.4 Panel cointegration testing

After testing for stationarity, the bounds cointegration test, developed by Pesaran *et al.* (2001), was applied to investigate whether the long-run relationship existed among variables. The rationale for testing for the long relationship is that the PMG estimation estimates both the short-and long-run effects of ICT intensity on the growth of labour productivity, output and employment. Accordingly, the bounds cointegration test was applied to test whether the long-run relationship existed among variables (ICT_t, EMP_t, LP_t and RO_t). In line with previous studies (Lee *et al*., 2005; Kuppusamy *et al*., 2009), if the test proved that a long-run relationship did not exist, only the short-run effects of ICT intensity were estimated. In case the test proved that the long-run relationship existed, both the short-and long-run effects of ICT intensity were estimated.

This test is preferred over other tests (Engle and Granger, 1987; Johansen, 1988; Johansen and Juselius, 1990; Phillips and Ouliaris 1990; Pedroni, 1999) as it is capable of testing for cointegration among variables irrespective of the order of integration (Pesaran *et al.*, 2001). Furthermore, the test is robust for studies characterised by small sample sizes (as is the case in this chapter). Hence, it has been widely applied to test for cointegration between variables of interest in the presence of a small sample (Pattichis, 1999; Mah, 2000; Tang and Nair, 2002; Narayan and Smyth, 2004). Moreover, the test has been applied in sample size studies to test for cointegration between ICT and variables of interest. For instance, Kuppusamy and Santhapparaj (2005) applied the test to evaluate the impact of ICT investment on the economic growth of Malaysia for the period 1975–2002 (i.e. 28 years). In a similar case, Kuppusamy *et al.* (2009) used the test to examine the impact of ICT investment on the economic growth of Malaysia during the period 1992 to 2006 (i.e.15 years).

In another case, Ahmed and Krishnasamy (2012) employed the test to examine the impact of telecommunications investment on the economic growth of ASEAN-5 countries for the period 1975–2007 (i.e. 33 years).[57] In brief, the bounds test is used, in this chapter, because it tests for cointegration among variables regardless of the order of integration and on account of small sample size (i.e. from 1994 to 2017).

The bounds cointegration test is composed of two sets of critical values for a given significance level: the upper bound $I(1)$ and the lower bound $I(0)$. The decision criteria for cointegration are as follows: (1) H_0 is rejected if the value of the F-statistic exceeds the critical value for the upper bound $I(1)$, which means that cointegration exists (i.e. there is a long-run relationship among variables); (2) H_0 cannot be rejected if the F-statistic is less than the critical value for the lower bound $I(0)$, which means that cointegration does not exist (i.e. no long-run relationship among variables); and (3) the test is considered inconclusive if the F-statistic falls between the upper bound $I(1)$ and the lower bound $I(0)$ (Pesaran *et al.*, 2001). Overall, if the long-run relationship exists among variables, it implies that such variables are related and can be modelled linearly. In other words, even if there were shocks in the short run, which may affect movement in the individual variables, they would converge with time (in the long run). From this perspective, where cointegration exists, both the short-and long-run coefficients are estimated (through the ECM) and if cointegration does not exist, only the short-run coefficients are estimated (Lee *et al.*, 2005; Kuppusamy *et al.*, 2009).

[57] The ASEAN-5 countries are Singapore, Malaysia, Philippines, Indonesia and Thailand.

Following Belloum (2014), the bounds test is conducted by estimating Equations (4.2)–(4.5) by ordinary least squares (OLS). This is followed by conducting an F-test for the joint significance of the coefficients of the lagged levels of the variables, H_0: $\lambda_1=\lambda_2=\lambda_3=\lambda_4=0$ against H_1: $\lambda_1\neq \lambda_2\neq \lambda_3\neq\lambda_4\neq 0$ for I = 1, 2, 3, 4. In other words, the F-statistic is conducted by setting each of the variables as endogenous as specified in Equations (4.2) to (4.5). The ARDL framework requires pre-testing before PMG estimation. The pre-testing discussed so far includes, in sequence, determination of the optimal lag, diagnostic testing, unit root testing and cointegration testing. The next section, therefore, describes the PMG estimation.

4.4.3.5 Pooled mean group (PMG) estimation

One of the limitations of the cointegration tests is that they cannot estimate the short-run and long-run effects as well as the speed of adjustment towards long-run equilibrium. To address this limitation, this chapter applies the PMG regression, developed by Pesaran *et al.* (1999), to estimate short-run and long-run relationship among variables as well as the error correction adjustment speed. The PMG is chosen because it allows for convergence speeds and short-term adjustments to vary across industries, thereby accounting for cross-industry heterogeneity. In addition, the PMG provides consistent and efficient estimates irrespective of the order of integration (Pesaran *et al.*, 1999). To apply PMG, the specific ARDL (p, q, r, s) is re-formulated in an error correction form as follows:

$$\Delta ICT_t = \alpha_{01} + \sum_{i=1}^{p-1}\alpha_{1i}\Delta ICT_{t-i} + \sum_{i=1}^{q-1}\alpha_{2i}\Delta LP_{t-i} + \sum_{i=1}^{r-1}\alpha_{3i}\Delta \mathrm{EMP}_{t-i} + \sum_{i=1}^{s-1}\alpha_{4i}\Delta R\mathrm{O}_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EM}P_{t-1} + \lambda_4 R\mathrm{O}_{t-1} + \Phi \mathrm{E}CT_{t-1} + \varepsilon_{1it} \qquad (4.8)$$

$$\Delta LP_t = \alpha_{02} + \sum_{i=1}^{p-1}\alpha_{1i}\Delta ICT_{t-i} + \sum_{i=1}^{q-1}\alpha_{2i}\Delta LP_{t-i} + \sum_{i=1}^{r-1}\alpha_{3i}\Delta \mathrm{EMP}_{t-i} + \sum_{i=1}^{s-1}\alpha_{4i}\Delta R\mathrm{O}_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EM}P_{t-1} + \lambda_4 R\mathrm{O}_{t-1} + \Phi \mathrm{E}CT_{t-1} + \varepsilon_{2it} \qquad (4.9)$$

$$\Delta EMP_t = \alpha_{03} + \sum_{i=1}^{p-1}\alpha_{1i}\Delta ICT_{t-i} + \sum_{i=1}^{q-1}\alpha_{2i}\Delta LP_{t-i} + \sum_{i=1}^{r-1}\alpha_{3i}\Delta \mathrm{EMP}_{t-i} + \sum_{i=1}^{s-1}\alpha_{4i}\Delta R\mathrm{O}_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EM}P_{t-1} + \lambda_4 R\mathrm{O}_{t-1} + \Phi \mathrm{E}CT_{t-1} \qquad (4.10)$$

$$\Delta RO_t = \alpha_{04} + \sum_{i=1}^{p-1}\alpha_{1i}\Delta ICT_{t-i} + \sum_{i=1}^{q-1}\alpha_{2i}\Delta LP_{t-i} + \sum_{i=1}^{r-1}\alpha_{3i}\Delta \mathrm{EMP}_{t-i} + \sum_{i=1}^{s-1}\alpha_{4i}\Delta R\mathrm{O}_{t-i} + \lambda_1 ICT_{t-1} + \lambda_2 LP_{t-1} + \lambda_3 \mathrm{EM}P_{t-1} + \lambda_4 R\mathrm{O}_{t-1} + \Phi \mathrm{E}CT_{t-1} + \varepsilon_{4it} \qquad (4.11)$$

where: ECTs are error-correction terms. Φ represents the speed of adjustment parameter (i.e. coefficient of the ECTs), which measures the speed of adjustment towards long-run equilibrium. Φ must be negative and significant to ensure that the model converges to a steady state (i.e. convergence from the short run towards the long run).

After estimation of the short-and long-run effects using Equations (4.8)–(4.11), it is necessary to test for the robustness of the long-run coefficient. Accordingly, the next section provides a description of the method used in this chapter to test for the robustness of the long-run coefficients derived from PMG estimation.

4.4.3.6 Dynamic ordinary least square (DOLS) estimation

Following estimation of the short-and long-run effects, the DOLS method, developed by Stock and Watson (1993), was applied to test for the robustness of the long-run coefficients. The DOLS method is applied for two reasons. Firstly, in the short term, ICT investment could be counterproductive to the growth of industries due to the training of labour, redesigning of job practices, as well as the realignment of work structures and scope (Lee *et al.*, 2005; Sharpe, 2006). Furthermore, predicaments in relation to the introduction of ICT systems and the obliteration of bugs and glitches in the systems could have an adverse effect on productivity. However, these should be eliminated over longer terms. Consequently, the beneficial effects of ICT intensity are expected to be observable over the longer term. For this reason, the present chapter tests for the robustness of the long-run estimates.

Secondly, the PMG method, which was applied to test if the short-and long-run effects, might be exposed to the problem that parameters of estimates in one equation could be affected by any misspecification in other equations (Al-Azzam and Hawdon, 1999), which could lead to simultaneity bias and serially correlated errors.[58] In the light of this, the DOLS estimation method, which is an improvement on OLS, was applied. The DOLS was applied specifically because it eliminates the potential simultaneity bias and small sample bias by augmenting lags and leads of the first difference of the regressors and serially correlated errors using a generalised least square (GLS) procedure.

[58] The data are susceptible to serial correlation since other variables not included in the model may be correlated with the exogenous variables in the system, giving rise to biased and inconsistent estimates.

Alternative approaches for correcting an endogeneity problem include, among others, the 2-stage least square (2-SLS) and the instrumental variable (IV) estimations. However, these techniques are not suitable for the current analysis for two reasons. Firstly, it is very difficult to find a proper instrument variable that is correlated with the exogenous variables but uncorrelated with the endogenous variable. Secondly, the 2-SLS and the IV techniques are more applicable and more reliable in a large sample, which is not the case in this study.

An alternative for checking the robustness of the long-run coefficients is the Johansen-Juselius (JJ) procedure, which is based upon the maximum likelihood estimation (MLE) (Masih and Masih, 1996). However, the DOLS is preferred over the JJ procedure as it eliminates simultaneity bias and provides efficient estimates in the presence of small samples (Masih and Masih, 1996; Salahuddin and Gow, 2016).

Other alternatives to the DOLS are the OLS and the fully modified OLS (FMOLS). However, according to Masih and Masih (1996), the Monte Carlo simulations by Stock and Watson (1993) have proved that the DOLS outstrips both the FMOLS and OLS in finite samples with respect to unbiased estimators. This is because the DOLS estimator controls for endogeneity in the model by augmenting the lags and leads of the first difference of the regressors to suppress the endogenous feedback (Kao and Chiang, 2001). The other advantage of using the DOLS is that it can be applied in the case of mixed order of integration, that is, irrespective of the order of integration of the variables (Ali, Abdullah and Azam, 2017). In brief, the justification for applying the DOLS is that it eliminates simultaneity bias and endogeneity and provides efficient estimates in the presence of small samples, regardless of the order of integration.

To apply the DOLS, the long-run relationship between ICT intensity, labour productivity, employment and output is modelled by using four equations as follows:

$$ICT_t = \delta_0 + \delta_1 LP_t + \delta_2 EMP_t + \delta_3 RO_t + \sum_{j=-k}^{k} \beta \Delta LP_{t-j} + \sum_{j=-k}^{k} \beta \Delta EMP_{t-j} + \sum_{j=-k}^{k} \beta \Delta RO_{t-j} + \varepsilon_t \tag{4.12}$$

$$LP_t = \delta_0 + \delta_1 ICT_t + \delta_2 EMP_t + \delta_3 RO_t + \sum_{j=-k}^{k} \beta \Delta ICT_{t-j} + \sum_{j=-k}^{k} \beta \Delta EMP_{t-j} + \sum_{j=-k}^{k} \beta \Delta RO_{t-j} + \varepsilon_t \tag{4.13}$$

$$EMP_t = \delta_0 + \delta_1 LP_t + \delta_2 ICT_t + \delta_3 RO_t + \sum_{j=-k}^{k} \beta \Delta LP_{t-j} + \sum_{j=-k}^{k} \beta \Delta ICT_{t-j} + \sum_{j=-k}^{k} \beta \Delta RO_{t-j} + \varepsilon_t \quad (4.14)$$

$$RO_t = \delta_0 + \delta_1 LP_t + \delta_2 ICT_t + \delta_3 EMP_t + \sum_{j=-k}^{k} \beta \Delta LP_{t-j} + \sum_{j=-k}^{k} \beta \Delta ICT_{t-j} + \sum_{j=-k}^{k} \beta \Delta EMP_{t-j} + \varepsilon_t \quad (4.15)$$

where k = the parameter for the lead-lag truncation parameter. According to Saikkonen (1991), cited in Hayakawa and Kurozumi (2006), the OLS estimators, δ_1, δ_2 and δ_3, are efficient and do not suffer from second-order bias.

In brief, the analytical techniques used in this chapter can be summarised as follows. The ICT intensity index was used to calculate the ICT intensity of the industries and to disaggregate into more ICT-intensive and less ICT-intensive industry groups. The PMG estimation of the framework of the ARDL model was used to estimate short-and long-run effects of ICT intensity on the growth of labour productivity output and employment. Several pre-tests were applied before PMG estimation. This included the determination of the optimal lag, diagnostic testing, unit root testing and cointegration testing. The DOLS model was applied to test for the robustness of the long-run coefficients from PMG estimation. The findings from the determination of the optimal lag, diagnostic testing, unit root testing, cointegration testing, PMG estimation and DOLS analysis are presented in the empirical results section. The following section provides the descriptive findings derived from the ICT intensity index and annual growth rates of labour productivity, output and employment.

4.5 DESCRIPTIVE RESULTS

This section provides descriptive statistics on the nature of the data (variables) used in the chapter. The descriptive results start with the ICT intensity index to disaggregate industries into more ICT-intensive and less ICT-intensive industry groups. This is followed by the results for the annual growth rates of industries to underscore which group of industries experienced the higher or lower growth of productivity, output and employment. The descriptive results also include summary statistics on the nature of the variables (i.e. ICT, LP, EMP and RO used in the chapter. The presentation of the descriptive statistics ends with results from the variance inflation factor (VIF) analyses, conducted in advance of the empirical analyses to determine the extent of multicollinearity among the regressors.

4.5.1 ICT intensity of industries

Using the ICT intensity index defined as the industries' direct requirements for intermediate ICT inputs, industries were distinguished into two categories (i.e. more ICT-intensive and less ICT-intensive industries). As in chapter three and following previous studies, the median value of the index was used as the point of reference for ranking industries into the two categories (Stiroh, 2002a; Engelbrecht and Xayavong 2006; Chen *et al.*, 2016). The ICT intensity index (I_j) results indicate that the median value was 7.37%. Therefore, industries with ICT intensity index values greater than the median of 7.37% were ranked as more ICT-intensive, while those with values less than 7.37% were ranked as less ICT-intensive industries. The ICT intensity results are as presented in Table 4.1.

Table 4.1: ICT intensity of agro-processing industries

Industry	ICT intensity index (%)
Food	37.20
Beverages	11.02
Tobacco	0.84
Textile	8.12
Wearing apparel	6.62
Leather	3.96
Wood	5.86
Paper	11.16
Rubber	10.08
Furniture	5.12
Total	**100**

Source: Author's calculations

The findings indicate that five industries, namely, food, beverages, textile, paper and rubber were ranked as more ICT-intensive. Conversely, the less ICT-intensive industries were tobacco, wearing apparel, leather, wood and furniture. Across the industries, the food industry accounted for the largest share (37.20%) of the direct requirement for intermediate ICT inputs. Paper (11.16%), beverages (11.02%), rubber (10.08%) and textile (8.12%) industries follow the food industry. In contrast, the tobacco industry accounted for the least share (0.84%) of the direct requirement for intermediate ICT inputs. Other industries that accounted for the lower share of the direct requirement for intermediate ICT inputs are leather (3.96%), furniture (5.12%), wood (5.86%) and wearing apparel (6.62%) industries.

The results further show that the more ICT-intensive industries accounted for 78% of the share of the direct requirement for intermediate ICT inputs, while the less ICT-intensive industries accounted for the remaining 22% as shown in Figure 4.1.

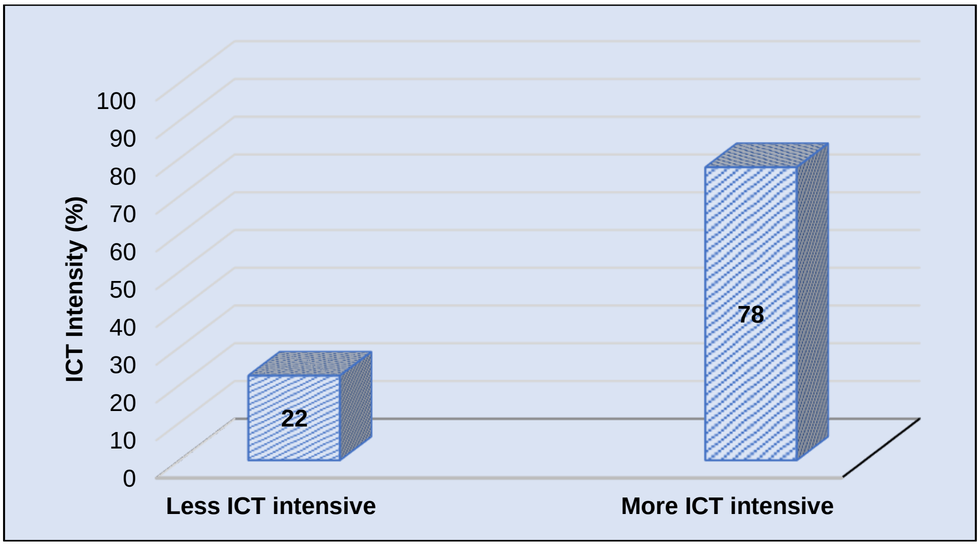

Figure 4.1: ICT intensity of agro-processing industries, 1994–2017
Source: Author's own compilation

While previous studies used various ICT intensity indexes to rank industries into more and less ICT-intensive industry groups (Stiroh, 2002a; van Ark *et al.*, 2002; Engelbrecht and Xayavong, 2006; Abri and Mahmoudzadeh, 2015; Niebel *et al.*, 2016), it is noted that they did not explicitly focus on agro-processing industries. Thus, these studies did not provide knowledge about which of the agro-processing industries are more ICT-intensive and which ones are less ICT-intensive. Such knowledge is critical because it has been empirically proven that the impact of ICT varies according to the intensity of usage, such that the more ICT-intensive industries would exhibit higher growth compared to the less ICT-intensive industries. Therefore, the ICT intensity findings provide an information base on the ICT intensity of the comprehensive agro-processing industries, which can be used to evaluate whether ICT investment would contribute more to the growth of either the more ICT-intensive industries or the less ICT-intensive industries.

4.5.2 Annual growth rates of industries

After calculating the ICT intensity of industries, the study calculated the weighted annual average growth rate of labour productivity, output and employment for industries over the period 1994 to 2017. The detailed results are presented in Table 4.2. The annual growth rate results indicate that the less ICT-intensive industries surpassed their counterparts with respect to the growth rates of both labour productivity and output. In terms of employment, both groups of industries experienced a decline in employment growth. However, the more ICT-intensive group experienced a lower decline in employment growth. In terms of the individual industries, the leather industry exhibited the highest growth in both labour productivity and output. In contrast, the beverages industry had the lowest growth in both labour productivity and output. In terms of employment, most industries experienced a decline in employment growth. Comparatively, the wearing apparel industry experienced the highest decline in employment growth, whereas the food industry experienced the least decline in employment.

Table 4.2: Annual average growth rate, 1994-2017

Industry	Employment (%)	Labour productivity (%)	Output (%)
More ICT-intensive	-3.6	7.0	7.7
Less ICT-intensive	-6.7	16.5	13.1
Food	-0.3	3.1	2.0
Beverages	-0.9	-0.2	0.8
Tobacco	-0.9	3.3	2.1
Textile	-2.3	2.6	1.2
Wearing apparel	-2.7	4.5	1.0
Leather	-1.8	4.9	3.8
Wood	0.9	1.1	3.2
Paper	1.7	0.1	2.4
Rubber	-1.8	1.3	1.3
Furniture	-2.1	2.8	2.2

Source: Authors' calculations based on Quantec (2018b) and Stats SA

The variance inflation factor (VIF) analyses were undertaken in advance of the empirical analyses to determine the extent of multicollinearity among the regressors.[59] Table B.1 presents the VIF results for the Panel of industries, while Tables B.2 and B.3 present the VIF results for industries contained in Panels B and C, respectively.[60] Overall, the results illustrate that all VIF values were less than 5, implying that there is no multicollinearity problem.[61] After determining that there was no multicollinearity among the variables, several analytical techniques were

[59] The VIF measures the severity of correlation in a set of multiple regression variables.
[60] Table B.1, Table B.2 and Table B.3 are included in the appendices.
[61] The VIF value of less than 5 indicates that there is no collinearity, whereas that of more than 5 signifies the presence of collinearity.

applied, including the determination of optimal lag, unit root testing and cointegration testing. Thereafter, the PMG estimation was conducted. The next section presents findings from the determination of the optimal lag, diagnostic testing, unit root testing and cointegration testing and PMG estimation.

4.6 EMPIRICAL RESULTS

This section provides empirical results derived from the determination of the optimal lag, unit root testing, cointegration testing and PMG estimation. The reporting of the results covers Panel A (All agro-processing industries), Panel B (More ICT-intensive industries) and Panel C (Less ICT-intensive industries) as well as individual industries embedded in Panels B and C. In the case of individual industries of Panels B and C, where there are areas of commonality concerning the nature of cointegration and results from PMG estimation, industries are discussed as a unit and not individually.

4.6.1 Optimal lag results

The findings from the determination of the optimal lags show that, in all cases, the optimal lags were either 1 or 2, which is in line with the recommendations by Pesaran and Shin (1999) for annual data (see Table B.4). The lag results are in line with those of Kuppusamy *et al.* (2009).[62] By determining the optimal lag, this chapter accounts for the lag effects of technology since ICT-led growth does not manifest in the same period in which the investment took place due to lags. Consequently, the potential effects of ICT intensity on growth of productivity, output and employment are expected to be realised with a lag. These lags are associated with ICT-complementary factors such as skills training, redesign of job practices, as well as the realignment of work structures and scope that usually ought to be undertaken for ICT to be effective (Brynjolfsson and Hitt, 1996, cited by Lee *et al.*, 2005; Sharpe, 2006).

Overall, the findings show that the optimal lags were either 1 or 2 and in line with the recommendations by Pesaran and Shin (1999) for annual data. The next step after determining the optimal lag involved diagnostic testing. Therefore, the next section presents the diagnostic test results.

[62] It should be noted that the lag length of more than 2 was not used as that would have involved the loss of a degree of freedom.

4.6.2 Diagnostic test results

The diagnostics tests for normality, functional form, heteroscedasticity and serial correlation were performed to test for the robustness of the ARDL model. Table B.5 presents the diagnostic test results for the Panel of industries, whereas Tables B.6 and B.7 present the results for industries contained in Panels B and C, respectively. Overall, the results for the Panel of industries demonstrate, when EMP, LP and RO are endogenous, that the error terms were normally distributed, the model was correctly specified, and that there was no autoregressive conditional heteroscedasticity and serial correlation. At the same time, there was evidence of non-normality of error terms for all the panels when ICT was endogenous, and misspecification errors and heteroscedasticity for Panel C industries when ICT was endogenous.

The diagnostic test results for individual industries illustrate that the error terms were normally distributed, the model was correctly specified, and that there was no autoregressive conditional heteroscedasticity and serial correlation when EMP, LP and RO were endogenous. However, evidence of non-normality of errors was observed for the food, rubber and leather industries when ICT was endogenous. Furthermore, there was evidence of misspecification errors for the food and wood industries when ICT was endogenous. To remedy the identified problem, the empirical analysis was conducted by setting EMP, LP and RO as endogenous to avoid the non-normality, misspecification and heteroscedasticity problems evident when ICT is endogenous.[63] Panel unit root testing was conducted after diagnostic testing to test for the order of integration among variables. Accordingly, the subsequent section presents the diagnostic test results.

4.6.3 Panel unit root test results

This section reports on the empirical results of the IPS unit root test. The results of the IPS unit root test for the Panel of industries are presented in Table 4.3.

[63] Since the study focuses on estimating the effects of ICT intensity, by setting EMP, LP and RO as endogenous, the study can capture effects on the growth of labour productivity, output and employment as ICT remains exogenous in all cases.

Table 4.3: Panel unit root test results

Variable	IPS-statistic	P-values	Order of integration
Panel A: All agro-processing industries			
ICT	-2.41152***	0.0079	*I*(0)
LP	-5.76321***	0.0000	*I*(0)
EMP	-5.55652***	0.0000	*I*(0)
RO	-6.54138***	0.0000	*I*(0)
Panel B: More ICT-intensive industries			
ICT	-0.60147	0.2738	*I*(1)
ΔICT	-5.115***	0.0000	
LP	-3.51433***	0.0002	*I*(0)
EMP	-3.78996***	0.0001	*I*(0)
RO	-3.78873***	0.0001	*I*(0)
Panel C: Less ICT-intensive industries			
ICT	-2.94489	0.0016	*I*(0)
LP	-7.04130	0.0000	*I*(0)
EMP	-6.86551	0.0000	*I*(0)
RO	-8.91867	0.0000	*I*(0)

Source: Author's own compilation

Notes: ICT = ICT intensity (%); LP =labour productivity growth rate (%); EMP = growth rate of employment (%); RO = real output growth rate (%); IPS-statistic = Im, Pesaran and Shin W-stat; *** Significant at 1% level; the test equation is the intercept.

The unit root testing process involved three Panel of industries: Panel A (all agro-processing industries), Panel B (more ICT-intensive industries) and Panel C (less ICT-intensive industries). The findings illustrate that all the variables in Panels A and C were stationary in their level forms and therefore required no differencing. In the same way, the variables EMP, LP and RO for Panel B required no differencing, as they were stationary in their level forms (i.e. integrated of order I (0). In contrast, the variable ICT became stationary after first differencing, which implies that it is integrated of order *I*(1).

Overall, the IPS test results show that variables in Panels A and C were integrated of order *I*(0), while those in Panel B were integrated of different orders (i.e. a combination of order *I*(1) and *I*(0)). These findings validate the use of the IPS test, which is used when variables are integrated of different orders. Since all variables were stationary, findings could be applicable in other periods, which validates the forecasting of the potential effects of ICT intensity.

Overall, the findings show that the variables were integrated of order *I*(1) and *I*(0), which is in line with the ARDL framework that is used regardless of whether variables are integrated of order *I*(1) or *I*(0). The next step after determining the order of integration involved cointegration testing to determine whether the long-run relation existed among the variables (ICTt, EMPt, LPt and ROt). The next section provides the results from the cointegration testing.

4.6.4 Panel cointegration test results

The unit root test results revealed that the variables were integrated of different orders, which justifies the use of bounds cointegration test, which is applicable regardless of whether variables are $I(1)$ or $I(0)$. This section, therefore, reports on the empirical results of the bounds test, which was applied to prove if a long-run relationship existed among variables. The section commences by reporting on the results of the Panel of industries (Panel A, Panel B and Panel C). This is followed by a discussion of the nature of cointegration by individual industries embedded in Panels B and C. The section ends with a summary of the results. This includes a deliberation of which method to estimate (between the ARDL and ECM) in the following section, given the bounds test results. The bound test results for the Panel of industries are presented in Table 4.4.

Table 4.4: Bound test cointegration results for Panel of industries

Endogenous variable	AIC lags	Computed F-statistic	Is there cointegration?	ARDL or ECM?
	Panel A: All agro-processing industries			
EMP	1	4.95	Yes	ECM
LP	2	5.73	Yes	ECM
RO	2	8.75	Yes	ECM
	Panel B: More ICT-intensive industries			
EMP	2	18.90	Yes	ECM
LP	1	15.70	Yes	ECM
RO	1	10.07	Yes	ECM
	Panel C: Less ICT-intensive industries			
EMP	1	32.86	Yes	ECM
LP	1	38.25	Yes	ECM
RO	2	30.79	Yes	ECM
Critical values 10% 5% 1%		$I(0)$ 2.37 2.79 3.65	$I(1)$ 3.2 3.67 4.66	

Source: Author's own compilation

Note 1: ICT is the ICT intensity (%); LP is the labour productivity growth rate (%); EMP is the growth rate of employment (%); RO is the real output growth rate (%).

Note 2: The critical values are available from Pesaran *et al.* (1999).

The general finding is that, for all the panels, the null hypothesis of no cointegration was rejected when the variables EMP, LP and RO are specified as endogenous. This is because the F-statistic values were higher than all the critical values for both the $I(0)$ and $I(1)$. The findings, therefore, validate the existence of a long-run relationship amongst the variables. Since a long-run relationship existed among variables, it implies that they were related and could be modelled linearly. In other terms, even if there were shocks in the short run, which may affect movement in the individual variables, they would converge with time (in the long run).

The cointegration analyses were extended to the individual industries embedded in Panels B and C. The nature of cointegration by individual industries contained in Panels B and C is presented in Table B.8. The general finding is that, for all the industries, the null hypothesis of no cointegration was rejected when the variables EMP, LP and RO are specified as endogenous. This is because the F-statistic values were higher than all the critical values for both the $I(0)$ and $I(1)$.

The findings, therefore, validate the existence of a long-run relationship amongst the variables for all the industries. This is except for the wood industry for which the test was further inconclusive when EMP was endogenous. This means that the test failed to prove whether there was a long-run relationship amongst the variables when EMP was endogenous. This is because the F-statistic values lie between the 5% critical values for $I(1)$ and $I(0)$ bounds.

In brief, for all the entire Panel and individual industries, the bounds test proved that a long-run relationship existed among variables when EMP, LP and RO were set as endogenous. In this case, the study estimated both the ARDL and ECM for the Panel of industries when EMP, LP and RO were endogenous. In the case of the wood industry, the study estimated both the ARDL model (short-run coefficients) and ECM (long-run coefficients) when LP and RO were endogenous and only the ARDL model (short-run coefficients) when EMP was endogenous. The next procedure after cointegration testing involved the PMG estimation to estimate the short-run and long-run effects of ICT intensity on the growth of labour productivity, output and employment. The findings from PMG estimation presented in the next section.

4.6.5 PMG results

The bound test results showed whether cointegration existed among variables. However, the test (as is the case with other cointegration tests) was only limited to the nature of cointegration (i.e. whether cointegration exists or not). The test, therefore, does not provide evidence of short-run and/or long-run causal effects among variables. To address this delimitation, the study estimated the short-run effects (in cases where the long-run relationship does not exist) and both the short-run and long-run effects (in cases where a long-run relationship exists). Since the chapter focuses on examining the effects of ICT intensity on growth, the discussion is limited to the effects of ICT intensity on the growth of labour productivity, output and employment. The results from the short-run and long-run estimates for the Panel of industries are presented in Table 4.5.

The ECM results for the Panel of industries are presented in Table 4.5 alongside the short-run and long-run results. Accordingly, ECM results for Panel B industries are contained in Table B.9, while those for Panel C are shown in Table B.10. The ECM results demonstrate that, in all the cases (i.e. panels and individual industries), the coefficients of the error correction terms (ECTs) were negative and significant at 1% level, implying a long-run reversion to equilibrium.

The discussion of the results from Table 4.5 covers both the short-run and long-run effects of ICT intensity on the growth of labour productivity, output and employment. The discussion of the results covers, in sequence, Panel A (i.e. all agro-processing industries), Panel B (i.e. more ICT-intensive industries) and Panel C (less ICT-intensive industries). Thereafter, follow the results for the individual industries contained in Panel B and Panel C. The next section provides a discussion of the short-run and long-run effects findings as presented in Table 4.5.

Table 4.5: Short-run and long-run results for Panel of industries

	Short-run effect				**Long-run effects**				**ECT_{-1}**
Endogenous variable	ICT	EMP	LP	RO	ICT	EMP	LP	RO	
Panel A: All agro-processing industries									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.00 (0.789)	-	-0.00 (0.435)	0.00 (0.340)	0.81 (0.690)	-	-0.83*** (0.000)	1.01*** (0.000)	-0.62*** (0.000)
LP	-0.03 *** (0.000)	-0.42 (0.132)	-	0.16 (0.368)	-1.13*** (0.000)	1.40 (0.546)	-	1.20 *** (0.000)	-0.48*** (0.000)
RO	-0.14** (0.032)	-0.09 (0.368)	-0.03 (0.259)	-	0.71*** (0.000)	-0.26 (0.874)	0.62*** (0.000)	-	-0.37*** (0.000)
Panel B: More ICT-intensive industries									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.25* (0.072)	-	-0.01 (0.822)	-0.12 (0.375)	0.41 (0.290)	-	-0.62*** (0.000)	0.52*** (0.000)	-0.38*** (0.000)
LP	-0.07 (0.725)	-0.00 (0.994)	-	-0.47*** (0.005)	0.48* (0.06)	-0.94 (0.334)	-	0.78** (0.014)	-0.87*** (0.000)
RO	0.09 (0.407)	0.15 (0.156)	0.14 ** (0.03)	-	0.39** (0.028)	-0.005 (0.874)	0.19*** (0.000)	-	-0.75*** (0.000)
Panel C: Less ICT-intensive industries									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.58* (0.07)	-	-0.05 (0.265)	0.14 (0.178)	-0.181 (0.359)	-	-0.28*** (0.000)	0.31*** (0.001)	-0.98*** (0.000)
LP	-0.02 (0.915)	-0.42 (0.558)	-	-0.493** (0.038)	-1.52*** (0.000)	-0.49 (0.334)	-	0.74** (0.025)	-0.97*** (0.000)
RO	-0.22*** (0.007)	-0.27 (0.263)	-0.05 (0.150)	-	0.27*** (0.002)	-0.002 (0.88)	0.13*** (0.002)	-	-0.89*** (0.000)

Source: Author's own compilation

Note 1: ICT = ICT intensity (%); LP = labour productivity growth rate (%); EMP = growth rate of employment (%); RO = real output growth rate (%).

Note 2: Figures in parenthesis are the P-values.

Note 3: ***, **, * significant 1%, 5% and 10%, respectively.

(a) Short-run and long-run effects result for the Panel of industries

- **Effects on employment growth**

The PMG findings show that ICT intensity had no significant effect on the employment growth of Panel A (i.e. all agro-processing industries) in both the short run and long run. These findings conform to those of previous studies that found zero significant effects of ICT when industries were aggregated (Jorgenson and Stiroh, 1999; Khan and Santos, 2002;

Edquist and Henrekson, 2017). Despite the effect being insignificant, it was positive, which dispels the pessimistic views regarding the effects of ICT on employment. Concerning disaggregated industries, positive significant effects were notable only in the short run for both the more and less ICT-intensive industry groups (i.e. Panels B and C). However, while it is noted that, in the short run, the effect was higher for the less ICT-intensive industries, in the long run, it was positive for the more ICT-intensive group but negative for the less ICT-intensive industries. These findings are in line with those of previous studies that found positive and significant effects of ICT for industries that are more ICT-intensive (Engelbrecht and Xayavong, 2006; Abri and Mahmoudzadeh, 2015; Moshiri, 2016).

- **Effects on labour productivity growth**

The PMG findings further show ICT intensity yielded a negative significant effect on the labour productivity of the aggregated industries in both the short and the long run. Yet again, the findings are in accordance with earlier studies, which found negative significant effects of ICT when industries were aggregated (Baily, 1986; Parsons, Gotlieb and Denny, 1993). In terms of the disaggregated industries, the findings show that, in the short run, ICT intensity yielded negative but insignificant effects on both groups of industries. However, in the long run, ICT intensity exhibited a positive significant effect on the labour productivity growth of the more ICT-intensive group but a negative significant effect in the less ICT-intensive group.

The findings specifically illustrate that, in the long run, a 1 percentage point increase in ICT intensity would increase the labour productivity growth of the more ICT-intensive group by 0.48 percentage point. Further to this, these results conform to those of previous studies that found positive and significant effects for the industries that invested more in ICT (Engelbrecht and Xayavong, 2006; Abri and Mahmoudzadeh, 2015; Moshiri, 2016). In contrast, an increase in ICT intensity would decrease the labour productivity growth of the less ICT-intensive group by 1.52 percentage point. These findings are in line with the observation by van Ark *et al.* (2002) about the declining growth contribution of less ICT-intensive industries.

- **Effects on output growth**

  In terms of output, the findings exhibit that ICT intensity had no significant effect on the output growth of the aggregated industries in both the short and the long run. However, while ICT intensity yielded positive and significant effects on the output growth of both the less and more ICT-intensive groups, in the long run, its effect was higher for the more ICT-intensive group.[64] To be exact, a 1 percentage point increase in ICT intensity would increase the output growth of the more ICT-intensive industries by 0.39 percentage point and that of less ICT-intensive industries by 0.27 percentage point. The findings conform to the previous study by Abri and Mahmoudzadeh (2015), which found a positive and significant effect on the productivity of all manufacturing, but higher effects for the more ICT-intensive industries than the less ICT-intensive industries.

(b) Short-run and long-run results for Panel B industries

The short-run and long-run results for individual industries embedded in Panel B are presented in Table B.9. Overall, the findings show that there was large variation across industries in terms of ICT intensity's contribution to the growth of labour productivity, output and employment. A key point to note is that ICT intensity displayed zero short-run and long-run effects on the growth rates of labour productivity, output and employment of the textile industry. These results are unexpected but logical given that, of the more ICT-intensive industries, the textile industry accounted for the lowest share of ICT investment.

- **Effects on employment growth**

  The findings show that ICT intensity yielded no significant short-run and long-run effects on the growth rate of employment of the more ICT-intensive industries, except in the case of the food industry in respect of which positive significant effects were detectable in the long-run only. More specifically, a 1 percentage point increase in ICT intensity would increase the employment growth of the food industry by 0.94 percentage point. One of the assumptions made in this chapter is that the effect of ICT on growth varies according to the intensity of usage, such that the industries with higher ICT intensity would exhibit higher

[64] It should also be noted that, while ICT intensity yields positive significant effects on the output growth of both the less and more ICT-intensive groups, in the long run, it yields no significant effect on the output of the more ICT-intensive group, and negative and significant effect on that of the less ICT-intensive group in the short run.

growth. The descriptive results showed that the food industry had the largest share of ICT intensity and contributed the most towards the employment of the agro-processing subsector. Therefore, these findings are in line with those of previous studies, which found that industries that invested more in ICT had higher growth rates than those that invested less (Kuppusamy *et al.*, 2009; Vu, 2013; Moshiri, 2016).

- **Effects on labour productivity growth**

The findings show that ICT intensity yielded no significant short-run effects on the labour productivity growth of any of the more ICT-intensive industries. However, significant long-run effects were notable for four industries (food, beverages, paper and rubber industries). Notably, ICT intensity would exhibit higher growth in labour productivity for the food industry. More precisely, the growth rate of labour productivity would increase by 0.89 percentage point as ICT intensity increased by 1 percentage point. In the case of the beverages industry, the growth rate of labour productivity would increase by 0.51 percentage point as ICT intensity increased by 1 percentage point. At the same time, an increase in ICT intensity of 1 percentage point would increase the labour productivity growth of the paper industry by 0.77 percentage point and that of the rubber industry by 0.56 percentage point. Overall, in the short run, ICT intensity yielded no significant effects on the labour productivity growth of the more ICT-intensive industries. In the long run, positive significant effects were observable for the food, beverages, paper and rubber industries.

- **Effects on output growth**

The findings demonstrate that ICT intensity yielded no significant short-run and long-run effects on output growth of two of the more ICT-intensive industries (i.e. beverages and textile industries). However, significant short-and long-run effects were notable for three industries (i.e. food, paper and rubber industries). Noteworthy were the higher effects for the paper industry. Quantitatively, in the long run, a 1 percentage point increase in ICT intensity would increase the growth rate of output of the paper industry by 0.96 percentage point and the growth of the food and rubber industries by 0.80 and 0.46 percentage points, respectively. The key point to note is that of the more ICT-intensive industries, the paper industry experienced the highest output growth. The descriptive results showed that the paper industry exhibited higher output growth than other industries. Therefore, these results suggest that the effects of ICT intensity on output growth are higher for industries that experience higher output growth.

(c) Short-run and long-run results for Panel C industries

The short-run and long-run results of individual industries embedded in Panel C are presented in Table B.10. Overall, the findings show that there was a large variation across industries in terms of ICT intensity's contribution to the growth of labour productivity, output and employment.

- **Effects on employment growth**

The findings from both the short-run and long-run analyses are that ICT yielded no significant effect on the employment growth rates of all the less ICT-intensive industries. The descriptive results revealed that the less ICT-intensive industries experienced the highest decline in employment growth. One of the assumptions made in this chapter is that the effect of ICT on growth varies according to the intensity of usage, such that the industries using ICT less intensively exhibit lower growth. Therefore, given the declining/lower employment growth of the less ICT-intensive industries, these findings suggest that such decline cannot be linked to ICT.

- **Effects on labour productivity growth**

The findings from the short-run analysis are that ICT yielded no significant effect on the growth rates of labour productivity of all the less ICT-intensive industries. However, significant effects were detected in the long run for all the less ICT-intensive industries. In particular, ICT intensity yielded a negative significant effect on the labour productivity growth rate of all the less ICT-intensive industries (tobacco (-1.13), wearing apparel (-1.52), leather (-1.79), wood (-0.98) and furniture (-1.02)). The implication is that a 1 percentage point increase in ICT intensity would lead to a decline in the labour productivity growth rate of the less ICT-intensive industries (i.e. tobacco -1.13 percentage point, wearing apparel -1.52 percentage point, leather -1.79 percentage point, wood -0.98 percentage point and furniture -1.02 percentage point).

Overall, the findings demonstrate that, in the short run, ICT intensity yields no significant effect on the labour productivity of the less ICT-intensive industries but a negative and significant effect in the long run. Therefore, these findings are as expected and in line with those of previous studies, which found no negative significant effects for less ICT-intensive industries. Further to this, the fact that significant effects were notable in the long run suggests that labour productivity effects from ICT investment manifest over a longer period.

- **Effects on output growth**

The finding from the short-run analysis was that ICT yielded no significant effect on the output growth of all the less ICT-intensive industries. However, significant effects were detectable in the long run in the case of four of the less ICT-intensive industries (i.e. tobacco, wearing apparel, wood and furniture). To be precise, an increase in ICT intensity by 1 percentage point would increase the output growth of these industries (tobacco 0.71 percentage point, wearing apparel 0.54 percentage point, wood 0.66 percentage point and furniture 0.69 percentage point).

4.6.6 Discussion of the PMG results

This section serves to provide a discussion of the PMG findings to underscore meanings, insights and implications. There are three rationales for discussing the results. The first rationale is to highlight which industry group and which of the individual industries would experience higher growth through ICT investment. The second rationale is to underline how long it would take for ICT to yield positive effects on the growth of labour productivity, output and employment (i.e. short run vs. long run). Therefore, where positive and significant effects are observable in the short run, it implies that ICT would yield positive effects in the short term, and vice-versa if positive and significant effects are observable in the long run. Where positive effects are notable in both periods, it implies that ICT would yield positive effects in both periods.

The third rationale is to highlight whether the ICT–LP–RO–EMP nexus holds, as suggested by the theoretical framework of the study. Where significant effects were obtained in terms of all the variables (i.e. labour productivity, output and employment), the implication is that the nexus holds. In contrast, if no significant effects were obtained or significant effects were obtained but not for all the growth variables, it implies that the nexus does not hold.

Since the aim of the study was to examine the contribution of ICT investment to the growth of the agro-processing industries, the findings are, therefore, explained in terms of whether ICT investment would contribute to the growth of the industries. In brief, the PMG findings indicated that the contributions of ICT investment to growth varied according to industry group and period of analysis (short run vs. long run). More specifically, significant and positive contributions of ICT investment to the growth of labour productivity, output and employment were notable only for the more ICT-intensive industry group in the long run.

Three implications are to be derived from this finding. The first implication is that ICT investment would make no significant contribution when industries are aggregated. The second implication is that the contribution would vary according to an industry group, such that significant and positive contributions would be notable for an industry group that invested more in ICT. The third implication is that the returns on ICT investment take time to materialise; hence, significant and positive contributions to the growth of labour productivity, output and employment would be notable in the long run for the more ICT-intensive industry group.

Overall, these findings have an implication on the question of whether the ICT–LP–RO–EMP nexus holds for the industry groups and individual industries. The answer to this question is that it does hold, but only for the more ICT-intensive industry group and only in the long run. This implies that the nexus would hold in the long term for an industry group that invested more in ICT. Hence, in the long run, ICT investment would increase the labour productivity, output and employment of the more ICT-intensive industry group. Therefore, the fact that employment would increase implies that ICT investment would increase labour productivity, resulting in higher output, and that higher output would be achieved by increasing the labour input, and employment would increase.

In terms of the individual industries, the PMG findings show that the contribution of ICT investment to the growth of the industries would vary according to the period of analysis (short run vs. long run) and growth variable. In terms of the period of analysis, the findings show that

ICT investment would not contribute to the growth of labour productivity, output and employment of all the industries in both the less ICT and more ICT-intensive industry groups.[65] However, significant and positive contributions of ICT investment to the growth of labour productivity, output and employment would be notable only for the food industry and only in the long run.

Two implications have been derived from the above findings. The first implication is that the contribution of ICT investment to growth would vary according to the industry, such that significant and positive contributions would be notable for the industry that invested more in ICT. The second implication is that returns on ICT investment take time to materialise, hence significant and positive contributions to the growth of labour productivity, output and employment would be notable in the food industry in the long run.

The above findings imply that the ICT–LP–RO–EMP nexus holds only for the food industry and only in the long run. This implies that the nexus would hold in the long term for an industry that invested more in ICT. Hence, in the long run, ICT investment would increase labour productivity, output and employment in the food industry. Therefore, the fact that employment would increase implies that ICT investment would increase labour productivity, resulting in higher output and that higher output would be achieved by increasing the labour input, hence employment would increase.

In terms of the growth variable, significant and positive contributions of ICT investment to the output growth would be notable, in the long run, for most industries in both the more ICT-intensive industry group (food, beverages, paper and rubber and textile) and the less ICT-intensive industry group (i.e. tobacco, wearing apparel, wood and furniture). Nonetheless, the comparison of the magnitude of such a contribution revealed that the contribution would be higher for the industries that are more ICT-intensive. In support of this, in the case of the paper industry and the wearing apparel industries (i.e. industries whose contribution was the highest from each group), it is noted that the contribution of ICT investment to output growth would be higher for the paper industry. Quantitatively, ICT investment would contribute 0.90

[65] The only case in which positive and significant contributions are notable, in the short run, is with respect to output growth of the food industry.

percentage point to the output growth of the paper industry, which was higher than its contribution to the wearing apparel industry (i.e. 0.54 percentage point).

In contrast, in the case of the textile and tobacco industries (i.e. industries whose contribution was the least from each group), it is notable that the contribution of ICT investment to output growth was higher for the textile industry. Quantitatively, ICT investment would contribute 0.46 percentage point to the output growth of the textile industry. This contribution was higher than its contribution to the output growth of the tobacco industry (i.e. 0.27 percentage point).

The reason significant and positive contributions of ICT investment to the output growth were notable for most industries is that the industries had experienced higher average output growth in the absence of ICT investment (as indicated in Table 4.2). It is on this basis that chapter five serves to validate whether the output growth observed from the PMG findings is due to ICT investment. It is equally important to note that the paper industry had experienced higher average growth (2.4%) than the food industry (2.0%) in the absence of ICT investment. The PMG findings showed that the paper industry would exhibit higher output growth (0.90 percentage point) than the food industry (0.80 percentage point). Consequently, it is necessary to test whether the higher growth in the paper industry is due to ICT investment.

4.6.7 DOLS results

This section presents the DOLS estimation results to validate the robustness of the long-run estimates obtained from the PMG estimation. In this context, the reporting focuses on whether the DOLS findings validate the PMG findings. The DOLS findings for the Panel of industries are presented in Table B.11, while those of industries of Panels B and C are displayed in Table B.12 and Table B.13, respectively. A summary of the DOLS results for the Panel of industries is presented in Table 4.6.

Table 4.6: Robustness of the long-run estimates for Panel of industries

Endogenous variable	ICT (PMG)	ICT (DOLS)	Is the long run robust?
Panel A: All agro-processing industries			
EMP	No effect	No effect	Yes
LP	Negative effect	No effect	No
RO	Negative effect	No effect	No
Panel B: More ICT-intensive industries			
EMP	Positive effect	Positive effect	Yes
LP	Positive effect	Positive effect	Yes
RO	Positive effect	Positive effect	Yes
Panel C: Less ICT-intensive industries			
EMP	No effect	No effect	Yes
LP	Negative effect	Negative effect	Yes
RO	Positive effect	No effect	No

Source: Author's own compilation

In terms of the Panel of industries, the DOLS findings confirm that ICT investment would make no significant contribution to the growth of labour productivity, employment and output of the aggregated industries. In contrast, the DOLS findings prove that positive and significant contributions of ICT investment to the growth of labour productivity, output and employment would be notable in the case of the more ICT-intensive industry group. In terms of the less ICT-intensive industry group, in cases where the PMG found significant contributions (positive or negative) of ICT investment, the DOLS estimates demonstrate that ICT investment would make no significant contribution. Table 4.7 presents a summary of the long-run coefficients for the individual industries. In terms of the individual industries, the DOLS coefficients show that ICT investment would not contribute to the growth of labour productivity, employment and output in all the less ICT-intensive industries. In other words, in cases where the PMG found significant contributions (positive or negative) of ICT investment, the DOLS estimates demonstrate that ICT investment would make no significant contribution.

Table 4.7: Summary of the long-run coefficients for the individual industries

Endogenous variable	ICT (PMG)	ICT (DOLS)	Is the long run robust?
		Food	
EMP	Positive effect	Positive effect	Yes
LP	Positive effect	Positive effect	Yes
RO	Positive effect	Positive	Yes
		Beverages	
EMP	No effect	No effect	Yes
LP	Positive effect	Positive effect	Yes
RO	Positive effect	Positive effect	Yes
		Textile	
EMP	No effect	No effect	Yes
LP	No effect	No effect	Yes
RO	No effect	No effect	Yes
		Paper	
EMP	No effect	No effect	Yes
LP	Positive effect	Positive effect	Yes
RO	Positive effect	Positive effect	Yes
		Rubber	
EMP	No effect	No effect	Yes
LP	Positive effect	Positive effect	Yes
RO	Positive effect	Positive effect	Yes
		Tobacco	
EMP	No effect	No effect	Yes
LP	Negative effect	No effect	No
RO	Positive effect	No effect	No
		Wearing apparel	
EMP	No effect	No effect	Yes
LP	Negative effect	No effect	No
RO	Positive effect	No effect	No
		Wood	
EMP	No effect	No effect	Yes
LP	Negative effect	No effect	No
RO	Positive effect	No effect	No

Table 4.7 continued

Leather			
EMP	No effect	No effect	Yes
LP	Negative effect	No effect	No
RO	No effect	No effect	Yes
Furniture			
EMP	No effect	No effect	No
LP	Negative effect	No effect	No
RO	Positive effect	No effect	No

Source: Author's own compilation

In terms of the more ICT-intensive industries, the DOLS findings prove that positive and significant contributions of ICT investment to the growth of labour productivity and output would be notable for the beverages, paper and rubber industries. The DOLS further prove that positive and significant contributions of ICT investment to the growth of labour productivity, output and employment would be notable for the food industry.

Overall, the DOLS findings validate the robustness of the long-run coefficients derived from the PMG estimation in the case of the more ICT-intensive industry group. The DOLS further validate the robustness of the long-run coefficients for labour productivity and output in the case of the more ICT-intensive industries (beverages, paper, and rubber). In addition to this, the DOLS validate the robustness of the long-run coefficients for the labour productivity, output and employment of the food industry, an industry that invested highly in ICT.

4.7 CHAPTER SUMMARY

This chapter has served to estimate the effects of ICT intensity on the productivity, output and employment of the agro-processing industries. To achieve this, the ICT intensity index developed by Engelbrecht and Xayavong (2006) was adapted to rank 10 agro-processing industries into more ICT-intensive and less ICT-intensive industry groups over the period 1994 to 2017. The ICT intensity index results showed that five industries, namely, food, beverages, textile, paper and rubber, were ranked as more ICT-intensive, while the rest of the industries, namely, tobacco, wearing apparel, leather, wood and furniture were ranked as less ICT-intensive. The results further signified that the more ICT-intensive industries accounted for

78% of ICT investment, whereas the less ICT-intensive industries accounted for the remaining 22%. Across the industries, the food industry accounted for the largest share of ICT investment (37.20%), whereas the tobacco industry accounted for the smallest share (0.84%).

The above findings on ICT intensity are important for this study, as previous studies have shown the impact of ICT to vary according to the industry concerned, such that the more ICT-intensive industries would exhibit higher growth compared to the less ICT-intensive industries. However, to date, there has been insufficient knowledge on which of the agro-processing industries are less and more ICT-intensive. Therefore, the ICT intensity findings provide an information base on the ICT intensity of the comprehensive agro-processing industries.

After calculating the ICT intensity of industries, the annual growth rates of the labour productivity, output and employment of all the industries for the period 1994–2017 were calculated. Consequently, the PMG estimations were undertaken to estimate short-and long-run effects of ICT intensity on the growth of labour productivity, employment and output. In the application, industries were classified into three panels, where Panel A comprised all the agro-processing industries. Panel B was composed of the more ICT-intensive industries, and Panel C comprised the less ICT-intensive industries. The analyses were further extended to individual industries embedded in Panels B and C.

The PMG findings indicated that the contribution of ICT investment to growth varied according to an industry group and the period of analysis (short run vs. long run). More specifically, significant and positive contributions of ICT investment to the growth of labour productivity, output and employment were notable only for the more ICT-intensive industries in the long run. Three implications were derived from this finding. Firstly, ICT investment would make no significant contribution when industries are aggregated. This implies that the lower growth contribution of less ICT-intensive industries outweighed the relatively higher growth contribution of more ICT-intensive industries.

Secondly, the contribution would vary according to an industry group, such that significant and positive contributions would be notable for an industry group that invested more in ICT. Thirdly, the returns on ICT investment take time to materialise, which means that significant and positive contributions to the growth of labour productivity, output and employment are notable in the long run in the case of the more ICT-intensive industry group.

The above findings imply that the ICT–LP–RO–EMP nexus holds only for the more ICT-intensive industry group and only in the long run. This implies that the nexus would hold in the long term for an industry group that invested more in ICT. Hence, in the long run, ICT investment would increase the labour productivity, output and employment of the more ICT-intensive industry group. The fact that employment would increase implies that ICT investment would increase labour productivity, resulting in higher output, and that higher output would be achieved by increasing the labour input, resulting in increased employment.

In terms of the individual industries, the PMG findings showed that the contribution of ICT investment to the growth of the industries would vary according to the period of analysis (short run vs. long run) and growth variable. In terms of the period of analysis, the findings showed that ICT investment would not contribute to the growth of labour productivity, output and employment of all the industries in both the more ICT and less ICT-intensive industry groups.[66] However, significant and positive contributions of ICT investment to the growth of labour productivity, output and employment would be notable only for the food industry and only in the long run.

Two key implications have been derived from the above findings. The first implication is that the contribution of ICT investment to growth would vary according to the industry, such that significant and positive contributions would be notable for the industry that invested more in ICT. The second implication is that returns on ICT investment take time to materialise, hence significant and positive contributions to the growth of labour productivity, output and employment would be notable in the long run in the case of the food industry. These findings imply that the ICT–LP–RO–EMP nexus holds only for the food industry and only in the long run. This implies that the nexus would hold in the long term for an industry that invested more in ICT. Hence, in the long run, ICT investment would increase the labour productivity, output and employment of the food industry. Therefore, the fact that employment would increase

[66] The only case in which positive and significant contributions are notable, in the short run, is with respect to the output growth of the food industry.

implies that ICT investment would increase labour productivity, resulting in higher output and that higher output would be achieved by increasing the labour input, and employment would increase.

In terms of growth variable, significant and positive contributions of ICT investment to the output growth would be notable, in the long run, for most industries in both the more ICT-intensive and the less ICT-intensive industry groups. However, a comparison of the magnitude of such contributions revealed that the contribution would be higher for the paper industry, which is more ICT-intensive, and lower for the tobacco industry, which is less ICT-intensive.

Overall, the PMG results indicated that the contribution of ICT investment to growth varied according to industry group, such that positive and significant contribution would be realised by an industry group that invested more in ICT. In support of this, the more ICT-intensive industry group accounted for the larger share of ICT investment. Accordingly, the PMG findings showed that positive and significant contributions of ICT investment to the growth of labour productivity, output and employment would be realised by the more ICT-intensive industry group.

The PMG findings further showed that the contribution of ICT investment to growth varied according to industry, such that positive and significant contribution would be realised by the food industry, an industry that invested more in ICT. In support of this, the food industry accounted for the largest share of ICT investment, whereas the tobacco industry accounted for the smallest share. Accordingly, the PMG findings showed that positive and significant contributions of ICT investment to the growth of labour productivity, output and employment would be realised by the food industry. In contrast, in cases where positive and significant contributions were notable with respect to output growth, the contribution would be lower for the tobacco industry, an industry that invested less in ICT.

CHAPTER 5: EXPLORING CAUSAL RELATIONSHIP BETWEEN ICT INTENSITY AND PRODUCTIVITY, OUTPUT AND EMPLOYMENT IN SOUTH AFRICA: AN INDUSTRY-LEVEL ANALYSIS

5.1 INTRODUCTION

In this chapter, the relationship between ICT intensity and growth of agro-processing industries is explored. This is done by testing for the causal relationship between ICT intensity and labour productivity, output and employment. In so doing, the third objective of the study, which is to examine the causal relationship between ICT intensity and labour productivity, output and employment, is achieved. Testing for causality is crucial for determining whether ICT intensity causes growth in labour productivity, output and employment. A background on lessons derived from the preceding chapters to explain the logical basis for conducting the current analysis is provided in the next section.

5.2 BACKGROUND AND RATIONALE

In chapter three, in the case of agro-processing industries, it was established that both the more and less ICT-intensive industries exhibited acceleration in labour productivity growth. However, overall, the more ICT-intensive industries experienced a slightly higher acceleration in LP (1.76% relative to 0.92%). At the same time, through the DD estimation, the difference in labour productivity growth between the two groups of industries could not be attributed to ICT use. For this reason, five delimitations, which could have influenced the results, were identified. Most of the delimitations were addressed in the preceding chapter.

The delimitation, addressed in this chapter, is that the DD technique does not capture the causal relationship between ICT and growth of the industries. Moreover, the PMG findings showed that ICT investment would contribute to the labour productivity, output and employment growth of the more ICT-intensive industry group and the food industry. The PMG findings further showed that ICT investment would contribute to the output growth of most of the industries of both the more ICT-intensive industry group (food, beverages, paper and rubber and textile) and the less ICT-intensive industry group (i.e. tobacco, wearing apparel, wood and furniture).[67]

It was noted that these industries had experienced higher average output growth in the absence of ICT investment. Furthermore, the paper industry had experienced higher average growth (2.4%) than the food industry (2.0%) in the absence of ICT investment. The PMG findings showed that the paper industry would exhibit higher output growth (0.90 percentage point) than the food industry (0.80 percentage point) due to ICT investment. However, the PMG does not test for the direction of the causal relationship among variables. Testing for the causal relationship is crucial for determining whether the observed growth from the PMG results was due to ICT investment (i.e. whether ICT investment is a source of growth of labour productivity, output and employment). Hence, the TY Granger non-causality test was applied to test for causality between ICT intensity and growth of labour productivity, output and employment. A discussion of the literature on the causal relationship between ICT and GDP/output, labour productivity and employment is presented in the next section.

5.3 REVIEW OF RELATED LITERATURE

Many studies have investigated the causal relationship between ICT investment and other measures of growth by using various data sources, periods and analytical approaches. In this section, the review is focused on the causal relationship between ICT and output/GDP growth, productivity and employment, with emphasis on the aggregate-level studies due to a dearth of empirical studies on the causal relationship between ICT investment and growth of various industries. However, the findings from the review on the aggregate-level studies are used as a source of reference for testing for causality between ICT and growth of the agro-processing industries (at the disaggregate level). The review covers three groups of studies. The first group includes studies on causality between ICT and GDP. The second group covers studies on causality between ICT and labour productivity, while the third group focuses on causality between ICT and employment. However, the review is focused on the effects of ICT on employment and not necessarily on causality due to a dearth of empirical studies that focused on causality between ICT and employment.

[67] Nonetheless, the comparison of the magnitude of such contribution, prove that the contribution would be higher for the industries that are more ICT-intensive.

In terms of the first group of studies, an aggregate-level study by Shiu and Lam (2008) applied the Granger causality framework to investigate the causal relationship between telecommunication development and economic growth for 107 countries for the period 1980–2006. The study found a bidirectional relationship between ICT and GDP for the developed countries that was attributable to higher levels of ICT investment, and a unidirectional relationship for the developing countries that was attributable to lower levels of ICT investment.[68] This finding implies that evidence of ICT-led growth (GDP) is concentrated in developed countries due to higher levels of ICT investment. Other studies (Cie'slik and Kaniewsk, 2004; Masood, 2012) have also found evidence of ICT-led growth for the developed countries, which is attributed to high levels of ICT investment.

Another aggregate-level study by Pradhan *et al.* (2014) applied the Panel vector autoregressive model to examine the causal relationship between the development of telecommunications infrastructure (DTI) and GDP growth for G20 countries for the period 2001–2012. The findings detected unidirectional causality from GDP growth to DTI for developing countries and unidirectional causality from DTI to economic growth for the developed countries. The variations in the direction of causality were attributed to the finding that the usage of mobile phones in developing countries had not attained the maturity level. As such, it was economic growth that stimulated mobile phone usage (Pradhan *et al.*, 2014). Thus, this study has shown that ICT investment was the source of GDP growth for the developed countries, which constitute countries that have invested more in ICT. Overall, the aggregate-level studies have revealed that causality between ICT and GDP growth varies per country, such that evidence of causality was detected for countries that have invested more in ICT.

In the case of the second group of studies that focused on causality between ICT and labour productivity, Lee *et al.* (2005) applied Granger causality techniques and a Johansen cointegration test to examine the causal relationship between ICT investment and productivity of 20 countries (i.e. 15 developed and 5 developing countries) from 1980 to 2000. The study showed evidence of a causal relationship between ICT investment and productivity for the

[68] Bidirectional causality is a two-way causal relationship between two variables. Unidirectional causality is a one-way causal relationship from one variable to the other, and not vice versa.

developed countries. The implication is that developing countries are yet to experience productivity gains from ICT investment due to their lower levels of ICT investment.

While the study by Lee *et al.* (2005) has revealed that productivity gains from ICT investment are confined to the developed countries, another set of studies have revealed that ICT-led growth depends on whether the analyses are undertaken in a bivariate (i.e. two variables) or multivariate (more than two variables) setting. For instance, studies that have examined the effects of ICT in a multivariate setting have found evidence of causality (Shahiduzzaman, Layton, and Alam, 2015; Salahuddin and Gow, 2016). In contrast, the bivariate studies have revealed zero evidence of causality (Rei, 2004; Beil, Ford and Jackson, 2005; Chakraborty and Nandi, 2011; Masood, 2012; Yousefi, 2015; Hong, 2017).

The ground for conducting causality analysis in a bivariate setting includes the scope of the analysis or data availability. Despite this, Payne (2010) noted that conducting the analysis in bivariate setting causes omitted variable bias, which casts doubt on the robustness of the statistical inferences of a causal relation. In contrast, and as stated by Zachariadis (2007), conducting the analysis in a multivariate setting allows researchers to reveal multiple causality channels that are undetectable under a bivariate setting, while avoiding omitted variable bias. Hence, studies that have been conducted in a multivariate setting have ascertained causality between ICT investment and labour productivity growth. Consequently, in this chapter, the analyses are conducted in a multivariate setting involving ICT intensity, labour productivity, output and employment.

In terms of the third group of studies that focused on causality between ICT and employment, it is noted that, unlike the first and second groups of studies, there are very few empirical studies on the causal relationship between ICT and employment. Therefore, the review includes studies that have examined the effect of ICT on employment, but not causality per se. However, empirical studies have striven to find a positive correlation between ICT and employment, especially aggregate-level studies in developed countries (Etro, 2009; Kolko, 2012; Jayakar and Park, 2013; Pantea *et al.*, 2014) and developing countries (Khan *et al.*, 2017).

The review of literature covered the aggregate-level studies, as empirical studies on causality did not examine whether there is a causal relationship between ICT and growth of industries. While the review focuses on the aggregate-level studies rather than on the disaggregate-level studies, the findings from the reviewed studies serve as a point of reference for this chapter as follows. The aggregate-level studies have revealed bidirectional causality for the developed countries due to higher levels of ICT investment. The studies further identified unidirectional causality for the developing countries due to lower levels of ICT investment.

Although the disaggregate-level studies did not test for causality, they have found a positive and significant effect of ICT investment on growth (GDP or labour productivity) for those industries that have invested more in ICT (i.e. more ICT-intensive industries) (Abri and Mahmoudzadeh, 2015; Moshiri, 2016, Niebel *et al.*, 2016). However, unlike the aggregate-level studies, these studies did not test for the direction of the causal relationship among variables. Therefore, the causal relationship between ICT and growth of labour productivity, output and employment of 10 agro-processing industries is examined in this chapter. The rationale for doing so is to validate whether ICT investment causes growth of labour productivity, output and employment. Specifically, the Granger causality test is applied, in this chapter, to test for a causal relationship between ICT intensity and growth in labour productivity, output and employment. Accordingly, the Panel Granger causality test used for the analyses is presented and discussed in the subsequent section.

5.4 PANEL GRANGER CAUSALITY TEST

While previous research techniques examined the presence of a relationship among variables (bounds test) and effects thereof (through PMG estimation), Lee *et al.* (2005) argued that an existence of a strong association between ICT and variables of interest does not prove a causal relationship. Furthermore, these techniques cannot test for the direction of the causal relationship among variables. For these reasons, the Toda and Yamamoto (TY) Granger non-causality test, developed by Toda and Yamamoto (1995), was applied to examine the causal relationship between ICT intensity and growth of labour productivity, output and employment. The TY Granger non-causality test is preferred over the renowned test by Engle and Granger (1987) because it can be applied when variables are integrated of different orders. By so doing, the TY test overcomes the pre-test bias and size distortion associated with unit root and cointegration tests (Yamada, 1998; Caragata and Giles, 2000; Clark and Mirza). The TY test model fits a standard vector autoregressive model in the level form of the variables, instead of the first differences, as is the case with other Granger causality tests. This minimises the risks related to the possibility of erroneously identifying the order of integration of the variable (Mavrotas and Kelly, 2001, cited by Wolde-Rufael, 2005).

There are two preconditions for applying the TY test. The first precondition is that the TY test requires testing for the maximal order of integration (d_{max}) and the true optimum lag length (k) (Toda and Yamamoto, 1995, cited by Yami, Meyer and Hassan, 2017).[69] This implies that the TY test is conducted by estimating the maximal $(k+d_{max})^{th}$ order of Vector Autoregression (VAR). The second precondition is that for the modified WALD test to be valid, the order of integration of the process must not outpace the true lag length of the model (Toda and Yamamoto, 1995, Yami *et al.*, 2017). To apply the TY version of the Granger non-causality test, the study represented the ICT intensity-growth nexus by augmenting an additional lag order to the optimal lag (Caporale and Pittis, 1999), as described in the following equations:

$$ICT_t = a_{01} + \sum_{i=1}^{p} a_{1i} ICT_{t-i} + \sum_{j=k+1}^{d\max} a_{2i} ICT_{t-j} + \sum_{i=1}^{q} \beta_{1i} LP_{t-i} + \sum_{j=k+1}^{d\max} \beta_{2i} LP_{t-j} + \sum_{i=1}^{r} d_{1i} EMP_{t-i} + \sum_{j=k+1}^{d\max} d_{2i} EMP_{t-j} + \sum_{i=1}^{s} p_{1i} RO_{t-i} + \sum_{j=k+1}^{d\max} p_{2i} RO_{t-j} + \varepsilon_{1t} \tag{5.1}$$

$$LP_t = a_{02} + \sum_{i=1}^{p} a_{1i} ICT_{t-i} + \sum_{j=k+1}^{d\max} a_{2i} ICT_{t-j} + \sum_{i=1}^{q} \beta_{1i} LP_{t-i} + \sum_{j=k+1}^{d\max} \beta_{2i} LP_{t-j} + \sum_{i=1}^{r} d_{1i} EMP_{t-i} + \sum_{j=k+1}^{d\max} d_{2i} EMP_{t-j} + \sum_{i=1}^{s} p_{1i} RO_{t-i} + \sum_{j=k+1}^{d\max} p_{2i} RO_{t-j} + \varepsilon_{2t} \tag{5.2}$$

[69] The determination of optimal lags and results thereof are as described in 4.3.

$$EMP_t = a_{03} + \sum_{i=1}^{p} a_{1i} ICT_{t-i} + \sum_{j=k+1}^{d\max} a_{2i} ICT_{t-j} + \sum_{i=1}^{q} \beta_{1i} LP_{t-i} + \sum_{j=k+1}^{d\max} \beta_{2i} LP_{t-j} + \sum_{i=1}^{r} d_{1i} EMP_{t-i} + \sum_{j=k+1}^{d\max} d_{2i} EMP_{t-j} + \sum_{i=1}^{s} p_{1i} RO_{t-i} + \sum_{j=k+1}^{d\max} p_{2i} RO_{t-j} + \varepsilon_{3t} \quad (5.3)$$

$$RO_t = a_{04} + \sum_{i=1}^{p} a_{1i} ICT_{t-i} + \sum_{j=k+1}^{d\max} a_{2i} ICT_{t-j} + \sum_{i=1}^{q} \beta_{1i} LP_{t-i} + \sum_{j=k+1}^{d\max} \beta_{2i} LP_{t-j} + \sum_{i=1}^{r} d_{1i} EMP_{t-i} + \sum_{j=k+1}^{d\max} d_{2i} EMP_{t-j} + \sum_{i=1}^{s} p_{1i} RO_{t-i} + \sum_{j=k+1}^{d\max} p_{2i} RO_{t-j} + \varepsilon_{4t} \quad (5.4)$$

where: (d_{max}) = maximal order of integration; k = true optimum lag length. k+d_{max} = maximal order of integration; k = true optimum lag length. In the context of causality, this study explored the ICT intensity-growth nexus involving three growth variables (i.e. labour productivity, employment and output) that could be affected by ICT intensity and/or affect ICT intensity. Therefore, as per Rei (2004), four varying outcomes are likely to emerge after performing TY non-causality test:

(i) Neither variable “Granger-causes” the other;

(ii) Unidirectional causality from ICT intensity to growth variable, for example, ICT intensity causes labour productivity but not vice versa;

(iii) Unidirectional causality from growth variable to ICT intensity, for example, labour productivity causes ICT intensity but not vice versa;

(iv) Bidirectional causality between ICT intensity and growth variable, for example, ICT intensity and labour productivity "Granger-causes" each other. This signifies that there exists bilateral causality (feedback effect) between the two variables (Rei, 2004).

The direction of causality is confirmed by testing for the null hypothesis of no Granger causality by applying the modified Wald statistics to Equations (5.1) to (5.4) as follows:

H_{1a}: $a_{1i} = b_{1i} = 0$ implies that ICT intensity does not granger cause labour productivity growth.

H_{1b}: $b_{1i} = a_{1i} = 0$ implies that labour productivity growth does not granger cause ICT intensity.

H_{2a}: $a_{1i} = p_{1i} = 0$ implies that ICT intensity does not Granger-cause output growth.

H_{2b}: $p_{1i}=a_{1i}=0$ implies that output growth does not Granger-cause ICT intensity.
H_{3a}: $a_{1i}=d_{1i}=0$ implies that ICT intensity does not Granger-cause employment growth.
H_{3b}: $d_{1i}=a_{1i}=0$ implies that employment growth does not Granger-cause ICT intensity.

In brief, by testing for these hypotheses, this chapter establishes whether ICT investment is a source of growth of labour productivity, output and employment of agro-processing industries. The findings are presented in the next section.

5.5 GRANGER CAUSALITY TEST RESULTS

This section provides the results of the TY causality test. The results are separated into two different categories. Category one (Case 1) consists of the three Panel of industries (i.e. Panel A, B and C) in a multivariate setting, while category two (Case 2) is composed of the individual industries in a multivariate setting. The TY causality results for case 1 are presented and discussed as follows.

Case 1: Multivariate setting (Panel of industries)

The multivariate Granger causality results for the Panel of industries are presented in Table 5.1. The multivariate TY results for Panel A industries show no evidence of causality in any direction between ICT intensity and growth rates of labour productivity, output and employment. This means that there was no causal relationship between ICT and growth in labour productivity, output and employment of the aggregated agro-processing industries. These results suggest that evidence of causality between ICT intensity and the growth variables is undetectable when industries are aggregated. The implication is that the relatively lower growth of some industries outweighs the higher contribution of other industries.

The multivariate TY results for Panel B industries demonstrate that there was no evidence of causality in any direction between ICT intensity and growth rates of labour productivity and output. This implies that there is no causal relationship between ICT intensity and growth in both labour productivity and output of the more ICT-intensive industry group. However, evidence of unidirectional causality from ICT intensity to employment growth was detectable. The results suggest that evidence of causality between ICT intensity and growth variables varies per growth variable, such that evidence of causality is detectable for employment growth. Specifically, the PMG findings established that ICT investment contributed positively to the growth in employment of the more ICT-intensive industry growth. Therefore, these results validate that ICT investment was a source of growth in employment of the more ICT-intensive industries.

Table 5.1: Multivariate TY Granger non-causality results for Panel of industries

Panel A (All agro-processing industries)				
Endogenous Variable	**Exogenous variables**			
	ICT	**LP**	**EMP**	**RO**
ICT	-	1.843 (0.397)	0.751(0.686)	3.780 (0.151)
LP	2.104(0.349)	-	0.422 (0.809)	16.49*** (0.000)
EMP	1.877(0.391)	0.959(0.6190)	-	1.145 (0.564)
RO	2.103 (0.349)	4.898* (0.086)	7.315** (0.025)	-
Panel B (More ICT-intensive industries)				
	ICT	**LP**	**EMP**	**RO**
ICT	-	0.886 (0.6419)	1.482 (0.476)	2.113 (0.347)
LP	0.815 (0.665)	-	0.516 (0.772)	5.974* (0.050)
EMP	3.204* (0.073)	1.174 (0.555)	-	2.029 (0.362)
RO	2.922(0.232)	2.879 (0.237)	2.055 (0.357)	-
Panel C (Less ICT-intensive industries)				
	ICT	**LP**	**EMP**	**RO**
ICT		0.831(0.361)	0.042 (0.836)	0.006 (0.720)
LP	1.228 (0.267)	-	0.483 (0.486)	6.396** (0.011)
EMP	3.544(0.169)	1.895 (0.168)	-	2.094 (0.147)
RO	0.272(0.601)	0.113 (0.736)	0.019 (0.888)	-

Source: Author's own compilation

Note 1: ICT =ICT intensity (%); LP=labour productivity growth rate (%); EMP=growth rate of employment (%); RO =real output growth rate (%).

Note 2: Figures in parenthesis are the p-values.

Note 3: * = 10 % significance level; ** = 5% significance level; *** 1% significance level.

The multivariate TY results for Panel C industries indicate that there was no evidence of causality in any direction between ICT intensity and growth rates of labour productivity, output and employment. This signifies that there was no causal relationship between ICT and growth in labour productivity, output and employment of the less ICT-intensive industries. These results are attributed to the fact that the less ICT-intensive industries accounted for 22% of ICT intensity. Therefore, the results imply that causality occurs in line with the ICT intensity, such that there was no evidence of causality for an industry group that invested more in ICT.

Case 2: Multivariate setting (individual industries)

The multivariate Granger causality results for individual industries of Panel C are presented in Table 5.2. The multivariate TY results show that there was no evidence of causality in any direction between ICT intensity and growth of labour productivity, output and employment. This signifies that there was no causal relationship between ICT intensity and growth in labour productivity, output and employment of the less ICT-intensive industries. These results suggest that the causal effects of ICT are undetectable for less ICT-intensive industries). The results are attributed to the fact that the less ICT-intensive industries have invested less in ICT as they accounted for 22% of ICT intensity. Therefore, the causality results imply that evidence of causality varies per industry group, such that there was no evidence of causality for an industry group that invested less in ICT.

Table 5.2: Multivariate: TY Granger non-causality results for Panel C industries

	Panel C (Less ICT-intensive industries)				
Industry	**Dependent variable**	**Exogenous variables**			
Tobacco		**ICT**	**LP**	**EMP**	**RO**
	ICT	-	0.454 (0.5004)	0.806 (0.369)	2.666 (0.102)
	LP	0.308 (0.578)	-	6.549**(0.010)	7.666 (0.005)
	EMP	0.077 (0.780)	3.733* (0.053)	-	3.207* (0.073)
	RO	0.418 (0.517)	0.139 (0.708)	0.647 (0.421)	-
Wearing Apparel		**ICT**	**LP**	**EMP**	**RO**
	ICT		0.870 (0.363)	0.236 (0.629)	0.008 (0.821)
	LP	1.0914(0.779)	-	2.688 (0.442)	0.222 (0.973)
	EMP	2.173 (0.537)	2.203 (0.531)	-	0.293 (0.961)
	RO	3.957(0.266)	2.694 (0.441)	4.803 (0.186)	-
Leather		**ICT**	**LP**	**EMP**	**RO**
	ICT	-	0.655 (0.418)	0.024 (0.875)	0.860 (0.353)
	LP	2.682 (0.101)	-	0.120 (0.728)	2.080 (0.149)
	EMP	1.822 (0.177)	0.339 (0.560)	-	6.270 (0.993)
	RO	1.404 (0.236)	0.246 (0.619)	0.166 (0.683)	-
Wood		**ICT**	**LP**	**EMP**	**RO**
	ICT	-	0.009 (0.921)	0.053 (0.817)	0.090 (0.760)
	LP	1.245 (0.264)	-	0.095 (0.757)	7.536***(0.0006)
	EMP	0.0008 (0.925)	0.108 (0.742)	-	0.007 (0.930)
	RO	1.010 (0.314)	0.577 (0.447)	0.486 (0.485)	-
		ICT	**LP**	**EMP**	**RO**
Furniture	**ICT**	-	0.007(0.933)	0.0004(0.945)	0.0009 (0.974)
	LP	0.333 (0.563)	-	0.001 (0.970)	2.773 (0.095)
	EMP	0.683 (0.408)	0.506 (0.476)	-	14.750*** (0.0001)
	RO	0.289(0.5908)	0.0325 (0.856)	1.255 (0.262)	-

Source: Author's own compilation

Note 1: ICT =ICT intensity (%); LP=labour productivity growth rate (%); EMP=growth rate of employment (%); RO =real output growth rate (%).

Note 2: * Significant at 10 % level; ** Significant at 5% level; *** Significant at 1% level.

The multivariate Granger causality results for individual industries of Panel B are presented in Table 5.3.

Table 5.3: Multivariate: TY Granger non-causality results for Panel B industries

	Panel B (More ICT-intensive industries)				
Industry	**Endogenous variable**	**Exogenous variables**			
Food		**ICT**	**LP**	**EMP**	**RO**
	ICT	-	1.843 (0.397)	12.692*** (0.004)	3.780 (0.151)
	LP	11.078** (0.011)	-	0.422 (0.809)	16.49*** (0.0003)
	EMP	1.877** (0.035)	0.959 (0.6190)	-	17.489*** (0.0006)
	RO	16.561***(0.0009)	4.898* (0.086)	7.315**(0.025)	-
Beverages		**ICT**	**LP**	**EMP**	**RO**
	ICT	-	0.830 (0.842)	4.610 (0.202)	4.454 (0.216)
	LP	7.161*(0.066)	-	6.024 (0.110)	17.738*** (0.0005)
	EMP	1.992 (0.574)	0.352 (0.949)	-	1.557 (0.669)
	RO	2.115* (0.058)	1.632 (0.652)	2.044 (0.563)	-
Textile		**ICT**	**LP**	**EMP**	**RO**
	ICT	-	3.130 (0.459)	1.612 (0.204)	0.829(0.445)
	LP	0.578 (0.708)	-	1.784 (0.181)	1.866 (0.171)
	EMP	0.644 (0.422)	0.059 (0.807)	-	0.928 (0.335)
	RO	1.21(0.450)	0.084(0.771)	0.209 (0.646)	-
Paper		**ICT**	**LP**	**EMP**	**RO**
	ICT	-	0.415 (0.519)	2.81 (0.1093)	1.107 (0.292)
	LP	4.798* (0.076)	-	0.056 (0.812)	0.356(0.550)
	EMP	1.438 (0.230)	0.479 (0.488)	-	1.263 (0.2610)
	RO	7.215**(0.035)	0.021 (0.883)	1.061 (0.302)	-
		ICT	**LP**	**EMP**	**RO**
Rubber	**ICT**	-	5.151 (0.137)	0.425 (0.529)	0.730 (0.742)
	LP	0.578* (0.078	-	6.235 (0.100)	8.229*** (0.004)
	EMP	0.061 (0.907)	14.243***(0.0026)	-	7.35**(0.045)
	RO	1.21** (0.045)	19.225*** (0.000)	12.924***(0.0048)	-

Source: Author's own compilation

Note 1: ICT =ICT intensity (%); LP=labour productivity growth rate (%); EMP=growth rate of employment (%); RO =real output growth rate (%). Note 2: * Significant at 10 % level; ** Significant at 5% level; *** Significant at 1% level.

The results indicate that there was no evidence of causality in any direction between ICT intensity and growth rates of labour productivity, output and employment of the textile industry. The descriptive results showed that, out of the more ICT-intensive industries, the textile industry accounted for the least share of ICT intensity. Therefore, these results suggest that there was no evidence of a causal relationship for the industry with a lower share of ICT intensity.

The findings further show that there was no evidence of causality in any direction between ICT intensity and employment growth of beverages, paper and rubber industries. These findings are in line with those of PMG findings, which showed that ICT investment did not contribute to the employment growth of these industries. However, evidence of causality was notable for labour productivity and output growth of the beverages, paper and rubber industries. These findings are in line with those of PMG findings in which positive and significant contributions of ICT investment to growth of labour productivity and output were observed for the beverages, paper and rubber industries. Therefore, the causality findings validate that ICT investment was the source of growth of labour productivity and output for the beverages, paper and rubber industries.

Again, since the descriptive results showed that there was a decline in employment growth, these findings show that such a decline was not due to ICT. Therefore, the results suggest that evidence of causality occurs in line with ICT intensity and growth performance of the industries, such that there was no causality for employment for the beverages, paper and rubber industries.

The results further show that the food industry was the only industry in which there was evidence of causality between ICT intensity and all the growth variables. More specifically, the findings signify that ICT intensity had a causal effect on the growth of labour productivity, output and employment of the food industry. These findings are in line with those of PMG findings in which positive and significant contributions of ICT investment to growth of labour productivity, output and employment were reported for the food industry. The descriptive results show that the food industry accounted for the largest share of ICT investment. Therefore, the results imply that the causal effects of ICT intensity on the growth variables vary per industry, such that evidence of a causal relationship between ICT intensity and growth of labour productivity, output and employment was notable for an industry that invested highly in ICT.

It should be noted that, while there was evidence of causality between ICT intensity and all the growth variables only for the food industry, such evidence was unidirectional and not bidirectional. In other words, causality was only from ICT intensity to growth variables, which implies that there is no feedback effect between ICT intensity and growth variables. This also applies to the industry groups and the rest of the individual industries.

5.6 DISCUSSION OF THE GRANGER CAUSALITY TEST RESULTS

This section serves to provide a discussion of the TY Granger causality test findings to underscore meanings, insights and implications. The rationale is to highlight whether ICT investment is a source of growth of labour productivity, output and employment. The multivariate Granger causality results are summarised and presented in Table 5.4.

Table 5.4: Summary of the direction of causality (individual industries)

Industry	**ICT-Employment nexus**	**ICT-Productivity nexus**	**ICT-Output nexus**
Panel B (More ICT-intensive industries)			
Food	Unidirectional (ICT→EMP)	Unidirectional (ICT→LP)	Unidirectional (ICT→RO)
Beverages	No causality	Unidirectional (ICT→LP)	Unidirectional (ICT→RO)
Textile	No causality	No causality	No causality
Paper	No causality	Unidirectional (ICT→LP)	Unidirectional (ICT→RO)
Rubber	No causality	Unidirectional (ICT→LP)	Unidirectional (ICT→RO)
Panel C (Less ICT-intensive industries)			
Tobacco	No causality	No causality	No causality
Wearing apparel	No causality	No causality	No causality
Leather	No causality	No causality	No causality
Wood	No causality	No causality	No causality
Furniture	No causality	No causality	No causality

Source: Author's own compilation

Note: ICT =ICT intensity (%); LP=labour productivity growth rate (%); EMP=growth rate of employment (%); RO =real output growth rate (%).

In brief, there was no evidence of a causal relationship between ICT and growth of labour productivity, output and employment for the less ICT-intensive industries. This means that causal effects occur in line with ICT investment, such that there was no evidence of causality for the industry group that invested more in ICT. Instead, evidence of a causal relationship was observable for the more ICT-intensive industries. Specifically, evidence of causality was notable for labour productivity and output growth of the beverages, paper and rubber industries. These findings are in line with those of PMG findings in which positive and significant contributions of ICT investment to growth of labour productivity and output were observed for the beverages, paper and rubber industries. The implication is that ICT investment was the source of growth of labour productivity and output for the beverages, paper and rubber industries.

The findings further showed that there was evidence of a causal relationship between ICT intensity and growth of labour productivity, output and employment growth of the food industry. These findings are in line with those of PMG findings in which positive and significant contributions of ICT investment to growth of labour productivity and output were observed for the food industry. This implies that ICT investment is the source of growth of labour productivity, output and employment of the food industry.

Overall, two key points were derived from TY Granger causality results. The first point was that the causal effects of ICT investment were undetectable when industries were aggregated. This implies that the lower causal effects of other industries outweighed the relatively higher causal effects of some industries. The second point was that the causal effects of ICT were observable for the more ICT-intensive industries, contrary to the less ICT-intensive industries. This means that causal effects occur in line with ICT investment, such that evidence of causality was detected for the industry group that invested more in ICT.

5.7 CHAPTER SUMMARY

The objective explored in this chapter was to examine the causal relationship between ICT intensity and growth of labour productivity, output and employment of agro-processing industries. Testing for the causal relationship is crucial for determining whether the observed growth from the PMG results was due to ICT investment (i.e. whether ICT investment was a source of growth of labour productivity, output and employment). Given this, the TY Granger non-causality test was applied to test for causality between ICT and growth of labour productivity, output and employment.

The results for the Panel of industries signified that there was no causal relationship between ICT intensity and growth in labour productivity, output and employment of the aggregated agro-processing industries. This implies that the lower causal effects of other industries outweighed the relatively higher causal effects of some industries. However, the results showed that there was evidence of causality for the industries that are more ICT-intensive. In contrast, the results showed that there was no evidence of a causal relationship for the less ICT-intensive industries. The descriptive results showed that the more ICT-intensive industries invested more in ICT, relative to the less ICT-intensive industries. Therefore, the results imply that causality occurs in line with the ICT intensity, such that there was evidence of causality for the industries that invested more in ICT.

The rationale for testing for causality was to validate whether the observed growth from the PMG results was due to ICT investment (i.e. whether ICT investment was a source of growth of labour productivity, output and employment). The findings showed that ICT investment was the source of growth of the more ICT-intensive industries. More specifically, the findings showed that ICT investment was the source of growth of labour productivity and output for the food, beverages, paper and rubber industries.

The results were also used to validate whether the observed decline in the annual growth rates of employment was attributed to ICT. The results suggested that ICT was not the source of the decline in employment growth of the agro-processing subsector and the less ICT-intensive industries, as there was no causal relationship. However, the results suggested that ICT investment was the source of employment growth of the more ICT-intensive industry group and the food industry, as there was a causal relationship. This implies is that ICT investment contributed to the employment growth of the more ICT-intensive industry group and the food industry.

CHAPTER 6: FORECASTING EFFECTS OF ICT INTENSITY ON PRODUCTIVITY, OUTPUT AND EMPLOYMENT IN SOUTH AFRICA: AN INDUSTRY-LEVEL ANALYSIS

6.1 INTRODUCTION

The effects of ICT intensity on the productivity, output and employment of agro-processing industries are forecast in this chapter. There are two rationales for forecasting this causal relationship. The first rationale is that the economic performance gains from ICT investment manifest only after a certain time (Becchetti *et al.*, 2003). This is because ICT's impact on the economy follows a Schumpeterian trend that begins with a negative or zero impact on productivity, followed by acceleration and then dying out (Moshiri, 2016). The underlying basis for this trend is that the returns on ICT investment are notable over a long period as ICT investment might be counter-productive in the beginning due to job redesign practices, scope and work structure realignment, and the training of labour (Lee *et al.*, 2005).

The second rationale is to provide an understanding of how ICT would impact on the growth of the agro-processing industries. Moreover, such understanding provides an insight into whether the impact of ICT on the growth of productivity, output and employment in agro-processing industries would start with a negative or zero impact followed by acceleration and then dying out. To achieve this, the effects of ICT intensity on the growth of industries are forecast over a 20-year period. The chapter begins with a summary of the lessons derived from the preceding chapter to provide the background and rationale for conducting the current analysis. This is followed by the description of the analytical approaches used for the analyses. The findings from the analyses are subsequently presented and discussed. The chapter concludes with a summary of key findings and the implications thereof.

6.2 BACKGROUND AND RATIONALE

In chapter five, it was proven empirically using the TY Granger non-causality test that there was no causal relationship between ICT intensity and growth in the labour productivity, output and employment of the aggregated industries. Similarly, the test revealed no evidence of a causal relationship in the case of the less ICT-intensive industry group and its industries (tobacco, wearing apparel, leather, wood and furniture). However, evidence of a causal relationship was only observable for the more ICT-intensive industry group and its industries (i.e. food, beverages, paper and rubber industries). It must be noted, however, as argued by Salahuddin and Gow (2016), that the causality techniques cannot forecast the future potential causal relationship beyond the sample size. In the light of this, the study applied the impulse response functions (IRFs) and variance decomposition (VDC) analyses to forecast the causal effects over a 20-year period. By so doing, the fourth objective of forecasting the potential effects of ICT intensity on the growth of labour productivity, output and employment of the agro-processing industries is achieved in this chapter. A discussion of the literature of future effects of ICT on growth in labour productivity, output and employment is presented in the next section.

6.3 REVIEW OF RELATED LITERATURE

Various studies have investigated the future effects of ICT investment and various measures of growth by using various data sources, periods and analytical approaches. In the context of this chapter, the review focuses on the future effects of ICT investment on labour productivity, output and employment. However, the review is confined to aggregate-level studies due to a dearth of empirical studies on the future effects of ICT investment on the growth of various industries. Despite this, the findings from the review on the aggregate-level studies are used as a source of reference for forecasting the effects of ICT on the growth of the agro-processing industries (at the disaggregated level). The review covers three groups of studies. The first group includes studies that focus on economic growth. The second group covers studies on productivity, and the third group includes studies on employment.

In terms of the first group of studies, Khumalo and Mongale (2015) investigated the impact of ICT on South Africa's economic growth for the period 1980–2013. The generalized impulse response function was used to analyse the data. The results revealed that ICT would impact positively on economic growth throughout the forecast period (i.e. from period 1 to 20), suggesting that the effects of ICT on economic growth would be observable in both the short and long term.

In a similar study, Salahuddin and Gow (2016) estimated the effects of internet usage on South Africa's economic growth using data for the period 1991–2013. Impulse response function and variance decomposition analyses were conducted to determine whether there was a causal link between internet usage and economic growth. The impulse response function results revealed that there is a causal link between internet usage and economic growth. Moreover, the variance decomposition results showed strong forecasts on the potential future effects of internet use on the South African economy. The results suggest that ICT would impact positively on South Africa's economic growth.

While the studies (Khumalo and Mongale, 2015; Salahuddin and Gow, 2016) have revealed that ICT would impact positively on South Africa's economic growth, an earlier comparative study by Kriz and Qureshi (2009) had revealed that positive impact would be notable for a developing country that invested more in ICT. In particular, Kriz and Qureshi (2009) evaluated the effects of ICT on the per capita GDP of Singapore and Malaysia. The impulse response functions were used to analyse data for the period 1977–2007. The results showed that ICT adoption would impact negatively on Malaysia's per capita GDP, suggesting that ICT adoption has been less effective in boosting capital formation and productivity growth.[70] The difference in the results is attributed to the higher level of ICT investment in Singapore. These results suggest that the impact of ICT on productivity growth varies according to country, such that positive effects would be notable for countries that invested more in ICT.

In another study on economic growth, Pradhan *et al.* (2019) forecast the effects of internet usage on real per capita GDP (i.e. economic growth) of 25 European countries. The generalised impulse response functions were used to analyse data for the period 1989–2016. The results showed that internet usage would impact positively on economic growth in the long run, suggesting that the effects of ICT on economic growth are observable over a longer period.

While the study by Pradhan *et al.* (2019) revealed that internet usage would impact positively on the economic growth of the European countries, in the long run, an earlier comparative study by Lee *et al.* (2005) showed that positive effects would be notable for the countries that invested more in ICT (i.e. developed countries). Lee *et al.* (2005) examined the impact of ICT investments on the economic growth of 20 countries (i.e. developed and developing countries)

[70] It should be noted that, while the results were negative, they were not statistically significant.

using data from 1980 to 2000.[71] The impulse response functions were used to determine whether ICT investments would impact positively or negatively on economic growth. The results showed that ICT investments contribute to economic growth in most of the developed countries and newly industrialised economies (NIEs), but not in the developing countries.

These results suggest that the impact of ICT on economic growth varies from country to country, such that positive effects would be notable for countries that invested more in ICT. In the case of the second group of studies, Chung (2018) analysed the impact of information and communications technology (ICT) on productivity growth in Korea using data from the period 1996–2015. The impulse response function and variance decomposition analyses were used to show the impacts of ICT investment-specific technological shocks on productivity growth. The results showed that ICT investment-specific technological shocks impact positively on productivity growth in the short run, suggesting that ICT usage could have enhanced productivity growth.

In a study focusing on both labour productivity and economic growth, Chiemeke and Imafidor (2021) investigated the impact of digital technology adoption on labour productivity and economic growth in Nigeria for the period 1990–2019. The impulse response function (IRF) and the forecast error variance decomposition (FEVD) were used to measure the response of labour productivity and economic growth. The results showed that shocks to digital technology adoption impact negatively on labour productivity and economic growth in the short run, but positively in the long run. The short-run results are in line with the assertion that the impact of ICT on the economy follows a Schumpeterian trend, which begins with a negative or zero impact (Moshiri, 2016). In line with Lee *et al*. (2005), the rationale for this trend is that ICT investments might be counter-productive at the start due to training of labour, redesigning of job practices, as well as realignment of work structures and scope, hence returns are only notable over a long period. The long-run results imply that ICT would impact positively on labour productivity and economic growth in the long run, suggesting that the effects of ICT on growth are observable over the longer term.

[71] The developing countries were China, Indonesia, India, the Philippines and Malaysia. The developed countries/newly-industrialised economies (NIEs) were Austria, Australia, Denmark, Canada, Finland, Ireland, France, Japan, Italy, Singapore, (South) Korea, Sweden, Spain, the United States and the United Kingdom.

In terms of the third group of studies, it is noted that, unlike the first and second groups of studies, there is a dearth of empirical studies on the future effects of ICT on employment. An existing study is by Emara (2020), which investigated the effects of technological progress on employment in Egypt. The impulse response functions and the variance decomposition analyses were conducted, analysing data for the period 1990–2019.

The IRF results revealed that a shock to patents, which are a measure of technological progress, would impact negatively on employment for the entire forecast period. The variance decomposition results revealed that patent is the least affecting shock in the short run, but it becomes the second most important shock in the long run. These results suggest that ICT might impact negatively on employment growth in the longer period. The results differ from those of causality studies, which found a positive correlation between ICT and employment (Etro, 2009; Crandall and Singer, 2010; Kolko, 2012; Jayakar and Park, 2013; Atasoy, 2013; Pantea, Biagi and Sabadash, 2014; Khan *et al.*, 2017). The difference in the results is attributed to the fact that the study by Emara (2020) used technological progress and not ICT per se, whereas the causality studies used ICT as defined in this study.

Given the dearth of disaggregate-level studies on the future effects of ICT investment on the growth of industries, the present review of literature covers the aggregate-level studies. Despite this, three points were derived from the reviewed studies and serve as points of reference for this chapter. The first point is that ICT investment would impact positively on labour productivity and economic growth, in the long run, suggesting that the effects of ICT on growth are observable over the longer term. The implication is that the returns on ICT investment take time to materialise. Therefore, in this chapter, it is postulated that ICT investment would impact positively on the growth of labour productivity and output of the agro-processing industries in the long run.

The second point is that the impact of ICT on labour productivity and economic growth were observable across countries, such that positive effects would be notable for the countries that invested more in ICT. Therefore, in this chapter, it is postulated that, while ICT investment impacts positively on growth of the agro-processing industries, in the long run, effects would be higher for the industries that invested more in ICT (i.e. more ICT-intensive industries).

The third point is that ICT might impact negatively on employment growth over the longer term. This varies from the TY Granger causality test results, which revealed that ICT was not a cause of the decline in the employment growth of the agro-processing industries. Therefore, since the test does not take into account the future effects of ICT, it is of interest to examine whether ICT might impact negatively on the employment growth of the agro-processing industries in the longer period.

In view of the three points derived from the review of aggregate-level studies, the impulse response function (IRF) and variance decomposition (VDC) analyses are applied, in this chapter, to forecast the effects of ICT intensity on the growth of labour productivity, output and employment of agro-processing industries. Accordingly, the IRF and VDC analyses are discussed in the next section.

6.4 ANALYTICAL TECHNIQUES

6.4.1 Impulse response function (IRF) and variance decomposition (VDC) analyses

As alluded to earlier, one of the drawbacks of the causality techniques is that one cannot predict the future potential causal relationship beyond the sample size (Salahuddin and Gow, 2016). To avoid this shortcoming, the innovation accounting approach (IAA) was applied to forecast the potential effects of ICT intensity beyond the sample. The IAA comprises two out of sample causality techniques, namely, the generalised impulse response functions (IRFs) and the variance decomposition (VDC) analysis.

The IRFs determine the length of time and extent to which the endogenous variable responds to a shock arising from the exogenous variables (Shahbaz, Rehman, Sbia and Hamdi, 2016). The output from the IRF analysis is confined to the graphical responses of the endogenous variables to shocks in the exogenous variables in order to determine whether the effect causes a negative or positive temporary jump along the forecast time horizons (Lee *et al.*, 2005). IRF analysis was, therefore, conducted as it provides an understanding of how ICT intensity would impact on the growth of labour productivity, output and employment over the forecast period. This is important in order to capture how long it would take for ICT-led growth to manifest among industries and how long the impact would last.

Although the IRF captures the length of time and the extent to which the endogenous variable responds to a shock resulting from the exogenous variables, it does not capture the magnitude of such effects (Salahuddin and Gow, 2016). Given this, the VDC analyses were undertaken to capture this magnitude. The VDCs calculate the percentage contribution of an unanticipated change in a variable attributable to its shocks and relative to shocks to other variables in the system (Lütkepohl, 2007). From this perspective, the VDC analyses were performed to predict the contribution of ICT intensity to the forecast error variance in the growth of labour productivity, output and employment of industries. In brief, the IRF and VDC techniques were applied to examine the degree or magnitude of causality among variables and the extent of exogeneity among the variables over and above the sample period (Shahbaz *et al.*, 2016). The results from the IRF and VDC analyses are provided in the next section.[72]

6.5 EMPIRICAL RESULTS

The reporting of the empirical results covers Panel A (i.e. all agro-processing industries), Panel B (i.e. more ICT-intensive industries) and Panel C (i.e. less ICT-intensive industries). The results include results for the individual industries embedded in Panels B and C. The IRF results are presented in the next section.

6.5.1 Impulse response function results

The results from the IRF analysis are presented, in this section, to highlight the response of the endogenous variables to one standard deviation (SD) shock in the exogenous variables. Special attention is paid to how labour productivity, output and employment respond to shocks in ICT intensity. In this regard, the ICT intensity is the exogenous variable, while labour productivity, output and employment are endogenous. As per the nature of the IRFs, the discussion is confined to the graphical (trends) responses of the endogenous variables instead of the numerical responses. The numerical responses are captured by the VDC results, which are fully discussed in the next section. The IRFs for the Panel of industries and individual industries of Panels B and C are presented in Appendix D.1. In all the cases (i.e. Panel of industries and individual industries), the blue line delineates the impulse response function, while the red lines

[72] It is worth noting that the sources of data and variables used in this chapter are as described in chapter four.

capture the 95% confidence interval. Moreover, in all cases, it is notable that the impulse response functions are located between the 95% confidence interval.

The discussion starts with the Panel of industries followed by that of the individual industries of Panels B and C. It is necessary to note that for Panels B and C, where the endogenous variables display a common trend in their responses to ICT intensity, industries are discussed together and not individually. The forecast period is separated into two periods: short-run and long-run periods. The rationale for separating the forecast period is to address two overarching questions: (1) how long would it take for the impact to occur? and (2) how long would it last? The short-run period addresses the first question, while the long-run period deals with the second question. In all cases, periods 1 to 5 are classed as the short-run period, whereas the remaining periods are classed as the long-run period. In all, five different outcomes are observable. More specifically, the responses of the endogenous variables to shock in ICT intensity are as follows:

(i) “Negative” – implies that the response of the endogenous variables to the shock in ICT intensity is negative throughout the period under consideration;
(ii) Positive – implies that the response of the endogenous variables to the shock in ICT intensity is positive throughout the period under consideration;
(iii) “Negative and positive” – imply that the response of the endogenous variables to the shock in ICT intensity starts with a negative followed by a positive effect;
(iv) “Positive and negative” – imply that the response of the endogenous variables to the shock in ICT intensity starts with a positive followed by a negative effect; and
(v) “Steady-state” – captures the period of forecast in which the response of the endogenous variables is constant.

The discussion of the IRF results for both periods (short run and long run) centres on what happens with respect to the five outcomes. The IRF results are presented in the next section.

6.5.1.2 IRF results for the Panel of industries

A summary of the IRF results for the Panel of industries is presented in Table 6.1. The results indicate that, in the long run, shocks to ICT intensity would exhibit positive effects on the growth of labour productivity, output and employment of both the less and more ICT-intensive industry groups. Therefore, the fact that positive effects were forecast for the less ICT-intensive industry group, in the long run, implies that the positive impact of ICT would be observable over the long term. The implication is that the returns on ICT investment take time to materialise.

Table 6.1: Summary of the IRF results for Panel of industries

Endogenous variables	Period 1-5 (Short run)	>5-20 (Long run)	Steady-state
Panel A (All agro-processing industries)			
EMP	Positive	Positive	>5-20
LP	Positive & Negative	Negative	10-20
RO	Positive & Negative	Positive	10-20
Panel B (More ICT-intensive industries)			
EMP	Negative & positive	Positive	10-20
LP	Positive & negative	Positive	10-20
RO	Positive & negative	Positive	5-20
Panel C (Less ICT-intensive industries)			
EMP	Positive	Positive	10-20
LP	Negative	Positive	10-20
RO	Negative & positive	Positive	5-20

Source: Author's own compilation

Note: EMP = Employment growth rate (%); LP = Labour productivity growth rate (%); RO = real output growth rate (%).

In the case of the aggregated industries, a negative effect was observable with respect to labour productivity. This means that, in the long run, a one SD shock in ICT intensity would exhibit a negative effect on the labour productivity growth of the aggregated industries. These findings conform to those of other studies, which found a negative impact of ICT when industries were aggregated (Khan and Santos, 2002; Mačiulytė-Šniukienėa and Gaile-Sarkane, 2014; Edquist and Henrekson, 2017). This implies that the lower growth contributions of the less ICT-intensive industries outweighed the relatively higher growth contributions of the more ICT-intensive industries.

The finding for the short-run period is that mixed effects ("Positive and Negative" and "Negative and Positive") were detectable with respect to the response to shocks in ICT intensity. This finding was different in the case of the aggregated industries and the less ICT-intensive industries, where positive effects with respect to employment growth were observable in both periods. The implication is that, in the short run, ICT investment would be counterproductive to the employment growth of aggregated and less ICT-intensive industry groups. However, in the long run, shocks to ICT intensity would exhibit positive effects on the growth of labour productivity, output and employment of all the industry groups.

Overall, the IRF results address the question of how long it would take for ICT to impact positively on the growth of the industry groups. The answer was that ICT intensity would impact positively on the growth of the labour productivity, output and employment of all the industry groups in the long run. In particular, it would impact positively on the employment growth of the aggregated industries and the less ICT-intensive industries over the 20-year period of forecast (in both the short run and long run).

Equally important, the findings provide an understanding of whether the impact of ICT on the agro-processing industries follows a Schumpeterian trend.[73] The results show that this varied according to the growth variable and industry group. Specifically, the trend was observable with respect to the employment growth of the more ICT-intensive industries and the output growth of the less ICT-intensive industries. This trend implies that, in the short run, ICT investment would be counterproductive to employment growth (of the more ICT-intensive industries) and labour productivity (of the less ICT-intensive industries).

In contrast, ICT intensity would be productive, in the short run, with respect to output growth (of the aggregated industries and the more ICT-intensive industries). Similarly, it would be productive in both periods with respect to the employment growth of the aggregated and the less ICT-intensive industries. Further to this, it would be productive in the long run with respect to the growth in labour productivity, output and employment of both the less and more ICT-intensive industries.

6.5.1.3 IRF results for Panel B industries

A summary of the IRF results for the Panel B industries is presented in Table 6.2. The results show that, in the long run, shocks to ICT intensity would exhibit positive effects on the growth of labour productivity, output and employment of all industries that are more ICT-intensive.

[73] The Schumpeterian trend starts with a negative or zero impact followed by acceleration and then dies out.

However, in the short run, the results varied according to growth variable and industry. Specifically, in the short run, mixed effects were notable with respect to the labour productivity, output and employment of the food, textile, paper and rubber industries. In contrast, positive effects were notable with respect to the labour productivity of the beverages industry. Once more, negative effects were notable with respect to the employment growth of the beverages industry.

Table 6.2: Summary of the IRF results for Panel B industries

Variable	Period 1-5 (Short run)	>5-20 (Long run)	Steady-state
Food			
EMP	Positive & Negative	Positive	5-20
LP	Positive & Negative	Positive	
RO	Positive & Negative	Positive	
Beverages			
EMP	Negative	Positive	5-20
LP	Positive	Positive	
RO	Negative & Positive	Positive	
Textile			
EMP	Negative & Positive	Positive	10-20
LP	Negative & Positive	Positive	
RO	Negative & Positive	Positive	
Paper			
EMP	Negative & Positive	Positive	5-20
LP	Positive & Negative	Positive	
RO	Positive & Negative	Positive	
Rubber			
EMP	Negative & Positive	Positive	5-20
LP	Positive & Negative	Positive	
RO	Positive & Negative	Positive	

Source: Author's own compilation
Note: EMP = Employment growth rate (%); LP = Labour productivity growth rate (%); RO = real output growth rate (%)

These findings provide an understanding of whether the impact of ICT on the more ICT-intensive industries follows a Schumpeterian trend. The results suggest that this would occur for each growth variable depending on the industry. Specifically, in the short run, ICT investment would be counterproductive with respect to the growth of labour productivity, output and employment of the textile industry, and employment of the beverages industry. However, in the long run, ICT investment would be productive for the growth of labour productivity, output and employment of all of the more ICT-intensive industries.

6.5.1.4 IRF results for Panel C industries

A summary of the IRF findings for the Panel C industries is presented in Table 6.3. The findings exhibit that, in the long run, shocks to ICT intensity would exhibit positive effects on the growth of labour productivity, output and employment of the less ICT-intensive industries. This result differs from that of the preceding chapter in which there was no causal relationship between ICT intensity and growth for the less ICT-intensive industries. Therefore, the fact that positive effects were forecast for the less ICT-intensive industries, in the long run, implies that the positive impact of ICT investment in the case of the less ICT-intensive industries is observable over a long period. The implication is that the returns on ICT investment for the less ICT-intensive industries are notable over a long period.

Table 6.3: Summary of the IRF results for Panel C industries

Variable	Period 1-5 (Short run)	>5-20 (Long run)	Steady-state
Tobacco			
EMP	Negative	Positive	10-20
LP	Negative & Positive	Positive	
RO	Negative	Positive	
Wearing apparel			
EMP	Positive & Negative	Positive	10-20
LP	Negative	Positive	
RO	Positive & Negative	Positive	
Leather			
EMP	Negative	Positive	5-20
LP	Negative & Positive	Positive	
RO	Negative & Positive	Positive	
Wood			
EMP	Negative	Positive	10-20
LP	Negative & Positive	Positive	
RO	Negative	Positive	
Furniture			
EMP	Positive	Positive	10-20
LP	Positive & Negative	Positive	
RO	Positive	Positive	

Source: Author's own compilation. Note: EMP = Employment growth rate (%); LP = Labour productivity growth rate (%); RO = real output growth rate (%).

The IRF findings further show that, in the short run, shocks to ICT intensity would exhibit mixed effects, depending on the growth variable and industry. Specifically, in the short run, mixed effects were notable with respect to labour productivity (tobacco, leather, wood and furniture industries), output (wearing apparel industry) and employment (leather industry). In contrast, negative effects were notable with respect to labour productivity (wearing apparel industry), output (tobacco and wood industries) and employment (tobacco, leather and wood industries). Further to this, positive effects were notable with respect to the growth of output and employment of the furniture industry.

These findings provide knowledge on whether the impact of ICT on the less ICT-intensive industries would follow a Schumpeterian trend. The results suggest that this would vary according to growth variable and industry. Specifically, in the short run, ICT investment would be counterproductive with respect to the growth of labour productivity (tobacco, wearing apparel leather and wood industries), output and employment (tobacco, leather and wood industries). However, in the long run, ICT investment would be productive to the growth of labour productivity, output and employment of all the less ICT-intensive industries.

6.5.2 Variance decomposition analysis results

The IRF results were confined to the graphical responses of the endogenous variables to shocks in the exogenous variables. The numerical responses with respect to how the behaviour of one variable was affected by its shocks relative to other variables are provided in this section. Special attention is given to the percentage of unexpected variation in the growth of labour productivity, output and employment that was produced by shocks from ICT intensity. In other terms, the results shed light on ICT intensity's share of the percentage forecast error variance decomposition in the growth of labour productivity, output and employment. The discussion covers the Panel of industries and individual industries of Panels B and C for the 20-year forecast period. The forecast is subdivided into 5 periods (i.e. periods 1, 5, 10, 15 and 20). It is worth noting that for Panels B and C, where ICT intensity exerted a similar influence on the endogenous variables, industries are discussed as a unit and not individually.

The results for the generalised forecast error variance decomposition of the Panel of industries are presented in Table C.1, while those of Panels B and C industries are presented in Table C.2 and Table C.3, respectively. Before reporting on the results, it must be noted that the VDC shows the percentage forecast error variance decomposition for the variables, ICT, EMP, LP and RO, respectively, when each variable is specified as an endogenous variable. By default, the forecast error variance in the endogenous variable and those of other variables sum up to

100. Moreover, in general, each endogenous variable contributes the most to the forecast error variance in the growth of itself.

A summary of the influence of ICT intensity on growth of labour productivity, output and employment is provided in Table 6.4. In all the cases, "stronger" implies that ICT intensity exhibits a higher influence on the endogenous variable than the other two exogenous variables do. "Strongest" implies that ICT intensity exhibits the highest influence, compared with the endogenous variable itself and the other two exogenous variables. "Weaker" implies that ICT intensity exhibits a higher influence on the endogenous variable than one endogenous variable does. "Weakest" implies that ICT intensity exhibits the lowest influence on the endogenous variable relative to all the exogenous variables.

Table 6.4: Summary of the influence of ICT intensity on endogenous variables

Industry	**Dependent variable**		
	EMP	**LP**	**RO**
Panel A (All agro-processing industries)	Stronger	Weakest	Weakest
Panel B (More ICT-intensive)	Stronger	Weakest	Weakest
Panel C (Less ICT-intensive)	Weaker	Weakest	Weaker
Panel B (More ICT-intensive industries)			
Food	Weak	Weakest	Weaker
Beverages	Stronger	Weak	Weaker
Textile	Weaker	Weakest	Weaker
Paper	Stronger	Weaker	Strongest
Rubber	Stronger	Strongest	Strongest
Panel C (Less ICT-intensive industries)			
Tobacco	Weaker	Weakest	Weakest
Wearing apparel	Weaker	Weaker	Weakest
Leather	Stronger	Weak	Weak
Wood	Stronger	Weakest	Weakest
Furniture	Weaker	Weaker	Weaker

Source: Author's own compilation

The VDC results (Table 6.4 and Tables C.1–C.3) are discussed to shed light on which Panel of industries and which industries embedded in Panels B and C would contribute the most or least to the forecast error variance in the growth of labour productivity, output and employment. The summary starts with the comparison of the findings for the Panel of industries, followed by those of the individual industries of Panels B and C.

6.5.2.1 VDC results for the Panel of industries

- **Forecast error variance in labour productivity growth**

The VDC findings for the Panel of industries show that ICT intensity was the weakest predictor of labour productivity growth relative to employment and output in the aggregated industries. However, it would contribute the most to the forecast error variance in the labour productivity growth of the more ICT-intensive industry group (i.e. 3.8% in period 1, and 3.9% between periods 10 to 20). By contrast, it would contribute the least to the forecast error variance in the labour productivity growth of the less ICT-intensive industry group (i.e. 0.19% in period 1, and 0.57 between periods 10 and 20). Overall, this implies that ICT intensity would contribute the most to the forecast error variance in the labour productivity growth of the more ICT-intensive industry group, contrary to both the aggregated and the less ICT-intensive industry groups.

- **Forecast error variance in output growth**

In terms of output, in all cases, ICT intensity was the weakest predictor of output growth relative to employment and labour productivity. Nonetheless, it would contribute the most to the forecast error variance in the output growth of the more ICT-intensive industry group relative to both the aggregated and less ICT-intensive industries. Quantitatively, ICT intensity would account for 18% in forecast error variance in period 1 and 3.7% between periods 10 and 20, which was higher than its contribution in the case of the aggregated and the less ICT-intensive industry groups in the same forecast periods. In contrast, it would contribute the least to the forecast error variance in output growth of the less ICT-intensive industry group (i.e. 0.15% in period 1, and 0.56 from periods 10 to 20). Yet again, the findings prove that ICT intensity would contribute the most to the forecast error variance in the output growth of the more ICT-intensive industries, contrary to both the aggregated and the less ICT-intensive industries.

- **Forecast error variance in employment growth**

In terms of employment, it is notable that, while ICT intensity was the stronger predictor of employment growth in the case of both the aggregated and the more ICT-intensive industry groups, it would contribute more to the forecast error variance in employment growth of the more ICT-intensive industries. In real terms, ICT intensity would contribute 0.97% to the forecast error variance in the employment growth of the more ICT-intensive industry group in period 1, and 2% between periods 5 and 20. In contrast, it would contribute the least to the forecast error variance in the employment growth of the less ICT-intensive industry group (i.e. 0.59% in period 1, and 0.73% between periods 10 and 20). Overall, this implies that ICT intensity would contribute the most to the forecast error variance in the employment growth of the more ICT-intensive industry groups, contrary to both the aggregated industries and the less ICT-intensive industry groups. The next section provides the VDC results for the individual industries embedded in Panel B.

6.5.2.2 VDC results for Panel B industries

- **Forecast error variance in labour productivity growth**

The VDC findings for Panel B industries signify that ICT intensity was the strongest predictor of labour productivity growth in the food industry. This is because it would contribute more to forecast error variance than labour productivity itself and both employment and output. In real terms, ICT intensity would contribute 33% of the forecast error variance in period 1, and 38% from period 10 to 20, which was higher than the contribution for the remaining industries that are more ICT-intensive. In contrast, it would contribute the least to the forecast error variance in the labour productivity growth of the textile industry (i.e. 0.19% in period 1 and greater than 4.0% from period 10 to 20).

- **Forecast error variance in output growth**

Moving on to output, it is observable that, while ICT intensity was the strongest influencer of output growth in the case of both the paper and rubber industries, its contribution to the forecast error variance was higher in the case of the food industry. This implies that ICT intensity would contribute the most to the forecast error variance in the output growth of the food industry (i.e. 29.91% in period 1, and 32.4% from period 5 to 20). This contribution was higher than in the case of other industries and higher than the contribution by output itself and by both employment and labour productivity. Once more, the textile industry was the industry in which ICT would contribute the least to the forecast error variance in output growth (i.e. 1.13 % in period 1, and more than 6% from period 10 to 20).

- **Forecast error variance in employment growth**

In terms of employment, ICT intensity would contribute the most to the forecast error variance in the employment growth of the food industry (i.e. 19.06% in period 1, and 39% from period 10 to 20). This contribution was higher than its contribution in the case of the remaining more ICT-intensive industries in the same period. In contrast, ICT would contribute the least to the forecast error variance in the employment growth of the textile industry (i.e. 4.15% in period 1 and 4.20% from period 10 to 20). Overall, these results imply that ICT intensity is the strongest predictor of labour productivity, output and employment growth in the food industry.

In brief, the findings for the more ICT-intensive industries showed that ICT investment would contribute the most to the growth of labour productivity, output and employment of the food industry. In contrast, ICT intensity would contribute the least to the growth of labour productivity, output and employment growth of the textile industry. The reason for this is that the food industry accounted for the largest share of ICT investment in the case of the more ICT-intensive industries, while the textile industry accounted for the least share of ICT investment. Therefore, the findings for the more ICT-intensive industries imply that the contribution of ICT investment to the growth of the industries would vary, such that higher growth would be realised by the industry that invested the most in ICT. The next section provides the VDC findings for individual industries embedded in Panel C.

6.5.2.3 VDC results for Panel C industries

- **Forecast error variance in labour productivity growth**

The VDC findings signify that, while ICT intensity was the weakest predictor of labour productivity growth, relative to employment and output, it would contribute more to the forecast error variance in the case of the wood industry than of other industries. Quantitatively, ICT intensity would contribute 15.48% of the forecast error variance in the labour productivity growth period 1, and 10.13% from period 10 to 20. This contribution would be higher than for the remaining less ICT-intensive industries. By contrast, ICT intensity would contribute the least to the forecast error variance in the labour productivity growth of the tobacco industry (i.e. 0.09% in period 1 and 2.66% from period 10 to 20).

- **Forecast error variance in output growth**

In terms of output, ICT intensity was a weak influencer of output growth for some industries (i.e. leather and furniture) and the weakest influencer for others (i.e. tobacco, wearing apparel and wood). However, its contribution to the forecast error variance was higher in the case of the furniture industry. This implies that ICT intensity would contribute the most to the forecast error variance in output growth of the furniture industry (i.e. 13.16% in period 1, and 18.08% from period 10 to 20). Once again, it would contribute the least to the forecast error variance in output growth of the tobacco industry (i.e. 0.42% in period 1, and 0.45% from period 5 to 20).

- **Forecast error variance in employment growth**

Moving on to employment, ICT intensity was the stronger influencer of employment growth in the case of both the leather and wood industries. However, its contribution to the forecast error variance was higher in the case of the leather industry. In quantitative terms, ICT intensity would contribute the most to the forecast error variance in the employment growth of the leather industry (i.e. 0.21% in period 1, and 7.25% from period 10 to 20). This contribution would be higher than for the remaining less ICT-intensive industries in the same periods. Comparatively, ICT intensity would contribute the least to the forecast error variance in the employment growth of the tobacco industry (i.e. 0.55% in period 1, and 3.4% from period 10 to 20).

In brief, the findings for the less ICT-intensive industries showed that ICT investment would contribute the least to the growth of labour productivity, output and employment of the tobacco industry. The reason for this is that the tobacco industry accounted for the smallest share of ICT investment by the less ICT-intensive industries. Therefore, the findings for the less ICT-intensive industries imply that the contribution of ICT investment to the growth of the industries would vary, such that lower growth would be realised by the industry that invested the least in ICT.

6.5.3 Discussion of the VDC results

This section serves to provide a discussion of the IRF and VDC findings to underscore meanings, insights and implications. The rationale is to highlight which of the industry group and individual industries would experience higher growth through ICT investment. The IRF results showed that, in the long run, ICT intensity would impact positively on the growth of all the industries of both the less ICT-intensive and more ICT-intensive industry groups. However, the VDC findings, which captured the magnitude of such impact, showed that the impact would vary according to the industry. It is, therefore, necessary to underline which industries would experience higher growth than others would.

Overall, while the IRF results showed that ICT intensity would impact positively on the growth of all the industries, the VDC results showed that higher growth would be realised by the more ICT-intensive industries. To support this, in the case of the food industry and the wood industry (i.e. industries whose contribution of ICT investment to labour productivity growth would be highest from each industry group), it is noted that the contribution of ICT investment to labour productivity growth would be higher for the food industry.

Similarly, in the case of the food industry and the furniture industry (i.e. industries whose contribution of ICT investment to output growth would be highest from each industry group), it is noted that the contribution of ICT investment to output growth would be higher for the food industry. Once again, in the case of the food industry and the leather industry (i.e. industries whose contribution of ICT investment to employment growth would be highest from each industry group), it is noted that the contribution of ICT investment to employment growth would be higher in the case of the food industry.

The reason the contribution of ICT investment to the growth of labour productivity, output and employment would be highest in the food industry is that the food industry accounted for the largest share of ICT investment (37.20%). The implication is that the contribution of ICT investment to the growth of labour productivity, output and employment varies from industry to industry, such that the highest growth would be realised by the food industry, an industry that invested highly in ICT. Overall, this implies that, while ICT investment would impact positively on the growth of all the industries, the highest growth would be realised by an industry that invested highly in ICT.

It is noted further that, while ICT intensity would impact positively on the growth of all the industries, its contribution would be lowest to the growth of the tobacco industry. To support this, in the case of the textile industry and the tobacco industry (i.e. industries whose contribution of ICT investment to labour productivity, output and employment would be lowest from each industry group), it is noted that the contribution of ICT investment to employment growth would be higher for the textile industry. For example, ICT intensity would contribute 0.19% (in period 1) and greater than 4.0% (from period 10 to 20) to labour productivity growth in the textile industry. In contrast, it would contribute 0.09% (in period 1), and 2.66% (from period 10 to 20) to labour productivity growth in the tobacco industry.

In terms of output, ICT intensity would contribute 1.13 % (in period 1), and greater than 6.0% (from period 10 to 20) to output growth of the textile industry. In contrast, it would contribute 0.42% % (in period 1), and 0.45% (from period 5 to 20) to output growth in the tobacco industry. In terms of employment, ICT intensity would contribute 4.1% (in period 1), and greater than 4.20% (from period 10 to 20) to employment growth in the textile industry. In contrast, it would contribute 0.55% % (in period 1), and 0.34% (from period 5 to 20) to the employment growth of the tobacco industry. The overall implication is that, while ICT investment would impact positively on the growth of all the industries, its contribution would be lowest to the growth of the tobacco industry, an industry that invested the least in ICT. This inference is supported by the descriptive results, which showed that the tobacco industry accounts for the smallest share of ICT investment (0.84%). The reasons for variations in ICT investment and thus growth in labour productivity, output and employment across the industries are presented in the next section.

6.6 REASONS FOR VARIATIONS IN ICT INVESTMENT AND GROWTH

The reasons for variations in ICT investment and growth across industries are provided in this section. The findings from the ICT intensity index showed that five industries were more ICT-intensive (i.e. food, beverages, textile, paper and rubber), while the remaining five were less ICT-intensive (i.e. tobacco, wearing apparel, leather, wood, and furniture). Further to this, the food industry accounted for the largest share of ICT intensity (i.e. 37.20%), while the tobacco industry accounted for the smallest share (i.e. 0.84%). It is, therefore, imperative to provide an insight into the determinants of variations in ICT investment across industries. By so doing, an information base on why some industries are more ICT-intensive, while others are less ICT-intensive, is provided. In other words, this study provides an understanding and knowledge of why the more ICT-intensive industries invest more in ICT relative to the less ICT-intensive industries.

Furthermore, the overall findings of the study were that the effect of ICT on the growth of the industries (i.e. labour productivity, output and employment) varied across the industries, such that an industry that invested the most in ICT experienced higher growth than one that invested the least. The PMG findings showed that, in the long run, significant and positive contributions of ICT investment to the growth of labour productivity, output and employment would be notable only for the food industry, which invested more highly in ICT. The findings further showed that, while significant and positive contributions of ICT investment to output growth would be notable, in the long run, in the case of most of the industries (food, beverages, tobacco, wearing apparel, wood and furniture), contributions would be lower in the case of the tobacco industry, which invested less in ICT.

The findings from the VDC analysis showed that, in the long run, while ICT investment would contribute to the growth of all agro-processing industries, it would contribute the most to the growth of the food industry, which invested more in ICT. In contrast, it would contribute the least to the growth of the tobacco industry, which invested less in ICT. It is, therefore, imperative to examine the key drivers, which reinforce or restrict ICT use across the industries. In this regard, special attention is given to the determinants of ICT use and the growth thereof between the food industry and the tobacco industry. These determinants are defined as follows: (a) value-chain information intensity, (b) policy environment, and (b) size of the firm.

(a) Value chain information intensity

According to the value chain information intensity construct, as goods and services move along the value-added chain, from suppliers through distributors to consumers, increasingly a major component of exchange is the exchange of information. From this perspective, the value-added chain can be regarded as a communications channel (Glazer, 1991), and ICT as the medium of communication. Accordingly, industries that are high-value chain information-intensive would invest more in ICT than those that are low-value chain information-intensive. This is because the efficiency of the industries that are high-value chain information-intensive depends heavily on the efficiency of information processing given the extreme complexity of inbound and outbound logistics and internal material flow and control. From this perspective, the use of ICT applications can severely reduce cycle time, errors, slacks, and so forth.

Consequently, an industry investing highly in ICT would have higher labour productivity and output growth, an indication of a more efficient organisation of production. Industries that are high-value chain information-intensive would, therefore, benefit more from ICT investments, in terms of growth in labour productivity, output and employment, than those that are low-value chain information-intensive. Given this, industries' share of value-added were calculated to determine whether the more ICT-intensive industries were more high-value information-intensive than the less ICT-intensive industries. In other words, value-added was used as a proxy for the value-chain information intensity of industries. The industries' share of value-added is presented in Table 6.5.

Table 6.5: Industries' share of value-added

Industry	**Share of value-added (%)**	**Total (%)**
More ICT-intensive industries		**74.29**
Food	**46.33**	
Paper	6.51	
Beverages	8.38	
Rubber	3.37	
Textile	9.70	
Less ICT-intensive industries		**25. 71**
Wearing apparel	1.33	
Wood	12.30	
Furniture	8.68	
Leather	1.33	
Tobacco	**2.07**	
Total		**100**

Source: Author's own compilation

The findings are that the more ICT-intensive industries accounted for the larger share of value-added (64.29) relative to the less ICT-intensive industries (25.71%). Given that the food industry invested highly and experienced higher ICT-led growth relative to the tobacco industry, it is imperative to compare the degree of value-added across these industries. The findings show the food industry had a higher share of value-added (46.33%) compared to the tobacco industry (2.07%).[74] It is on this basis that the food industry had higher growth of labour productivity, output and employment than the tobacco industry. Thus, ICT investment contributed more to the growth of an industry with a higher share of value-added (high-value chain information-intensive industry) than to the growth of an industry with a lower share of value-added (low-value chain information-intensive industry).

(c) Size of the industry

Various empirical studies have found a positive relationship between ICT adoption and the size of the firm (Delone, 1981; Fabiani, Schivardi and Trento, 2005; Morgan, Colebourne and Thomas, 2006; Morionez, 2007). The key finding from these studies was that the larger the size of the firm, the higher the chances of ICT adoption. Another empirical study by Hollenstein (2004) showed that firm size was positively correlated with the intensive use of ICT. The descriptive results from this study showed that the food industry used ICT most intensively, while the tobacco industry used ICT less intensively. Therefore, it is necessary to examine whether the size of the industry is one of the determinants of the difference in ICT use between the food industry and the tobacco industry.

To carry out this analysis, in line with previous studies (Leung, Meh and Terajima, 2008; Findik and Tinsel, 2015), the study used the average number of employees within the industry as a proxy for the size of the industry. The results for the average number of employees are presented in Table 6.6.

[74] This does not negate the fact that the Tobacco industry had a higher share of value-added than two of the less ICT-intensive industries (i.e. wearing apparel and leather), which had the lowest share of value-added (1.33% each) across the agro-processing industries.

Table 6.6: Size of the industry

Industry	**Average number of employees**
Food	**236 172.6**
Beverages	44 563.1
Tobacco	**3 889.4**
Textile	52 536.8
Wearing apparel	84 137.9
Leather	6 961.8
Wood	62 248.5
Paper	35 926.3
Rubber	18 820.2
Furniture	47 204.9

Source: Author's own compilation

The findings are that the food industry had the highest average number of employees (about 23 6173) across the industries, whereas the tobacco industry had the lowest average number of employees (3 889). These statistics demonstrate that the food industry was larger than the tobacco industry. These findings are supported by a report by Research and Markets (2019), which indicated that there were 16 formal tobacco manufacturing firms in South Africa. As for the food industry, the report by the US Department of Agriculture (2018) stated that there were more than 1800 food production firms in South Africa.

The size of the industries is considered a determinant of the variation in ICT use between the food industry and the tobacco industry. In other words, the larger the size of the industry, the higher the number of firms using ICT. This assertion is supported by findings, which indicate that the food industry was larger than the tobacco industry and had a higher share of ICT use than the tobacco industry. These findings, in turn, explain why the tobacco industry would experience lower growth in labour productivity, employment and output than the food industry. To support the aforementioned, empirical evidence by Leung *et al.* (2008) found a positive relationship between firm size and labour productivity and employment.

According to Findik and Tinsel (2015), the relationship between firm size and ICT use is based on costs. Specifically, ICTs ensure that information is equally available to decision-making parties in the exchange, which reduces uncertainty surrounding the transaction and therefore reduces transaction cost. If ICT use lowers average costs, a large industry will have a larger output relative to a small industry, because of the economies of scale. In other words, as the level of output increases, costs are spread over the units of output, thus decreasing cost. In turn, a reduction in costs leads to an increase in productivity, which allows industries to increase output (Brynjolfsson and Hitt, 2000). In addition to the aforementioned, higher productivity could lead to employment growth through its contribution to higher output (which means higher labour demand). The overall implication is that intensive use of ICT by the food industry could have led to a reduction in costs, giving rise to higher labour productivity, output and employment.

(c) Policy environment

One of the key findings of the study is that the tobacco industry accounted for the smallest share of ICT investment and experienced the lowest growth. For this reason, it is necessary to highlight the policy environment under which the tobacco industry operates to identify the key drivers that have restricted ICT use and the growth of the tobacco industry. South Africa, as a party to the World Health Organization (WHO) Framework Convention on Tobacco Control (FCTC), is obliged to reduce the prevalence of tobacco-related disease and death by restraining the use, promotion and advertisement of tobacco products.

To this effect, the government has implemented the Tobacco Products Control Act 83 of 1993 (as amended), which prohibits, among others, tobacco advertising, promotion and sponsorship, and supply, distribution and sale of tobacco products through the internet, postal services, or other electronic media. In the light of this, the Act has the potential to hinder ICT use by the tobacco industry, as it prohibits the advertisement and promotion of tobacco products through broadcast and print media, and the distribution and sale of tobacco products through the internet, postal services, or other electronic media.

To determine the extent to which the Act impedes ICT use, the study calculated the share of intermediate ICT inputs related to the advertisement, promotion and distribution of products. These intermediate ICT inputs were "Printing", "Postal & Courier" and "Computer and Related Activities". The reasons for using the three intermediate inputs are as follows. The print media (newspapers, magazines, brochures, posters, flyers, etc.) is the medium through which products are advertised and promoted, while the postal and courier services are the channels through which the products are delivered to customers. In addition, computers and related activities

(Apps, internet, etc.) are electronic mediums through which products are sold to consumers. Table 6.7 shows the share of industries' expenditure on the three intermediate inputs.

Table 6.7: Share of intermediate ICT inputs

Industry	Printing (Share %)	Postal & Courier Activities (Share %)	Computer & Related Activities (Share %)
Food	**49.68**	**30.46**	**53.09**
Paper	22.47	8.86	6.13
Beverages	6.21	8.40	1.90
Rubber	6.62	9.87	8.54
Textile	4.41	10.08	5.09
More ICT-intensive	**89.39**	**67.67**	**74.75**
Wearing apparel	1.64	9.72	2.39
Wood	3.05	7.99	2.29
Furniture	3.24	5.53	3.03
Leather	1.86	8.70	1.85
Tobacco	**0.79**	**0.34**	**0.77**
Less ICT-intensive	**10.61**	**32.33**	**25.25**
TOTAL	**100**	**100**	**100**

Source: Author's own compilation

The findings from Table 6.7 are that the tobacco industry accounted for the smallest share of the industries' expenditure on all the intermediate inputs, whereas the food industry accounted for the largest share. The difference in the share of expenditure on the three ICT inputs between the food and the tobacco industries is due to the absence and presence of policies/laws that prohibit advertisement and promotion of products, as well as sale and distribution of products.

Specifically, there are no laws that restrict the food industry's investment in printing services, postal services and computer and related activities. In contrast, the Tobacco Products Control Act 83 of 1993 (as amended) restricts the tobacco industry from investing in printing activities by prohibiting the advertisement and promotion of tobacco products through the print media. It further restricts investment in postal & courier activities by prohibiting the supply and distribution of tobacco products through postal and courier services. Moreover, it restricts investment in computer and related activities by prohibiting the sale of tobacco products through the internet and other electronic means.

Overall, the Tobacco Products Control Act 83 of 1993 (as amended) affects the growth of the tobacco industry in several ways. The role of advertisement and promotion is to induce the demand for products by creating awareness and entice potential customers to use the product. An increase in the demand will reduce unemployment, as more labour input will be required to produce more output to meet the increased demand, *ceteris paribus*. In turn, and following (Barnichon, 2018), this leads to a temporary increase in labour productivity as firms seek to increase labour effort to meet the demand in the short run, *ceteris paribus*. Therefore, the prohibition of advertisement and promotion of tobacco products constrain demand, giving rise to sluggish growth in output, employment and labour productivity.

Overall, the findings from both the PMG estimation and VDC analyses showed that, in the long run, ICT investment would contribute more to the growth of the food industry, which invests more in ICT, and less to the growth of the tobacco industry, which invests less in ICT. Against this backdrop, the key drivers that could restrict ICT investment by the tobacco industry were identified as (a) value-chain information intensity, (b) size of the industry and (c) policy environment. In particular, the tobacco industry invests less in ICT and consequently realise low growth because it is low-value chain information-intensive and is comprised of fewer firms. Moreover, the tobacco industry invests less in ICT and consequently realises low growth because of the policies that prohibit the advertisement and promotion of tobacco products, and the distribution and sale of tobacco products through postal services, the internet, or other electronic means.

6.7 CHAPTER SUMMARY

The objective explored in this chapter was to forecast the potential effects of ICT intensity on the growth of the agro-processing industries. To achieve this, the IRF and VDC analyses were performed to forecast the effects of ICT intensity on the growth of labour productivity, output and employment for a 20-year time horizon. By so doing, a detailed understanding of how ICT impacts on the agro-processing industries was provided in this chapter.

The IRF findings showed that, in the long run, ICT intensity would impact positively on the growth of labour productivity, output and employment in both the less and more ICT-intensive industries. This result differs from the preceding chapter in which there was no causal relationship between ICT intensity and growth in the case of the less ICT-intensive industries. Therefore, the fact that positive effects were forecast for the less ICT-intensive industries, in the long run, implies that the positive impact of ICT in the case of the less ICT-intensive industries is observable over the longer term. The implication is that the returns on ICT investment in the case of the less ICT-intensive industries are notable over a longer period.

The IRF analysis determined whether the effect of shocks in ICT intensity caused a negative or positive jump along the 20-year forecast period, instead of the magnitude of such effects. However, the VDC findings, which captured the magnitude of such impact, showed that effects would be higher for the more ICT-intensive industries. In particular, the VDC findings showed that the contribution of ICT investment to the growth of labour productivity, output and employment varied from industry to industry, such that the higher growth would be realised by the more ICT-intensive industry group. The results imply that, while ICT investment would impact positively on the growth of all the industry groups, higher growth would be realised by the industry group that invested more in ICT.

The findings for the individual industries showed that, while ICT investment would contribute to the growth of all the industries, the highest growth would be realised by the food industry, an industry that invested highly in ICT. In contrast, the lowest growth would be realised by the tobacco industry, an industry with the smallest share of ICT investment. The overall implication is that growth occurs in line with ICT investment, such that the more an industry invests in ICT, the higher the growth in labour productivity, output and employment.

CHAPTER 7: SUMMARY AND CONCLUSION, AND POLICY IMPLICATIONS

7.1 SUMMARY AND CONCLUSION

South Africa has been experiencing numerous economic challenges such as low economic growth (GDP) and high rates of unemployment. Consequently, the agro-processing subsector has been identified in various policy plans as one of the sectors with the potential to stimulate growth. However, to date, efforts to develop the subsector have been ineffective in driving the required growth. This study, therefore, examined the extent to which ICT investment would contribute to the growth of the agro-processing subsector.

The overall objective of this study was to examine the contribution of ICT investment to the growth of the agro-processing industries. The specific objectives were as follows: (1) to examine whether ICT policies contributed to the labour productivity of the agro-processing industries; (2) to estimate short-and long-run effects of ICT intensity on growth of labour productivity, output and employment; (3) to examine the relationship between ICT intensity and productivity, output and employment growth; and (4) to forecast the potential effects of ICT intensity on growth of labour productivity, output and employment.

To achieve the first objective, the DD technique was applied to examine the link between ICT intensity and the labour growth of the agro-processing industries for the entire period (1970–2016) and two sub-periods, 1970–1995 (pre-policy era) and 1996–2016 (post-policy era). The ICT intensity index was used to disaggregate the industries into two industry groups (i.e. less ICT-intensive and more ICT-intensive industry groups). The rationale for disaggregating industries was to identify which group of industries contributed more or less to labour productivity growth. After grouping the industries, the mean growth rates of labour productivity were calculated.

The findings showed that the more ICT-intensive industry group exhibited higher acceleration (an increase over time) in labour productivity growth than the less ICT-intensive industries. However, the DD estimator was insignificant, which means that the difference in labour productivity between the less and more ICT-intensive industries cannot be attributed to ICT. The implication is that the labour productivity effects of ICT on the agro-processing industries are yet to be observable. The policy implication is that there is no evidence to support the hypothesis that ICT policies contributed to the labour growth of the agro-processing industries. This is attributable to the observation that the existing policies have not yet focused on ensuring access to and usage of ICT by other non-ICT industries, including the agro-processing industries.

Five delimitations of the analytical approach, which could have influenced the results, were identified. Firstly, in calculating ICT intensity, data for the year 1996 were considered, neglecting that some industries might have used ICT more or less, intensively pre-and post-1996. Secondly, since the study was conducted within a manufacturing sector setting, the intermediate ICT inputs used to calculate the ICT intensity were limited to the ICT manufacturing industries. Thirdly, the focus was on labour productivity. However, as set out in the theoretical framework of the study, there exists a relationship between ICT and labour productivity, output and employment. Hence, there was a need to examine whether ICT would contribute to the growth of not only labour productivity but also output and employment. Fourthly, the study noted that the DD technique could not detect the existence of a causal relationship between ICT and the labour productivity growth of industries. Lastly, it was also acknowledged that the DD technique could not forecast the future potential effects of ICT.

The aforementioned delimitations were addressed in chapters four, five and six utilising several techniques. The ICT index was used to calculate the ICT intensity of the industries using the intermediate ICT inputs from both the ICT manufacturing industries and ICT service industries for the period 1994–2017. Thereafter, in chapter four, the PMG estimations were performed to estimate the effects of ICT intensity on the growth of labour productivity, output and employment. In chapter five, the TY Granger causality test was used to examine the causal relationship between ICT intensity and the growth of labour productivity, output and employment, and in chapter six, IRF and VDC analyses were conducted to forecast the potential effects of ICT intensity on the growth of labour productivity, output and employment. The ICT intensity findings showed that five industries, namely, food (37.20%), paper (11.16%), beverages (11.02%), rubber (10.08%) and textile (8.12) were ranked as more ICT-intensive (i.e. 78% of the ICT intensity). In contrast, the less ICT-intensive industries were tobacco (0.84%), wearing apparel (6.62%), leather (3.96%), wood (5.86%) and furniture

(5.12%), which accounted for 22% of ICT intensity. Overall, the food industry accounted for the largest share of ICT investment, whereas the tobacco industry accounted for the smallest share. These findings are crucial for this study, as previous studies have proven that the impact of ICT varies from industry to industry, such that the more ICT-intensive industries would exhibit higher growth compared to the less ICT-intensive industries. However, before this study, there was a lack of knowledge on which of the agro-processing industries were more and less ICT-intensive. Therefore, the ICT intensity findings provide an information base on the ICT intensity of the comprehensive agro-processing industries.

After calculating the ICT intensity of industries, the annual growth rates of labour productivity, output and employment were calculated. Ultimately, the PMG estimations, the TY Granger causality test, and the IRF and VDC analyses were conducted to achieve objectives (2)–(4), respectively. In the course of the data analyses, industries were classified into three panels (i.e. Panel A (all agro-processing industries), Panel B (more ICT-intensive industries) and Panel C (less ICT-intensive industries). The analyses were further extended to individual industries embedded in Panels B and C.

The PMG findings indicated that the contribution of ICT investment to growth varies according to industry group and period of analysis (short run vs. long run). More specifically, significant and positive contributions of ICT investment to the growth of labour productivity, output and employment were notable only for the more ICT-intensive industries in the long run. Three implications were derived from this finding. Firstly, ICT investment would make no significant contribution when industries are aggregated. This implies that the lower growth contributions of the less ICT-intensive industries outweighed the relatively higher growth contributions of the more ICT-intensive industries.

Secondly, the contribution would vary according to an industry group, such that significant and positive contributions would be notable for an industry group that invested more in ICT. Thirdly, the returns on ICT investment take time to materialise; hence, significant and positive contributions to the growth of labour productivity, output and employment would be notable in the long run in the case of the more ICT-intensive industry group.

The above findings imply that the ICT–LP–RO–EMP nexus holds only for the more ICT-intensive industry group and only in the long run. This implies that the nexus would hold in the long term for an industry group that invested more in ICT. Hence, in the long run, ICT investment would increase labour productivity, output and employment of the more ICT-intensive industry group. Therefore, the fact that employment would increase implies that ICT investment would increase labour productivity, resulting in higher output and that higher output would be achieved by increasing the labour input, resulting in increased employment.

In terms of the individual industries, the PMG findings showed that the contribution of ICT investment to the growth of the industries would vary according to the period of analysis (short run vs. long run) and growth variable. In terms of the period of analysis, the findings showed that ICT investment would not contribute to the growth of labour productivity, output and employment of all the industries in both the more ICT and less ICT-intensive industry groups.[75] However, significant and positive contributions of ICT investment to the growth of labour productivity, output and employment would be notable only for the food industry and only in the long run.

Two implications have been derived from the above findings. The first implication is that the contribution of ICT investment to the growth would vary according to industry, such that significant and positive contributions would be notable for the industry that invested more in ICT. The second implication is that returns on ICT investment take time to materialise, hence significant and positive contributions to the growth of labour productivity; output and employment would be notable in the long run for the food industry. These findings imply that the ICT–LP–RO–EMP nexus holds only for the food industry and only in the long run. This implies that the nexus would hold in the long term for an industry that invested more in ICT. Hence, in the long run, ICT investment would increase labour productivity, output and employment of the food industry. Therefore, the fact that employment would increase implies that ICT investment would increase labour productivity, resulting in higher output, and that higher output would be achieved by increasing the labour input, resulting in increased employment.

[75] The only case in which positive and significant contributions are notable, in the short run, is with respect to the output growth of the food industry.

In terms of growth variable, significant and positive contributions of ICT investment to the output growth would be notable, in the long run, for most industries in both the more ICT-intensive and the less ICT-intensive industry groups (food, beverages, paper and rubber and textile, tobacco, wearing apparel, wood and furniture). However, the comparison of the magnitude of such contributions revealed that the contribution would be highest for the paper industry, which is more ICT-intensive and lowest for the tobacco industry, which is less ICT-intensive. This implies that in cases where positive and significant contributions were notable with respect to output growth, the contribution would be lowest for the tobacco industry, an industry that invested less in ICT.

The TY Granger causality test was conducted to validate whether the observed growth from the PMG results was due to ICT investment (i.e. whether ICT investment was a source of growth in labour productivity, output and employment). The findings for the Panel of industries signified that there was no causal relationship between ICT intensity and growth in the labour productivity, output and employment of the aggregated agro-processing industries. These results imply that the lower causal effects of other industries outweighed the relatively higher causal effects of some industries. In the same vein, the test found no evidence of a causal relationship in the less ICT-intensive group. The same applied to individual industries that are less ICT-intensive. In contrast, the test showed that there was evidence of causality for the more ICT-intensive industry group. This implies that causal effects occur in line with ICT intensity, such that evidence of causality was detected for the industry group that invested more in ICT.

The findings for the individual industries showed that there was no evidence of a causal relationship between ICT and the growth of labour productivity, output and employment in the less ICT-intensive industries. Instead, evidence of a causal relationship was observable in the case of the more ICT-intensive industries. Specifically, evidence of causality was notable in the case of the labour productivity and output growth of the beverages, paper and rubber industries. The implication is that ICT investment was a source of growth in labour productivity and output in the case of the beverages, paper and rubber industries.

The findings further showed that there was evidence of a causal relationship between ICT intensity and the growth of labour productivity, output and employment growth of the food industry. The implication is that ICT investment is a source of growth of labour productivity, output and employment in the food industry. The overall implication is that causal effects occur in line with ICT intensity, such that evidence of causality was detected for industries that invested more in ICT.

The IRF and VDC analyses were performed to forecast the potential effects of ICT intensity on productivity, output and employment in agro-processing industries for a 20-year time horizon. The IRF findings showed that in the long run, ICT intensity would impact positively on the growth of labour productivity, output and employment in both the less and more ICT-intensive industries. This result differs from the result in chapter five in which there was no causal relationship between ICT intensity and growth in the case of the less ICT-intensive industries. Therefore, the fact that positive effects were forecast for the less ICT-intensive industries, in the long run, implies that the positive impact of ICT in the less ICT-intensive industries is observable over a long period. The implication is that the returns on ICT investment for the less ICT-intensive industries are notable over a long period.

The output from the IRF results showed whether ICT intensity would impact positively or negatively (graphical response) on the growth of industries, rather than the magnitude of such impact. Hence, the VDC analyses were performed to capture the magnitude of the impact. The findings showed that, while ICT intensity would impact positively on the growth of all the industries, the highest growth would be realised by an industry that invested highly in ICT. In contrast, the lowest growth would be realised by the tobacco industry, an industry that invested the least in ICT. Overall, this implies that, while ICT investment would impact positively on the growth of all the industries, the lowest growth would be realised by an industry that invested the least in ICT.

Given these overall findings, three key determinants of variations in ICT investment and growth were identified as follows: (a) value-chain information intensity, (b) size of the industry and (c) policy environment. In particular, the tobacco industry invested less in ICT and consequently realised low growth because it is low-value chain information-intensive and comprises fewer firms. Furthermore, the tobacco industry invested less in ICT and consequently realised low growth because of the policies prohibiting the advertisement and promotion of tobacco products, and the distribution and sale of tobacco products through postal services, the internet, or other electronic means.

7.2 DISCUSSION OF THE HYPOTHESES

Four hypotheses were formulated from the four objectives of the study to define the relationship between ICT intensity and three growth variables (i.e. labour productivity, output and employment). Accordingly, four different analytical techniques were used in achieving the four objectives of the study. Therefore, this section discusses whether the findings from the analytical techniques were in line with the stated hypotheses.

The first objective was to examine whether ICT policies contributed to labour productivity growth in agro-processing industries. The corresponding hypothesis stated that ICT policies contribute to labour productivity growth of the agro-processing industries. The DD estimations showed that ICT policies did not contribute to labour productivity growth of the agro-processing industries, as the DD estimator was insignificant. Therefore, the findings were not in line with the stated hypothesis as the DD results revealed that ICT policies did not contribute to labour productivity growth of the agro-processing industries.

The second objective was to estimate short-run and long-run effects of ICT intensity on the growth of labour productivity, output and employment. The corresponding hypothesis stated that ICT intensity has positive and significant short-run and long-run effects on the growth of labour productivity, output and employment of the more ICT-intensive industries, and vice versa in the case of the less ICT-intensive industries. The PMG results revealed that ICT intensity had positive and significant effects on the growth of labour productivity, output and employment in the case of more ICT-intensive industry groups only in the long run. Therefore, this hypothesis was rejected as the PMG found positive and significant effects in the case of the more ICT-intensive industries only in the long run.

The third objective was to examine the causal relationship between ICT intensity and growth of labour productivity, output and employment. The corresponding hypothesis stated that there is a causal relationship between ICT intensity and the growth of labour productivity, output and employment of the more ICT-intensive industries, contrary to the less ICT-intensive industries. The TY Granger causality test revealed that there was a causal relationship between ICT intensity and the growth of labour productivity, output and employment in the case of the more ICT-intensive industries, contrary to the less ICT-intensive industries. On these grounds, the study failed to reject the hypothesis, which proposes that there is a causal relationship between ICT intensity and the growth of labour productivity, output and employment of the more ICT-intensive industries, and vice versa for the less ICT-intensive industries.

The fourth objective of the study was to forecast the potential effects of ICT intensity on the growth of labour productivity, output and employment. The corresponding hypothesis stated that ICT intensity would contribute more to the growth of labour productivity, output and employment of the more ICT-intensive industries relative to the less ICT-intensive industries. The VDC and IRF analyses showed that, while ICT intensity would contribute to labour productivity, output and employment growth in both the more and less ICT-intensive industries, in the long run, higher growth would be realised by the more ICT-intensive industries. Therefore, the study failed to reject this hypothesis as the findings showed that ICT intensity would contribute more to the growth of the more ICT-intensive industries, relative to the less ICT-intensive industries.

The hypothesis for the fourth objective stated that ICT intensity would contribute more to the growth of labour productivity, output and employment of the more ICT-intensive industries relative to the less ICT-intensive industries. Therefore, the study failed to reject this hypothesis as the findings showed that ICT intensity would contribute more to the growth of the more ICT-intensive industries, relative to the less ICT-intensive industries.

7.3 POLICY IMPLICATIONS

Three main findings of this study have key implications for policy decision making. The first finding is that the existing ICT policies have not yet contributed to the labour productivity growth of the agro-processing industries, as shown in chapter three. This is attributable to the observation that the reviewed ICT policies have not yet focused on ensuring access to and usage of ICT by other sectors of the economy including the agro-processing subsector. From this perspective, it is recommended that ICT should be integrated into the macro-economic and industrial policy plans for agro-processing. This can be achieved through the inclusion of policy instruments such as ICT-complementary factors like human capacity development (skills development), infrastructure and tax incentives in the policy plans. The inclusion of skills development and ICT infrastructure would ensure effective use of ICT, and the introduction of tax incentives would incentivise industries to invest in ICT. The details on how these policy instruments should be implemented are discussed below.

(a) Skills development

The rationale for recommending skills development is that it has been acknowledged that growth gains from ICT use can only be fully realised through complementary factors such as skills development (Edquist, 2005; Yousefi, 2011; World Bank, 2016). Skills development is correlative to ICT use in that, in an innovative and technologically connected world, ICT increases the demand for skilled workers because the adoption and use of ICT systems require a skilled workforce.

This assertion is supported by an empirical study by O'Mahony, Robinson and Vecchi (2008), which showed that the use of ICT increased the demand for labour from the highest skill group rather than the lowest skill group. However, it is noted that the reviewed ICT policies in relation to skills development have focused on skills in the ICT sector, rather than across the sectors. Therefore, this study recommends the inclusion of skills development in the policy plans for the agro-processing subsector. An introduction of skills development in the policy plans for agro-processing would enhance the skills of the lower-skilled labour input resulting in an increase in employment.

However, there are externalities involved in investing in skills development. For example, industries may not invest in skills development based on the consideration that they might not fully capture all the returns on investment due to the movement of workers between firms once they are trained. Such a movement of workers represents a loss of investment in human capital for firms. In such a case, an investing firm would not be able to attain all the returns on investment due to the existence of positive externalities and spillover effects beyond the investing industry. Therefore, the existence of externalities implies that government, rather than firms, should invest in human capital to ensure the supply of skilled workers to industries so that growth-enhancing effects of ICT can be experienced across industries. Where private firms invest in human capital, the government should compensate private firms through tax incentives as these positive externalities are beyond the control of the investing firm.[76]

(b) ICT infrastructure

ICT infrastructure encompasses the information and communications technology systems and infrastructures such as software, hardware, networks, web servers, content and application, platforms and telecommunication, communication and computing services. The role of ICT infrastructure is to ensure the effective use of ICT within and outside an organisation. ICT infrastructure is correlated to growth in that investment in infrastructure expansion generally enhances the productive capacity of an economy, and therefore its economic growth (Badran, 2012).

As with the case of skills development, externalities are involved in the investment in some infrastructure, which makes it less desirable for private firms to invest, as they would not be able to attain all the returns on investment. Two factors underlie the argument about investment in infrastructure: non-excludability and non-rivalry. In this case, an ICT infrastructure can be regarded as non-excludable if it is difficult for private firms to preclude nonpayers from consumption (i.e. no excludability) and as non-rival if anyone can use the infrastructure as wanted without diminishing the amount available for others (i.e. no rival consumption). Therefore, infrastructures that are non-excludable and non-rival are best provided and paid for by the government rather than private firms, as they cannot preclude non-payers from consumption.

Examples of infrastructures that are best provided for by private firms and paid for by the government include network infrastructure for telecommunication and broadband. In this case, the government should provide such infrastructure by contracting the telecommunications service providers to develop and expand such infrastructure. The rationale is that the telecommunications service providers can charge a price for usage while precluding non-payers from usage. An example of an infrastructure that is best provided by firms includes computer infrastructure. The latter includes services to connect to the internet and facilities such as

[76] The government should compensate private firms through tax incentive, which is discussed later in this section.

telecommunication lines, application platforms like web servers, document management software, data backup services and intrusion detection software. These examples of infrastructures are best provided and paid for by the firms since they can charge a price for their usage while precluding non-payers from usage. Hence, private firms should invest in such infrastructure and be compensated for their investment by the government.

(c) ICT tax incentive programme

This study recommends the integration of ICT into the growth and development policy plans related to agro-processing through the inclusion of skills development and infrastructure development. However, as discussed earlier, there are positive externalities involved in investing in skills development and ICT infrastructure. This means that an investing firm cannot fully capture the returns on investment. Therefore, where private firms provide skills development, it is recommended that the government should compensate private firms through tax incentives. Moreover, where private firms invest in ICT infrastructure, the government should compensate private firms through tax incentives.

Against this backdrop, it is recommended that the government introduce an ICT tax incentive programme in the growth and development policy plans for the agro-processing subsector. Tax incentive is defined, in this study, as a reduction in tax payments by firms in return for their expenditure on skills development, ICT infrastructure and ICT goods and services. The proposed ICT Tax Incentive Programme should be implemented in a similar way to the current research and development (R&D) Tax Incentive Programme, which aims to stimulate R&D private sector investment in R&D and innovation in South Africa. Therefore, the aim of the proposed ICT Tax Incentive Programme should be to stimulate investment in ICT by the agro-processing industries to ensure access to and use of ICT by the non-ICT sectors.

The Department of Science and Technology (DST), along with the National Treasury and the South African Revenue Service (SARS), administer the R&D Tax Incentive Programme. From this perspective, it is recommended that the proposed ICT Tax Incentive Programme be administered by the Department of Trade Industry and Competition, along with the National Treasury and SARS. Moreover, the proposed ICT Tax Incentive Programme should be provided for in Section 11D of the South African Income Tax Act, as is the case with the R&D

Tax Incentive Programme. Specifically, Section 11D of the income tax allows for a tax deduction equal to 150% of the expenditure incurred directly and only for R&D activity in South Africa.

It is, therefore, recommended that Section 11D of the Income Tax Act should be extended to allow for a tax deduction equal to 150% of the expenditure incurred directly and only for ICT activity. The R&D programme is for businesses of all sizes across all sectors of the economy. In terms of the period of the programme, the R&D programme was implemented in 2006 and is set to end in 2022.[77] This proposed ICT Tax Incentive Programme should be implemented over a longer period as the empirical findings revealed that the growth effects of ICT investment take time to materialise. While the R&D programme is for businesses of all sizes and across all sectors of the economy, in the case of the proposed ICT Tax Incentive Programme a decision should be taken on which group of industries to support.

The above decision should be in line with the relevant findings of the present study as follows. The study found that the contribution of ICT investment to growth would vary according to an industry group, such that ICT-led growth would be realised by the industry group that invested more in ICT in the long run. In terms of the individual industries, the highest growth would be realised by an industry that invested highly in ICT, whereas the lowest growth would be realised by an industry that invested the least in ICT. The overall implication is that growth occurs in line with ICT investment, such that the more an industry invests in ICT, the higher growth in labour productivity, output and employment. Hence, there is a need to introduce a tax incentive programme to stimulate investment in ICT. Three criteria can be used to decide on which industries to support through the ICT Tax Incentive programme.

The first criterion depends on the policy objective that the government would like to pursue. If it is growth objectives then, in terms of the economic variables studies used in this study (i.e. labour productivity, output and employment), it is best to support the industries with higher ICT-led growth. The empirical findings revealed that ICT investment would contribute more to the growth of the more ICT-intensive industries (food, beverages, paper and rubber).

[77] There are indications that the Programme will be extended beyond 2022.

Therefore, priority should be given to those industries. Nevertheless, this does not preclude that other industries could realise higher growth through an increase in ICT investment.

The second criterion should be based on the industries' requirements for intermediate ICT inputs. Specifically, the ICT intensity index used in this study to calculate the ICT intensity of industries is defined as an industry's requirements for intermediate ICT inputs to total requirements by all the industries. This partly explains the differential ICT investments across industries. In other words, some industries require ICT more than others, which in turn explains the higher growth effects for industries that invest more in ICT. Therefore, any policy measure aimed at improving the growth of industries through the proposed ICT Tax Incentive Programme should consider the ICT requirements of each industry.

For instance, the tobacco industry does not require more ICT as The Tobacco Products Control Act 83 of 1993 (as amended) prohibits tobacco manufacturers from promoting and advertising tobacco products through print media and distributing and selling tobacco products through the postal and courier services and other electronic means. Consequently, the tobacco industry does not require more ICT because of these restrictions under the Act. However, this does not preclude that the tobacco industry's growth could be strengthened through an increase in ICT investment. Therefore, it would be desirable for this study to recommend that the Act be amended to allow for the advertisement and promotion of tobacco products through print media and the distribution and sale of tobacco products through postal and courier services or other electronic means.

An amendment to the Act would increase investment in ICT resulting in growth in labour productivity, output and employment in various ways. Advertising and promotion of tobacco products through print media (newspapers, magazines, brochures, posters, flyers, etc.) would entice potential customers and induce the demand for tobacco products. An increase in the demand would reduce unemployment, as more labour input would be required to produce the increased output needed to meet the increased demand, *ceteris paribus*. All these changes would lead to a temporary increase in labour productivity, as firms seek to increase labour effort to meet the demand in the short run, *ceteris paribus*.

However, such growth would come at the expense of health in that it would increase the prevalence of tobacco-related diseases and death. This assertion is supported by a recent report by Health-E News, which projected approximately 44 000 smoking-related deaths in South Africa every year, which equates to 121 deaths every day (Jacobs, 2018). While it is desirable, from an economic perspective, for this study to recommend the amendment of the Tobacco Product Control Act, it is undesirable to do so from a health perspective. Moreover, it would be highly improbable that South Africa would amend the Act as it is a party to the WHO's Framework Convention on Tobacco Control (FCTC). It is, therefore, recommended that the tobacco industry be excluded from the proposed ICT Tax incentive programme because it does not require more ICT because of the existence of the Tobacco Products Control Acts.

In terms of the period of the programme, it is recommended that the proposed ICT tax incentive programme be implemented over a longer period as the growth effects from ICT investment take time to materialise. In terms of the beneficiary industries, priority should be given to the more ICT-intensive industries as the findings of the study showed that they would exhibit higher ICT-led growth. These findings suggest that growth could be realised by other industries through an increase in ICT investment. Therefore, it is recommended that other agro-processing industries, with the exception of the tobacco industry, be considered for support through the ICT tax incentive programme, in addition to the more ICT-intensive industries. The rationale for excluding the tobacco industry is that it is constrained from investing highly in ICT because of the existence of the Tobacco Products Control Act.

While it is recommended that the government should compensate industries through the proposed ICT tax incentive programme, money would be required to implement the programme. This raises two fundamental questions of how the government will source the money to fund the proposed programme and what gains could be accrued by the government. These questions have been addressed by pertinent observations in this study as follows. It has been established that ICT investment would contribute to output growth and employment in the long run. An increase in output will result in an increase in government revenue through tax. Moreover, increased employment translates to an increase in revenue for the government through income tax. Therefore, the government would gain through increased tax revenue. Accordingly, the tax revenue should be ploughed back into the agro-processing subsector through the proposed ICT tax incentive programme. In addition, investment in ICT would contribute towards a reduction in the rates of poverty and inequality. It was established in chapter three that an increase in wages would increase the labour productivity of the manufacturing industries, including the agro-processing industries. Therefore, workers in the agro-processing subsector would benefit from being more productive by earning higher wages, if increased labour productivity were to lead to higher wages. This would increase the agro-processing sector's contribution to the reduction of poverty and income inequality, thereby attaining some of the policy objectives that the subsector has been earmarked to achieve.

7.4 IMPLICATIONS FOR FUTURE RESEARCH

While the study examined the extent to which ICT investment contributes to the growth of labour productivity, output and employment in the agro-processing subsector, the study could be extended in six areas. Firstly, by definition, ICT covers a wide range of ICT goods and services, as described in chapter two of this study.[78] However, due to the lack of comprehensive data on all intermediate ICT inputs, the intermediate ICT inputs considered in this study were limited to printing, telecommunication, postal and courier services, and computer and related activities. Therefore, different results could be obtained if more comprehensive data were considered. Hence, there is scope to extend the analysis to other intermediate ICT inputs in the future, as and when data become available.

Secondly, the rationale for focusing on a bundle of intermediate ICT inputs instead of a single input is that previous studies could not detect impact due to a smaller share of ICT investment by a single input to total ICT investment. The impact could be detectable if the share of ICT investment in the case of a single input were to increase. Therefore, there is a need for future researchers to examine the impact of an increase in a single intermediate input on the growth of industries.

Thirdly, the PMG results were used to establish whether the ICT–LP–RO–EMP nexus holds as suggested by the theoretical framework of the study. The results showed that the nexus holds for the food industry, implying that ICT investment would increase labour productivity, output

[78] (See Table A. 3).

and employment in the food industry. However, the theoretical implications were not fully explored within the context of a specific economic theory, and thus points to an area of future research. The appropriate economic theory is the theory of elasticity of demand, which measures how the demand for a product changes as the price of the product changes.

The rationale for identifying the elasticity of demand theory is that it categorises industries into various constructs (elastic, inelastic and unitary) based on the responsiveness of consumer demand to changes in the price. The elasticity of demand theory can be used to identify which of the agro-processing industries exhibit elastic demand, inelastic demand and unitary demand. For instance, the food industry might exhibit inelastic demand given that a change in price results only in a small change in the demand for quantity, as food is a basic need. Therefore, if food prices rise, consumers might not reduce their food purchases, although they may shift to substitute food items. However, this is suggestive rather than conclusive, and thus requires further investigation.

Fourthly, ICTs are said to be the drivers of the current revolution, namely, the fourth industrial revolution, an era characterised by the fusion of digital technologies with the physical and biological spheres. These technologies include, among others, machines that can substitute and duplicate human actions. From this perspective, the revolution is expected to bring important changes to all sectors, from agriculture and mining to manufacturing and service industries (Schwab, 2016). Accordingly, industries are expected to experience changes in the way in which goods and services are produced. The outcomes of the expected changes include, among others, new areas of demand, the emergence of new industries and products and services, the generation of new employment and the modernisation of business processes. Based on the anticipated radical change in the digital age, it would be imperative to identify and estimate the effects of such technologies on agro-processing industries in order to detect how such technologies would impact on industries compared to ICT.

Fifthly, the findings of the study showed that ICT had a positive effect on the growth of labour productivity and output in some of the more ICT-intensive industries. In this regard, changes in the use of ICT by these industries may indirectly affect other sectors, and ultimately lead to structural change in the economy. This is because agro-processing industries are embedded within the economic system consisting of suppliers of inputs, government, factor market, investors, households, foreign market and other economic sectors. On this basis, an economy-wide modelling technique like the computational general equilibrium model (CGE) is thus required to capture and quantify ICT effects and examine how changes in ICT use in the agro-processing sector could impact on other sectors. Relevant spheres of the economy include, among others, final users of agro-processing products (e.g. households or consumers, exporters, and others), and investment and trade.

Lastly, the findings of the study revealed that the effects of ICT vary from industry to industry and that higher effects are realised by industries that invest highly in ICT. It is acknowledged that growth gains from ICT investment can be fully experienced through ICT-complementary factors such as investment in human capital and infrastructure development. However, this study did not account for complementary factors because of the absence of data in this area. Therefore, future research could strengthen the findings of this study by examining the contribution of ICT investment to the growth of industries, taking into account ICT-complementary factors. Despite the identified delimitations, new knowledge has been gained from this study as discussed in the next section.

7.5 DISCUSSION OF THE CONTRIBUTION OF THE STUDY TO KNOWLEDGE

This section provides a discussion of the contribution of the study to underline the new knowledge that has been generated and the context under which the knowledge will be applicable. The new knowledge was generated by filling three knowledge gaps in the literature (as described in section 1.7 of this study). The first gap is the absence of an information base on the ICT intensity of the agro-processing industries (which of the agro-processing industries are less ICT-intensive and which ones are more ICT-intensive). The results from the ICT intensity index showed that the more ICT-intensive industries are food, beverages, textile, paper and rubber industries, while the less ICT-intensive industries are tobacco, wearing apparel, wood, leather and furniture. The database on the ICT intensity of the agro-processing industries can be used by other researchers to investigate the effect of ICT investment on industries using other economic variables of interest, besides labour productivity, output and employment. The database can also be used to evaluate which of the industry groups, between the less and more ICT-intensive industry groups, would exhibit higher growth in the economic variables of interest as a result of ICT investment.

The second knowledge gap is that there was no empirical evidence on how long it would take for ICT to yield a positive and significant impact on the agro-processing industries. The empirical results indicated that ICT investment would yield a positive and significant impact on the agro-processing industries in the long run. The implication is that growth effects from ICT investment take time to materialise. The present findings serve to inform policymakers about the length of time it takes to support the agro-processing industries through ICT investment. Based on these findings, policies aimed at ensuring growth through ICT investment should be implemented over a longer period since the returns on ICT investment would be realised over a longer period.

The third knowledge gap is that there was a lack of empirical evidence on which of the agro-processing industries would exhibit higher growth as a result of ICT investment. The empirical results showed that ICT investment would contribute more to the growth of the more ICT-intensive industries. These findings serve to inform policymakers regarding which industry group to prioritise for ICT-related investment. Based on these findings, policies aimed at ensuring growth through ICT investment should focus on the more ICT-intensive industries as higher growth in labour productivity, output and employment would be realised by the more ICT-intensive industries.

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APPENDICES

APPENDIX A

Table A.1: Classification of manufacturing industries

Division	Group	Class	Description
10			**Manufacture of food products**
	101	1010	Processing and preserving of meat
	102	1020	Processing and preserving of fish, crustaceans and molluscs
	103	1030	Processing and preserving of fruit and vegetables
	104	1040	Manufacture of vegetable and animal oils and fats
	105	1050	Manufacture of dairy products
	106		Manufacture of grain mill products, starches and starch products
		1061	Manufacture of grain mill products
		1062	Manufacture of starches and starch products
		107	Manufacture of other food products
		1071	Manufacture of bakery products
		1072	Manufacture of sugar
		1073	Manufacture of cocoa, chocolate and sugar confectionery
		1074	Manufacture of macaroni, noodles, couscous and similar farinaceous products
		1075	Manufacture of prepared meals and dishes
		1079	Manufacture of other food products n.e.c.
	108	1080	Manufacture of prepared animal feeds
11			**Manufacture of beverages**
		1101	Distilling, rectifying and blending of spirits
		1102	Manufacture of wines
		1103	Manufacture of malt liquors and malt
		1104	Manufacture of soft drinks; production of mineral waters and other bottled waters
12			**Manufacture of tobacco products**
	120	1200	Manufacture of tobacco products
13			**Manufacture of textiles**
	131		Spinning, weaving and finishing of textiles
		1311	Preparation and spinning of textile fibres
		1312	Weaving of textiles
		1313	Finishing of textiles
	139		Manufacture of other textiles
		1391	Manufacture of knitted and crocheted fabrics
		1392	Manufacture of made-up textile articles, except apparel
		1393	Manufacture of carpets and rugs
		1394	Manufacture of cordage, rope, twine and netting
		1399	Manufacture of other textiles n.e.c.
14			**Manufacture of wearing apparel**
	141	1410	Manufacture of wearing apparel, except fur apparel
	142	1420	Manufacture of articles of fur
	143	1430	Manufacture of knitted and crocheted apparel
15			**Manufacture of leather and related products**
	151		Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness; dressing and dyeing of fur
		1511	Tanning and dressing of leather; dressing and dyeing of fur
		1512	Manufacture of luggage, handbags and the like, saddlery and harness
	152	1520	Manufacture of footwear
16			**Manufacture of wood and wood products, except furniture**
	161	1610	Sawmilling and planing of wood

	162		Manufacture of products of wood, cork, straw and plaiting materials
		1621	Manufacture of veneer sheets and wood-based panels
		1622	Manufacture of builders' carpentry and joinery
		1623	Manufacture of wooden containers
		1629	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials
17			**Manufacture of paper and paper products**
		1701	Manufacture of pulp, paper and paperboard
		1702	Manufacture of corrugated paper and paperboard and of containers of paper and paperboard
		1709	Manufacture of other articles of paper and paperboard
18			**Printing and reproduction of recorded media**
	181		Printing and service activities related to printing
		1811	Printing
		1812	Service activities related to printing
	182	1820	Reproduction of recorded media
19			**Manufacture of coke and refined petroleum products**
	191	1910	Manufacture of coke oven products
	192	1920	Manufacture of refined petroleum products
20			**Manufacture of chemicals and chemical products**
	201		Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms
		2011	Manufacture of basic chemicals
		2012	Manufacture of fertilizers and nitrogen compounds
		2013	Manufacture of plastics and synthetic rubber in primary forms
	202		Manufacture of other chemical products
		2021	Manufacture of pesticides and other agrochemical products
		2022	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
		2023	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
		2029	Manufacture of other chemical products n.e.c.
	203	2030	Manufacture of man-made fibres
21			**Manufacture of pharmaceuticals, medicinal chemical and botanical products**
	210	2100	Manufacture of pharmaceuticals, medicinal chemical and botanical products
22			**Manufacture of rubber and plastics products**
	221		Manufacture of rubber products
		2211	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
		2219	Manufacture of other rubber and plastics products
	222	2220	Manufacture of plastics products
23			Manufacture of other non-metallic mineral products
	231	2310	Manufacture of glass and glass products
		239	Manufacture of non-metallic mineral products n.e.c.
		2391	Manufacture of refractory products
		2392	Manufacture of clay building materials
		2393	Manufacture of other porcelain and ceramic products
		2394	Manufacture of cement, lime and plaster
		2395	Manufacture of articles of concrete, cement and plaster
		2396	Cutting, shaping and finishing of stone
		2399	Manufacture of other non-metallic mineral products n.e.c.
24			**Manufacture of basic metals**
	241	2410	Manufacture of basic iron and steel

	242	2420	Manufacture of basic precious and other non-ferrous metals
	243		Casting of metals
		2431	Casting of iron and steel
		2432	Casting of non-ferrous metals
25	**Manufacture of fabricated metal products, except machinery and equipment**		
		251	Manufacture of structural metal products, tanks, reservoirs and steam generators
		2511	Manufacture of structural metal products
		2512	Manufacture of tanks, reservoirs and containers of metal
		2513	Manufacture of steam generators, except central heating hot water boilers
	252	2520	Manufacture of weapons and ammunition
	259		Manufacture of other fabricated metal products; metalworking service activities
		2591	Forging, pressing, stamping and roll-forming of metal; powder metallurgy
		2592	Treatment and coating of metals; machining
		2593	Manufacture of cutlery, hand tools and general hardware
		2599	Manufacture of other fabricated metal products n.e.c.
26			**Manufacture of computer, electronic and optical products**
	261	2610	Manufacture of electronic components and boards
	262	2620	Manufacture of computers and peripheral equipment
	263	2630	Manufacture of communication equipment
	264	2640	Manufacture of consumer electronics
	265		Manufacture of measuring, testing, navigating and control equipment; watches and clocks
		2651	Manufacture of measuring, testing, navigating and control equipment
		2652	Manufacture of watches and clocks
	266	2660	Manufacture of irradiation, electromedical and electrotherapeutic equipment
	267	2670	Manufacture of optical instruments and photographic equipment
	268	2680	Manufacture of magnetic and optical media
27			**Manufacture of electrical equipment**
	271	2710	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
	272	2720	Manufacture of batteries and accumulators
	273		Manufacture of wiring and wiring devices
		2731	Manufacture of fibre optic cables
		2732	Manufacture of other electronic and electric wires and cables
		2733	Manufacture of wiring devices
	274	2740	Manufacture of electric lighting equipment
	275	2750	Manufacture of domestic appliances
	279	2790	Manufacture of other electrical equipment
28			**Manufacture of machinery and equipment n.e.c.**
	281		Manufacture of general-purpose machinery
		2811	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
		2812	Manufacture of fluid power equipment
		2813	Manufacture of other pumps, compressors, taps and valves
		2814	Manufacture of bearings, gears, gearing and driving elements
		2815	Manufacture of ovens, furnaces and furnace burners
		2816	Manufacture of lifting and handling equipment
		2817	Manufacture of office machinery and equipment (except computers and peripheral

			equipment)
		2818	Manufacture of power-driven hand tools
		2819	Manufacture of other general-purpose machinery
	282		Manufacture of special-purpose machinery
		2822	Manufacture of metal-forming machinery and machine tools
		2823	Manufacture of machinery for metallurgy
		2824	Manufacture of machinery for mining, quarrying and construction
		2825	Manufacture of machinery for food, beverage and tobacco processing
		2826	Manufacture of machinery for textile, apparel and leather production
		2829	Manufacture of other special-purpose machinery
29	**Manufacture of motor vehicles, trailers and semi-trailers**		
	291	2910	Manufacture of motor vehicles
	292	2920	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
	293	2930	Manufacture of parts and accessories for motor vehicles
30			**Manufacture of other transport equipment**
	301		Building of ships and boats
		3011	Building of ships and floating structures
		3012	Building of pleasure and sporting boats
	302	3020	Manufacture of railway locomotives and rolling stock
	303	3030	Manufacture of air and spacecraft and related machinery
	304	3040	Manufacture of military fighting vehicles
	309		Manufacture of transport equipment n.e.c.
		3091	Manufacture of motorcycles
		3099	Manufacture of other transport equipment n.e.c.
31			**Manufacture of furniture**
	310	3100	Manufacture of furniture
32			Other manufacturing
	321		**Manufacture of jewellery, bijouterie and related articles**
		3211	Manufacture of jewellery and related articles
		3212	Manufacture of imitation jewellery and related articles
	322	3220	Manufacture of musical instruments
	323	3230	Manufacture of sports goods
	324	3240	Manufacture of games and toys
	325	3250	Manufacture of medical and dental instruments and supplies
	329	3290	Other manufacturing n.e.c.
33			**Repair and installation of machinery and equipment**
	331		Repair of fabricated metal products, machinery and equipment
		3311	Repair of fabricated metal products
		3312	Repair of machinery
		3313	Repair of electronic and optical equipment
		3314	Repair of electrical equipment
		3315	Repair of transport equipment, except motor vehicles
		3319	Repair of other equipment
	332	3320	Installation of industrial machinery and equipment

Source: ISIC (Rev.4)

Table A.2: Classification of agro-processing industries

Division	Group	Class	Description
10			**Manufacture of food products**
	101	1010	Processing and preserving of meat
	102	1020	Processing and preserving of fish, crustaceans and molluscs
	103	1030	Processing and preserving of fruit and vegetables
	104	1040	Manufacture of vegetable and animal oils and fats
	105	1050	Manufacture of dairy products
	106		Manufacture of grain mill products, starches and starch products
		1061	Manufacture of grain mill products
		1062	Manufacture of starches and starch products
		107	Manufacture of other food products
		1071	Manufacture of bakery products
		1072	Manufacture of sugar
		1073	Manufacture of cocoa, chocolate and sugar confectionery
		1074	Manufacture of macaroni, noodles, couscous and similar farinaceous products
		1075	Manufacture of prepared meals and dishes
		1079	Manufacture of other food products n.e.c.
	108	1080	Manufacture of prepared animal feeds
11			**Manufacture of beverages**
		1101	Distilling, rectifying and blending of spirits
		1102	Manufacture of wines
		1103	Manufacture of malt liquors and malt
		1104	Manufacture of soft drinks; production of mineral waters and other bottled waters
12			**Manufacture of tobacco products**
	120	1200	Manufacture of tobacco products
13			**Manufacture of textiles**
	131		Spinning, weaving and finishing of textiles
		1311	Preparation and spinning of textile fibres
		1312	Weaving of textiles
		1313	Finishing of textiles
	139		Manufacture of other textiles
		1391	Manufacture of knitted and crocheted fabrics
		1392	Manufacture of made-up textile articles, except apparel
		1393	Manufacture of carpets and rugs
		1394	Manufacture of cordage, rope, twine and netting
		1399	Manufacture of other textiles n.e.c.
14			**Manufacture of wearing apparel**
	141	1410	Manufacture of wearing apparel, except fur apparel
	142	1420	Manufacture of articles of fur
	143	1430	Manufacture of knitted and crocheted apparel
15			**Manufacture of leather and related products**
	151		Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness; dressing and dyeing of fur
		1511	Tanning and dressing of leather; dressing and dyeing of fur
		1512	Manufacture of luggage, handbags and the like, saddlery and harness
	152	1520	Manufacture of footwear
16			**Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials**
	161	1610	Sawmilling and planing of wood
	162		Manufacture of products of wood, cork, straw and plaiting materials
		1621	Manufacture of veneer sheets and wood-based panels

		1622	Manufacture of builders' carpentry and joinery
		1623	Manufacture of wooden containers
		1629	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials
17			**Manufacture of paper and paper products**
		1701	Manufacture of pulp, paper and paperboard
		1702	Manufacture of corrugated paper and paperboard and of containers of paper and paperboard
		1709	Manufacture of other articles of paper and paperboard
22			Manufacture of rubber and plastics products
	221		**Manufacture of rubber products**
		2211	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
		2219	Manufacture of other rubber products
	222	2220	Manufacture of plastics products
31			**Manufacture of furniture**
	310	3100	Manufacture of furniture

Source: ISIC (Rev.4)

Table A.3: Classification of ICT economic activities

Classification of ICT economic activities				
Division	**Group**	**Class**	**Subclass**	**Description**
ICT MANUFACTURING ACTIVITIES				
Division 18				**Printing and reproduction of recorded media**
	181			**Printing and service activities related to printing**
		1811	18110	Printing
		1812	18120	Service activities related to printing
	182			**Reproduction of recorded media**
		1820	18200	Reproduction of recorded media
Division 26				**Manufacture of computer, electronic and optical products**
	261			**Manufacture of electronic components and boards**
		2610	26100	Manufacture of electronic components and boards
	262			**Manufacture of computers and peripheral equipment**
		2620	26200	Manufacture of computers and peripheral equipment
	263			**Manufacture of communication equipment**
		2630	**26300**	**Manufacture of communication equipment**
	264			**Manufacture of consumer electronics**
		2640	26400	Manufacture of consumer electronics
	265			**Manufacture of measuring, testing, navigating and control equipment; watches and clocks**
		2651	26510	Manufacture of measuring, testing, navigating and control equipment
		2652	26520	Manufacture of watches and clocks
	266			**Manufacture of irradiation, electromedical and electrotherapeutic equipment**
		2660	**26600**	
	267			**Manufacture of optical instruments and photographic equipment**
		2670	26700	Manufacture of optical instruments and photographic equipment
	268			**Manufacture of magnetic and optical media**
		2680	26800	Manufacture of magnetic and optical media
ICT TRANSPORTATION SERVICES				
Division 53				**Postal and courier activities**
	531			**Postal activities**
		5310	53100	Postal activities
	532			**Courier activities**
		5320	**53200**	**Courier activities**
ICT TRADE INDUSTRIES				
	465			**Wholesale of equipment and supplies**
		4651	46510	Wholesale of computers, computer peripheral equipment and software
		4652	46520	Wholesale of electronic and telecommunications equipment and parts
Information and content activities				
Division 58				**Publishing activities**
	581			Publishing of books, periodicals and other publishing activities

		5811	58110	Book publishing
		5812	58120	Publishing of directories and mailing lists
		5813	58130	Publishing of newspapers, journals and periodicals
		5819	58190	Other publishing activities
	582			**Software publishing**
		5820	58200	Software publishing
Division 59				**Motion picture, video and television programme production, sound recording and music publishing activities**
	591			**Motion picture, video and television programme activities**
		5911	59110	Motion picture, video and television programme production activities
		5912	59120	Motion picture, video and television programme post-production activities
		5913	59130	Motion picture, video and television programme distribution activities
		5914	59140	Motion picture projection activities
	592			**Sound recording and music publishing activities**
		5920	59200	Sound recording and music publishing activities
Division 60				**Programming and broadcasting activities**
	601			**Radio broadcasting**
		6010	60100	Radio broadcasting
	602			Television programming and broadcasting activities
		6020	60200	Television programming and broadcasting activities
Division 61				**Telecommunications**
	611			**Wired telecommunications activities**
		6110	61100	Wired telecommunications activities
	612			**Wireless telecommunications activities**
		6120	61200	Wireless telecommunications activities
	613			**Satellite telecommunications activities**
		6130	61300	Satellite telecommunications activities
	619			**Other telecommunications activities**
		6190	61900	Other telecommunications activities
Division 62				**Computer programming, consultancy and related activities**
	620			Computer programming, consultancy and related activities
		6201	62010	Computer programming activities
		6202	62020	Computer consultancy and computer facilities management activities
		6209	62090	Other information technology and computer service activities
Division 63				**Information service activities**
	631			Data processing, hosting and related activities; web portals
		6311	63110	Data processing, hosting and related activities
		6312	63120	Web portals
	639			**Other information service activities**
		6391	63910	News agency activities
		6399	63990	Other information service activities n.e.c

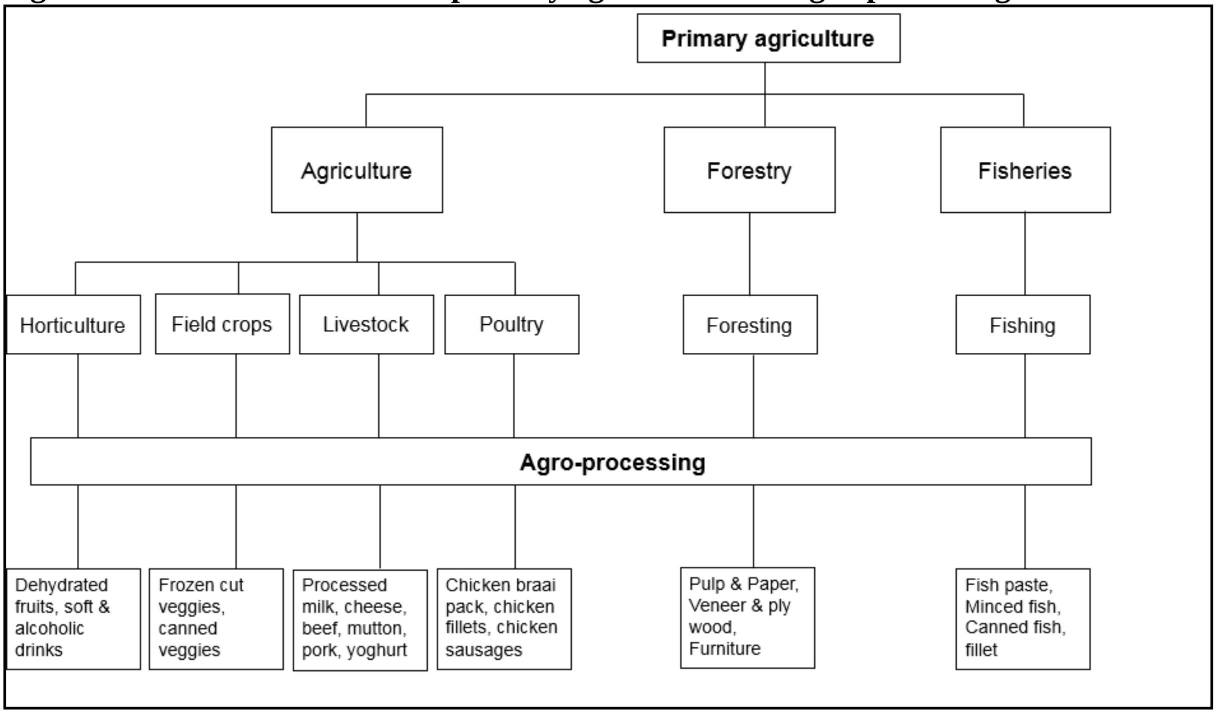
Source: ISIC (Rev.4)

Table A.4: Overview of key ICT policies / action plans in South Africa post-1994

Policy	Objective (s)
The national information society and development (ISAD) plan (1996)	"To establish South Africa as an advanced Information Society in which Information and ICT tools are key drivers of economic and societal development"
Sentech Act, 1996 (Act No. 63 of 1996, as amended	"To provide for the conversion of Sentech (Pty) Ltd from a private to a public company"
Telecommunications Act, 1996 (Act No. 103 of 1996)	"To provide for the regulation of the telecommunication activities/sector"
Postal Service Act, 1998 (Act No. 124 of 1998), as amended	"To provide for the regulation of the postal sector to ensure accessible, efficient, equitable, effective, and affordable postal services"
State Information Technology Agency Act (SITA), 1998 (Act No. 88 of 1998), as amended	"To provide for the establishment of SITA, state-owned agency, for the provision of information systems and services to, or on behalf of the government"
Broadcasting Act, 1999 (Act No.4 of 1999)	"To provide for the establishment of the state broadcaster, the South African Broadcasting Corporation (SABC) and the licensing and regulation of the broadcasting system"
ICASA Act, 2000 (Act No. 13 of 2000), as amended	"To provide for the regulation of the broadcasting, postal and telecommunications industries to ensure access to high quality and affordable communication services"
Telecommunications Act 2001 (Act No. 64 of 2001), as amended	"To allow for the formation of competitors to Telkom (i.e. semi-state-owned telecommunications company)"
Electronic Communications and Transactions (ECT) Act 2002 (Act No. 25 of 2002), as amended	"To facilitate and regulate electronic communications and transactions"
Electronic Communications Act, 2005 (Act No. 36 of 2005)	"To provide for the regulation of electronic communications, network and broadcasting services"
Broadband Infraco Act, 2007 (Act No. 33 of 2007)	"To provide for the establishment of Broadband Infraco, state-owned agency to provide long-distance connectivity to the licensed private sector"
South African Post Bank Limited Act, 2010 (Act No. 9 of 2010)	"To provide for the governance and functions of the Postbank company and allow for the conversion of the Postbank from deposit-taking to a fully-fledged bank" (DTPS, 2015)
South African Post Office SOC Ltd Act, 2011 (Act No. 22 of 2011)	"To ensure the provision of accessible, universal, affordable and reliable postal services"
National e-Skills Plan of Action (NeSPA) (2012)	"To develop human capacity in the digital age to increase overall socio-economic development"
National Broadband Policy and Strategy (2013)	"To ensure access to reliable, fast, and available and secure internet by all citizens, particularly those living in rural areas."
The National Integrated ICT Policy (2016)	"To provide for the alignment of ICT policies with the National Development Plan (NDP) 2030"
Broadcasting Digital Migration Policy (2016)	"To provide for the migration from analogue to digital terrestrial television broadcasting"
National e-government strategy and roadmap (2017)	"To digitize government services while transforming South Africa into digital society and economy"
ICT SMME Development Strategy (2017)	"Opening up of business opportunities and creating an enabling administrative and business environment for SMMEs in the ICT sector"

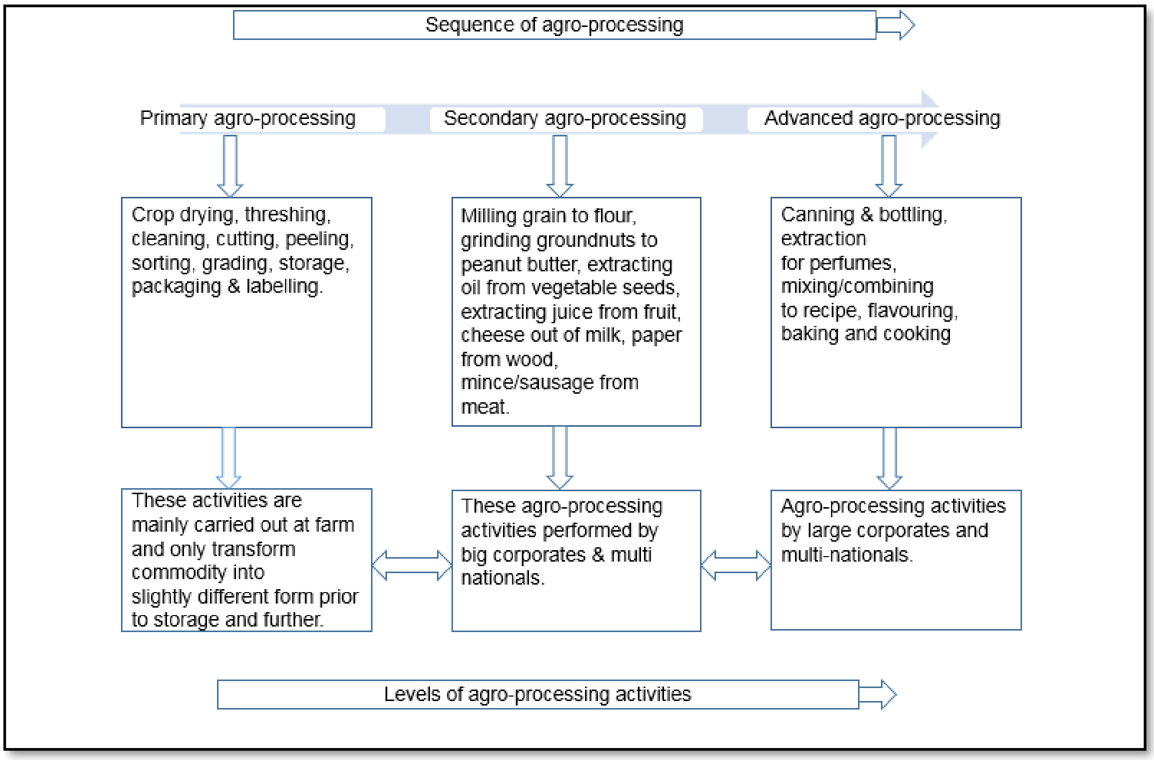
Source: Adapted from Lefophane and Kalaba (2020)

Figure A.1: Delineation between primary agriculture and agro-processing



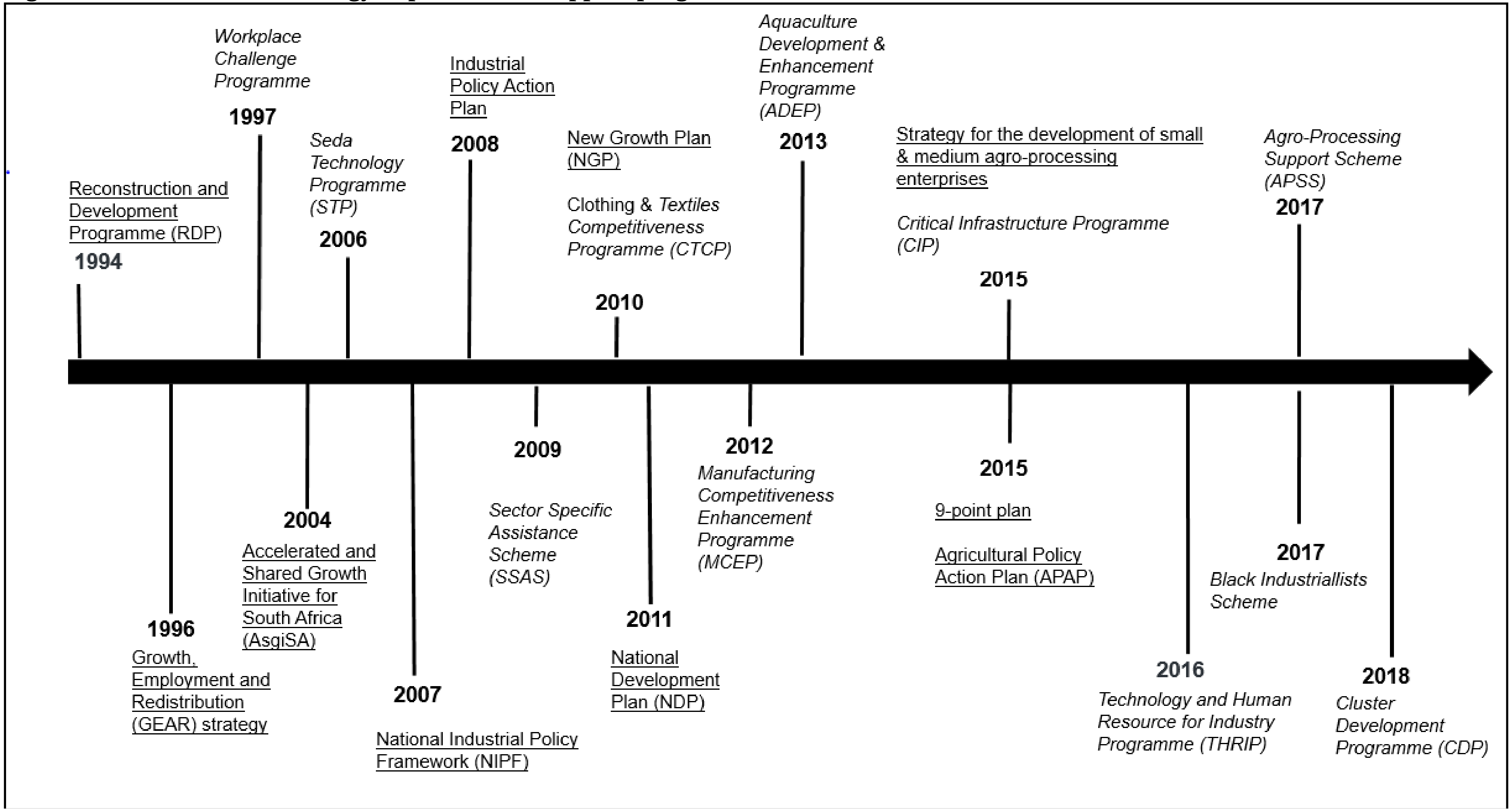
Source: Author's own illustration

Figure A.2: Phases of agro-processing activities



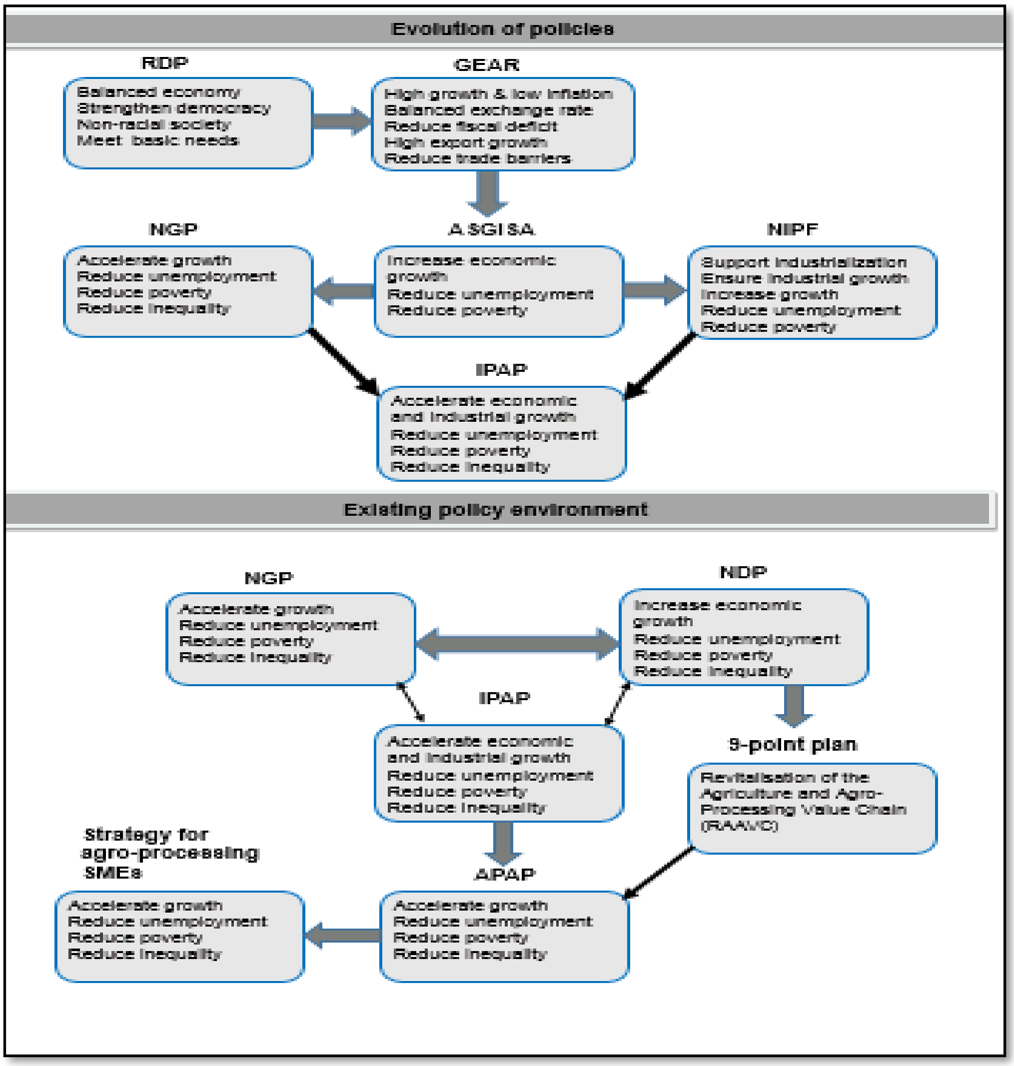
Source: DAFF (2015)

Figure A.3: Historical chronology of policies and support programmes



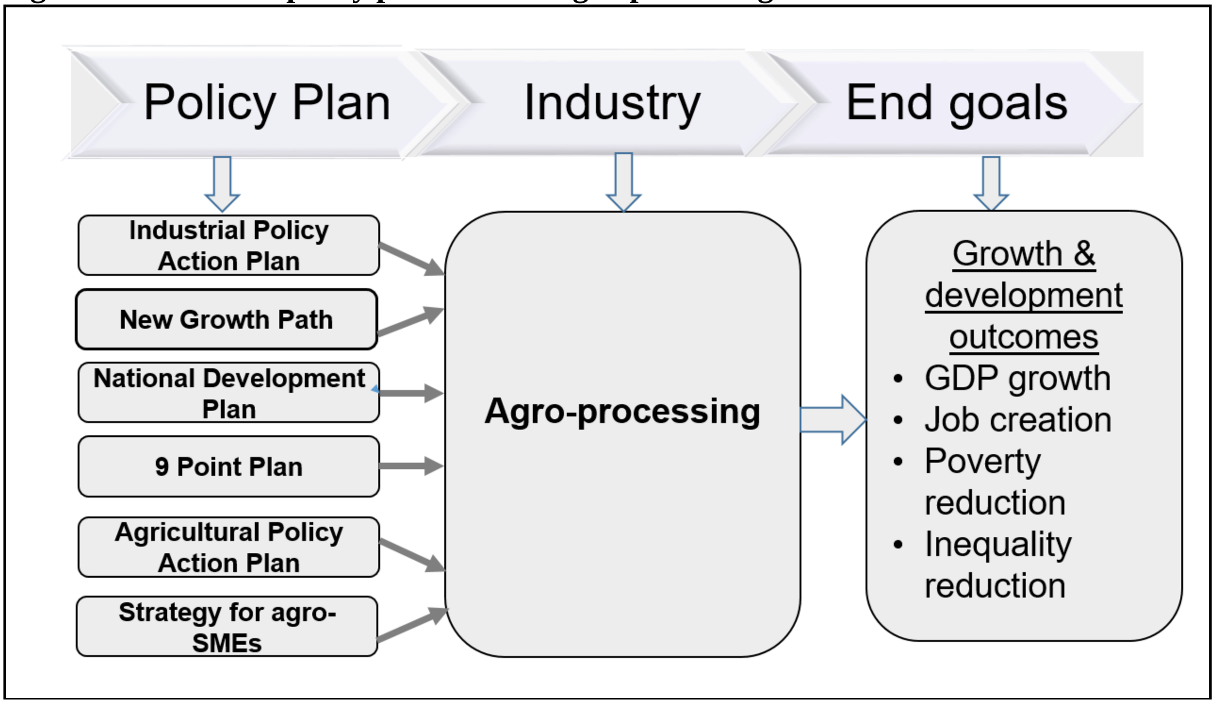
Source: Author's own elaboration

Figure A.4: Progression of policy plans



Source: Author's own illustration based on applicable policy plans

Figure A.5: Current policy plans for the agro-processing subsector



Source: Author's own illustration, based on applicable policy plans

APPENDIX B

Table B.1: Variance inflation factors for Panel of industries

Endogenous variable	Exogenous variable			
	Panel A (All agro-processing industries)			
	ICT	**EMP**	**LP**	**RO**
ICT	-	1.59	1.77	1.24
EMP	1.00	-	1.12	1.11
LP	1.00	1.00	-	1.00
RO	1.00	1.43	1.43	-
Panel B (More ICT-intensive industries)				
	ICT	**EMP**	**LP**	**RO**
ICT	-	1.94	2.26	1.48
EMP	1.00	-	1.17	1.17
LP	1.00	1.01	-	1.01
RO	1.00	1.54	1.54	-
Panel C (Less ICT-intensive industries)				
	ICT	**EMP**	**LP**	**RO**
ICT	-	1.58	2.20	1.75
EMP	2.46	-	1.43	1.5
LP	2.42	1.02	-	1.15
RO	2.49	1.39	1.48	-

Note: ICT is the ICT intensity (%); LP is the labour productivity growth rate (%); EMP is growth rate of employment (%); RO is the real output growth rate (%).

Table B.2: Variance inflation factors for Panel B

Endogenous variable	Exogenous variable			
	ICT	EMP	LP	RO
Food				
ICT	-	1.59	1.77	1.24
EMP	1.00	-	1.12	1.11
LP	1.00	1.00	-	1.00
RO	1.00	1.43	1.43	-
Beverages				
ICT	-	1.43	2.42	2.09
EMP	1.41	-	2.39	2.05
LP	1.17	1.17	-	1.00
RO	1.26	1.26	1.26	-
Textile				
ICT	-	1.89	1.86	1.20
EMP	1.07	-	1.05	1.06
LP	1.07	1.07	-	1.10
RO	1.03	1.59	1.62	-
Paper				
ICT	-	2.22	2.48	1.95
EMP	1.13	-	1.19	1.33
LP	1.15	1.03	-	1.16
RO	1.01	1.96	1.96	-
Rubber				
ICT	-	1.94	2.27	1.45
EMP	1.00	-	1.18	1.18
LP	1.00	1.01	-	1.00
RO	1.01	1.60	1.59	-

Note: ICT is the ICT intensity (%); LP is the labour productivity growth rate (%); EMP is growth rate of employment (%); RO is the real output growth rate (%).

Table B.3: Variance inflation factors for Panel C

Endogenous variable	Exogenous variable			
	ICT	**EMP**	**LP**	**RO**
		Tobacco		
ICT	-	2.47	2.49	2.18
EMP	1.00	-	2.07	2.0
LP	1.02	1.04	-	1.02
RO	1.01	1.35	1.34	-
		Wearing apparel		
ICT	-	2.42	2.39	1.99
EMP	1.03	-	1.29	1.29
LP	1.02	1.00	-	1.02
RO	1.02	2.20	2.24	-
		Leather		
ICT	-	1.40	1.51	1.11
EMP	1.14	-	1.14	1.12
LP	1.08	1.01	-	1.07
RO	1.09	1.36	1.47	-
		Wood		
ICT	-	2.39	2.45	2.21
EMP	1.24	-	1.15	1.26
LP	1.22	1.21	-	1.45
RO	1.50	1.17	1.65	-
		Furniture		
ICT	-	1.91	2.32	1.34
EMP	1.20	-	1.21	1.42
LP	1.21	1.01	-	1.20
RO	1.03	1.73	1.76	-

Note: ICT is the ICT intensity (%); LP is the labour productivity growth rate (%); EMP is growth rate of employment (%); RO is the real output growth rate (%).

Table B.4: Optimal lag results

Variable	Optimal lag
Panel A	
ICT	2
EMP	1
LP	2
RO	2
Panel B	
ICT	2
EMP	2
LP	1
RO	1
Panel C	
ICT	1
EMP	1
LP	1
RO	2
Individual industries	
Food	
ICT	**1**
EMP	**1**
LP	**1**
RO	**1**
Beverages	
ICT	**1**
EMP	**1**
LP	**2**
RO	**1**
Tobacco	
ICT	**1**
EMP	**1**
LP	**1**
RO	**1**
Textile	
ICT	**1**
EMP	**1**
LP	**1**
RO	**1**
Wearing apparel	
ICT	**2**
EMP	**1**
LP	**1**
RO	**1**
Leather	
ICT	**1**
EMP	**1**
LP	**1**
RO	**1**
Wood	
ICT	**1**

EMP	**1**
LP	**1**
RO	**2**
Paper	
ICT	**2**
EMP	**2**
LP	**2**
RO	**1**
Rubber	
ICT	**2**
EMP	**1**
LP	**1**
RO	**1**
Furniture	
ICT	**1**
EMP	**1**
LP	**1**
RO	**1**

Note 1: ICT=ICT intensity (%); LP=labour productivity growth rate (%); EMP= growth rate of employment (%); RO =real output growth rate (%). Note 2: Criterion=AIC.

Table B.5: Diagnostic test results for Panel of industries

Variables	Diagnostic test			
	J-B test	**Ramsey RESET**	**ARCH test**	**LM test**
Panel A (All agro-processing industries)				
ICT	493.28 (0.000)***	0.00(0.953)	1.77(0.197)	1.10(0.306)
EMP	0.53(0.521)	1.31 (0.997)	1.08(0.309)	0.13(0.84)
LP	0.47(0.640)	1.16 (0.106)	5.16(0.036)	1.49(0.365)
RO	1.22(0.682)	0.00 (0.958)	0.83(0.371)	0.03(0.878)
Panel B (More ICT-intensive industries)				
ICT	68.32 (0.000)***	0.06 (0.923)	0.11 (0.754)	0.13 (0.876)
EMP	0.57(0.751)	0.46 (0.495)	0.03 (0.956)	2.01 (0.183)
LP	0.34 (0.432)	0.04 (0.172)	0.74(0.841)	0.05 (0.702)
RO	1.63 (0.277)	0.07 (0.923)	0.34 (0.911)	0.44 (0.822)
Panel C (Less ICT-intensive industries)				
ICT	22.27 (0.000)***	40.00 (0.000)***	13.58 (0.000)***	0.24(0.623)
EMP	2.41 (0.956)	1.75 (0.357)	0.32(0.570)	0.24(0.623)
LP	1.89 (0.140)	1.20(0.274)	0.34(0.557)	0.34(0.557)
RO	2.02 (0.157)	1.43(0.109)	1.54 (0.216)	1.99(0.141)

Note 1: ICT is the ICT intensity (%); LP is the labour productivity growth rate (%); EMP is growth rate of employment (%); RO is the real output growth rate (%). Note 2: J-B =Jarque-Bera; RESET=Ramsey Regression Specification Error Test; ARCH= Autoregressive Conditional Heteroskedastic; LM= Lagrange multiplier. Note 3: Figures in parenthesis are the P-values. Note 4: ** significant at 5% level; *** significant at 1% level.

Table B.6: Diagnostic test results for Panel B industries

Variables	Diagnostic test			
	J-B test	**Ramsey RESET**	**ARCH test**	**LM test**
		Food		
ICT	612.70 (0.000)***	81.48 (0.000)***	0.75(0.677)	0.45(0.854)
EMP	1.47(0.616)	1.35(0.378)	0.78(0.521)	0.21(0.865)
LP	0.06(0.865)	0.01(0.920)	0.88(0.401)	0.821(0.241)
RO	0.41(0.953)	0.66(0.578)	0.53(0.626)	0.25 (0.810)
		Beverages		
ICT	0.75 (0.68)	0.56 (0.463)	1.08 (0.309)	1.00 (0.3305)
EMP	2.37 (0.305)	0.68 (0.421)	0.50 (0.486)	0.36(0.5553)
LP	0.50 (0.775)	1.32 (0.267)	2.55 (0.126)	0.02 (0.8791)
RO	1.68 (0.43)	1.24(0.556)	0.68 (0.416)	0.03(0.8453)
		Textile		
ICT	2.55 (0.278)	0.05 (0.823)	0.10 (0.743)	0.03 (0.847)
EMP	1.30 (0.520)	0.71 (0.410)	0.02 (0.865)	0.06 (0.801)
LP	0.64 (0.722)	0.02 (0.870)	0.94(0.341)	0.01 (0.917)
RO	2.73 (0.387)	0.05 (0.821)	0.14 (0.711)	0.03 (0.858)
		Paper		
ICT	0.88 (0.643)	0.03 (0.860)	0.01 (0.988)	0.18 (0.832)
EMP	0.82 (0.660)	1.75 (0.207)	0.56 (0.579)	2.0 (0.173)
LP	0.96(0.616)	0.73 (0.501)	1.38 (0.276)	0.34 (0.712)
RO	1.34 (0.510)	0.22 (0.640)	0.52 (0.475)	0.00 (0.981)
		Rubber		
ICT	29.50 (0.000)***	1.46 (0.164)	0.37 (0.692)	0.08 (0.917)
EMP	1.93 (0.380)	0.00 (0.948)	0.28(0.601)	1.33(0.264)
LP	1.85 (0.395)	0.82(0.376)	0.00 (0.988)	0.31(0.583)
RO	1.01 (0.602)	0.39(0.541)	0.64 (0.431)	0.54 (0.470)

Note 1: ICT is the ICT intensity (%); LP is the labour productivity growth rate (%); EMP is growth rate of employment (%); RO is the real output growth rate (%). Note 2: J-B =Jarque-Bera; RESET=Ramsey Regression Specification Error Test; ARCH= Autoregressive Conditional Heteroskedastic; LM= Lagrange multiplier. Note 3: Figures in parenthesis are the P-values. Note 4: ** significant at 5% level; *** significant at 1% level.

Table B.7: Diagnostic test results for Panel C industries

Variables	Diagnostic test			
	J-B test	**Ramsey RESET**	**ARCH test**	**LM test**
Tobacco				
ICT	0.42(0.810)	0.00(0.953)	1.77(0.197)	1.10(0.306)
EMP	0.62(0.731)	1.31 (0.997)	1.08(0.309)	0.12(0.733)
LP	0.57(0.750)	5.16 (0.036)	5.16(0.036)	1.38(0.256)
RO	1.115(0.572)	0.00 (0.958)	0.83(0.371)	0.02(0.888)
Leather				
ICT	34.75 (0.000)***	1.65 (0.215)	0.14(0.705)	0.00(0.951)
EMP	2.99 (0.220)	1.41 (0.145)	0.22(0.636)	0.12(0.732)
LP	2.87(0.187)	0.03(0.862)	0.02(0.876)	0.02(0.886)
RO	1.34(0.132)	1.75(0.203)	0.05(0.815)	0.46(0.503)
Wearing apparel				
ICT	0.21(0.896)	0.88 (0.388)	0.19(0.823)	1.04(0.374)
EMP	1.944(0.378)	0.78(0.388)	2.43(0.480)	1.18(0.293)
LP	0.199(0.905)	0.07(0.944)	0.60(0.447)	0.17(0.678)
RO	1.901(0.386)	0.01 (0.909)	0.43(0.516)	0.43(0.517)
Wood				
ICT	3.33(0.189)	5.25 (0.035)**	0.01(0.919)	0.02(0.870)
EMP	0.05(0.974)	0.69 (0.416)	0.67(0.420)	0.53(0.476)
LP	1.28(0.524)	1.40(0.252)	0.20 (0.65)	0.02(0.878)
RO	1.98(0.369)	0.44(0.513)	0.31(0.731)	0.16(0.846)
Furniture				
ICT	2.74(0.254)	0.24(0.629)	0.54(0.467)	0.23(0.634)
EMP	1.36(0.506)	1.25(0.278)	0.67(0.419)	0.10(0.751)
LP	0.07(0.965)	0.01(0.920)	0.77(0.390)	0.91(0.351)
RO	0.31(0.853)	0.55(0.468)	0.43(0.516)	0.14(0.708)

Note 1: ICT is the ICT intensity (%); LP is the labour productivity growth rate (%); EMP is growth rate of employment (%); RO is the real output growth rate (%). Note 2: J-B =Jarque-Bera; RESET=Ramsey Regression Specification Error Test; ARCH= Autoregressive Conditional Heteroskedastic; LM= Lagrange multiplier. Note 3: Figures in parenthesis are the P-values. Note 4: ** significant at 5% level; *** significant at 1% level.

Table B.8: Bound test cointegration results for Panels B and C industries

Dependent variable	AIC lags	F-statistic	Is there cointegration?	ARDL or ECM?
Panel B industries				
Food				
EMP	1	7.23	Yes	ECM
LP	1	6.56	Yes	ECM
RO	1	4.83	Yes	ECM
Beverages				
EMP	2	5.87	Yes	ECM
LP	1	13.34	Yes	ECM
RO	1	23.65	Yes	ECM
Textile				
EMP	1	15.02	Yes	ECM
LP	1	6.39	Yes	ECM
RO	1	6.84	Yes	ECM
Paper				
EMP	2	20.61	Yes	ECM
LP	2	26.04	Yes	ECM
RO	1	18.60	Yes	ECM
Rubber				
EMP	1	9.17	Yes	ECM
LP	1	17.46	Yes	ECM
RO	1	16.46	Yes	ECM
Panel C industries				
Tobacco				
EMP	1	72.80	Yes	ECM
LP	1	367.37	Yes	ECM
RO	1	151.94	Yes	ECM
Wearing apparel				
EMP	1	11.21	Yes	ECM
LP	1	16.56	Yes	ECM
RO	1	19.99	Yes	ECM
Leather				
EMP	1	5.41	Yes	ECM
LP	1	5.05	Yes	ECM
RO	1	5.29	Yes	ECM
Wood				
EMP	1	3.26	Inconclusive	ARDL
LP	1	19.75	Yes	ECM
RO	2	16.14	Yes	ECM
Furniture				
EMP	1	10.34	Yes	ECM
LP	1	16.94	Yes	ECM
RO	1	5. 47	Yes	ECM
Critical values 10% 5% 1%		*I*(0) 2.37 2.79 3.65	*I*(1) 3.2 3.67 4.66	

Note: ICT=ICT intensity (%); LP=labour productivity growth rate (%); EMP= growth rate of employment (%).

Table B.9: Short-run and long-run effects for Panel B industries

Endogenous variable	Short-run effects				Long-run effects				ECT-1
	ICT	EMP	LP	RO	ICT	EMP	LP	RO	
Food									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	-0.20 (0.219)	-	0.11 (0.703)	0.613 (0.157)	0.94*** (0.000)	-	0.46*** (0.000)	0.72* (0.059)	-0.68*** (0.000)
LP	0.32 (0.136)	0.66 (0.227)	-	-1.38** (0.022)	0.89*** (0.000)	0.98 (0.467)	-	0.58* (0.087)	-0.35*** (0.000)
RO	0.10 (0.340)	0.34 (0.225)	0.42* (0.052)	-	0.80**(0.015)	0.33* (0.076)	0.85 (0.629)	-	-0.52*** (0.000)
Beverages									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	-0.37 (0.312)	-	0.27* (0.078)	-0.52* (0.089)	-0.44 (0.371)	-	-0.38* (0.050)	0.69* (0.095)	-0.86*** (0.000)
LP	0.34 (0.792)	0.15 (0.848)	-	-0.45 (0.670)	0.51*** (0.00)	0.94** (0.029)	-	1.26*** (0.002)	-1.39*** (0.000)
RO	-0.11 (0.756)	0.45* (0.077)	0.16 (0.286)	-	0.57* (0.077)	-0.320 (0.158)	0.29 ** (0.012)	-	-1.13*** (0.000)
Textile									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.35 (0.831)	-	0.08 (0.716)	-0.35 (0.317)	1.23 (0.167)	-	-0.98** (0.012)	-0.79 (0.243)	-0.57*** (0.000)
LP	1.27 (0.565)	0.27 (0.577)	-	-0.45 (0.333)	-0.51 (0.129)	1.33 * (0.075)	-	-0.79 (0.191)	-0.92*** (0.000)
RO	0.46 (0.671)	0.38 (0.123)	0.11 (0.465)	-	0.46*** (0.006)	0.42 (0.296)	0.16 (0.314)	-	-1.1*** (0.000)
Paper									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.90 (0.384)	-	-0.16 (0.620)	0.10 (0.826)	-0.07 (0.832)	-	0.76*** (0.000)	0.424 (0.133)	-1.18*** (0.000)
LP	-1.74 (0.240)	-0.32 (0.645)	-	0.21 (0.749)	0.77** (0.013)	-0.11 (0.732)	-	0.41 (0.113)	-1.7*** (0.000)
RO	0.103 (0.836)	-0.24 (0.437)	0.06 (0.772)	-	0.96*** (0.00)	0.41 (0.182)	0.615** (0.012)	-	-0.98 (0.000)
Rubber									
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.64 (0.116)	-	-0.11 (0.524)	0.40* (0.097)	-0.48 (0.305)	-	-.67*** (0.002)	0.76** (0.036)	-0.86*** (0.000)
LP	-0.85 (0.136)	-0.31 (0.463)	-	-0.53 (0.119)	0.56*** (0.000)	-0.611 (0.1358)	-	0.91*** (0.000)	-1.13*** (0.000)
RO	0.21 (0.749)	-0.21 (0.397)	0.04 (0.747)	-	0.54* (0.097)	0.60** (0.020)	0.60*** (0.000)	-	-1.23*** (0.000)

Note 1: ICT=ICT intensity (%); LP=labour productivity growth rate (%); EMP= growth rate of employment (%); RO =real output growth rate (%). Note 2: Figures in parenthesis are the P-values. Note 3: ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table B.10: Short-run and long-run effects for Panel C industries

Endogenous variable	Short-run effects				Long-run effects				ECT-1
	ICT	EMP	LP	RO	ICT	EMP	LP	RO	
					Tobacco				
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	-6.86 (0.471)	-	-0.19 (0.570)	0.24 (0.714)	0.81 (0.690)	-	-0.83*** (0.000)	1.01*** * (0.000)	-0.95*** (0.000)
LP	4.01 (0.719)	1.83*** (0.002)	-	-1.71** (0.038)	-1.13*** (0.000)	1.40 (0.546)	-	1.20*** (0.000)	-1.00*** (0.000)
RO	-1.13 (0.841)	0.89*** (0.003)	0.59*** (0.008)	-	0.27** (0.039)	-0.26 (0.874)	0.62*** (0.000)	-	-1.02*** (0.000)
					Wearing apparel				
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.31 (0.608)	-	0.06 (0.800)	-0.00 (0.988)	-0.031 (0.931)	-	-0.56*** (0.000)	0.83*** (0.009)	-0.93*** (0.000)
LP	-0.55 (0.628)	-0.15 (0.835)	-	-0.12 (0.766)	-1.52*** (0.000)	-0.020 (0.975)	-	1.18 *** (0.001)	-0.79*** (0.000)
RO	-0.32 (0.627)	0.10 (0.804)	-0.08 (0.767)	-	0.47*** (0.003)	-0.00 (0.994)	0.40*** (0.000)	-	-1.36*** (0.000)
					Leather				
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	0.66 (0.380)	-	-0.03 (0.756)	0.04 (0.887)	-0.08 (0.906)	-	-0.17** (0.022)	0.20 (0.443)	-0.98*** (0.000)
LP	-0.95 (0.666)	-0.43 (0.578)	-	-0.82 (0.364)	-1.79** (0.029)	-1.72 (0.448)	-	1.15 (0.242)	-0.83*** (0.000)
RO	-0.36 (0.487)	0.05 (0.779)	0.0 (0.477)	-	0.17 (0.460)	-0.47 (0.448)	0.008 (0.293)	-	-0.99*** (0.000)
					Wood				
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	-0.31 (0.356)	-	0.34 (0.264)	-0.02 (0.950)	-0.28 (0.662)		-0.59** (0.015)	0.18 (0.682)	-0.78*** (0.000)
LP	-0.89 (0.347)	0.21 (0.590)	-	-1.17 ** (0.020)	-0.98*** (0.001)	-0.66 (0.272)	-	-0.07 (0.85)	-0.82*** (0.000)
RO	0.49 (0.453)	0.47* (0.097)	0.370 (0.153)	-	0.37** (0.039)	-0.42 (0.364)	0.51* (0.080)	-	-0.40*** (0.000)
					Furniture				
ICT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
EMP	1.30 (0.163)	-	-0.18 (0.379)	0.76*** (0.009)	n/a	n/a	n/a	n/a	n/a
LP	-1.16 (0.422)	-0.63 (0.136)	-	-0.76 * (0.082)	-1.02 *** (0.008)	-0.51 (0.595)	-	0.74 (0.038)	-0.86*** (0.000)
RO	0.37 (0.690)	0.04 (0.873)	-0.04 (0.851)	-	0.40** (0.029)	1.27* (0.073)	0.47*** (0.002)	-	-0.92*** (0.000)

Note 1: ICT=ICT intensity (%); LP=labour productivity growth rate (%); EMP= growth rate of employment (%); RO =real output growth rate (%). Note 2: Figures in parenthesis are the P-values. Note 3: ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table B.11: DOLS long-run estimates for Panel of industries

Dependent variable	Long-run effects			
	ICT	**EMP**	**LP**	**RO**
Panel A: All agro-processing industries				
ICT	n/a	n/a	n/a	n/a
EMP	0.01 (0.610)	-	-0.32*** (0.000)	0.27** (0.039)
LP	0.00 (0.923)	-1.36*** (0.000)	-	0.82*** (0.003)
RO	0.00 (0.916)	0.18 (0.176)	0.08 (0.185)	-
Panel B: More ICT-intensive industries				
ICT	n/a	n/a	n/a	n/a
EMP	0.07* (0.086)	-	-0.72*** (0.000)	0.64*** (0.004)
LP	0.697* (0.06)	-0.73*** (0.000)	-	0.94*** (0.000)
RO	0.37** (0.042)	0.15 (0.371)	0.31** (0.022)	-
Panel C: Less ICT-intensive industries				
ICT	n/a	n/a	n/a	n/a
EMP	-0.31 (0.225)	-	-0.25*** (0.000)	0.29*** (0.095)
LP	0.01 (0.016)	-1.82*** (0.000)	-	0.72* (0.054)
RO	0.37 (0.117)	0.45** (0.018)	0.07 (0.329)	-

Note 1: ICT = ICT intensity (%); LP = labour productivity growth rate (%); EMP = growth rate of employment (%); RO = real output growth rate (%). Note 2: Figures in parenthesis are the P-values. Note 3: ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table B.12: DOLS long-run elasticities for Panel B industries

Dependent variable	Long-run effects			
	ICT	EMP	LP	RO
Food				
ICT	n/a	n/a	n/a	n/a
EMP	1.25*(0.050)	-	-0.31***(0.000)	0.23***(0.001)
LP	1.20*(0.070)	1.31***(0.000)	-	0.72***(0.003)
RO	0.97*(0.060)	0.08(0.474)	0.07(0.208)	-
Beverages				
ICT	n/a	n/a	n/a	n/a
EMP	0.87(0.451)	-	-1.20*(0.070)	2.03(0.169)
LP	1.6 (0.520)	-0.30(0.811)	-	4.22(0.198)
RO	0.01(0.982)	-0.27(0.419)	-0.08(0.782)	-
Textile				
ICT	n/a	n/a	n/a	n/a
EMP	-0.17 (0.611)	-	-0.08(0.534)	-0.11(0.770)
LP	0.75(0.303)	-0.19(0.743)	-	-0.17(0.843)
RO	0.01 (0.564)	0.47(0.472)	-0.23(0.586)	-
Paper				
ICT	n/a	n/a	n/a	n/a
EMP	0.10(0.874)	-	-0.47(0.270)	0.19(0.717)
LP	0.94**(0.058)	-0.68(0.587)	-	0.49(0.623)
RO	1.29*(0.060)	0.79(0.224)	0.81(0.156)	-
Rubber				
ICT	n/a	n/a	n/a	n/a
EMP	0.21(0.637)	-	-0.74 (0.196)	0.50(0.589)
LP	0.23***(0.001)	0.86(0.248)	-	2.41***(0.001)
RO	0.82*(0.067)	-0.98(0.162)	0.18(0.532)	-

Note 1: ICT = ICT intensity (%); LP = labour productivity growth rate (%); EMP = growth rate of employment (%); RO = real output growth rate (%). Note 2: Figures in parenthesis are the P-values. Note 3: ***, **, * indicate significance at 1%, 5% and 10%, respectively.

Table B.13: DOLS long-run elasticities for Panel C industries

Dependent variable	Long-run effects			
	ICT	**EMP**	**LP**	**RO**
Tobacco				
ICT	n/a	n/a	n/a	n/a
EMP	2.57(0.42)	-	-0.72***(0.000)	1.80**(0.015)
LP	3.79(0.306)	-1.21***(0.000)	-	2.47***(0.007)
RO	-1.46(0.530)	0.27(0.295)	0.20(0.309)	-
Wearing apparel				
ICT	n/a	n/a	n/a	n/a
EMP	-0.00 (0.9623)	-	-0.48***(0.000)	0.07(0.783)
LP	-0.55(0.6453)	1.35(0.118)	-	1.35(0.118)
RO	1.39(0.2119)	-0.02(0.981)	0.21(0.660)	-
Leather				
ICT	n/a	n/a	n/a	n/a
EMP	0.26(0.4021)	-	-0.08 (0.165)	-0.03(0.83)
LP	-6.69(0.266)	-2.05(0.601)	-	-0.76(0.69)
RO	-2.14(0.230)	-0.60(0.476)	-0.32(0.1693)	-
Wood				
ICT	n/a	n/a	n/a	n/a
EMP	-0.34(0.769)	-	-0.80(0.129)	0.09(0.871)
LP	-0.13(0.901)	-0.85(0.138)	-	-0.10(0.885)
RO	0.37(0.292)	0.67**(0.011)	-0.44*(0.083)	-
Furniture				
ICT	n/a	n/a	n/a	n/a
EMP	-0.60(0.709)	-	0.33(0.608)	0.66(0.180)
LP	-3.4(0.238)	-2.09(0.240)	-	1.76(0.156)
RO	0.08(0.770)	1.30***(0.000)	0.00(0.985)	-

Note 1: ICT = ICT intensity (%); LP = labour productivity growth rate (%); EMP = growth rate of employment (%); RO = real output growth rate (%). Note 2: Figures in parenthesis are the P-values. Note 3: ***, **, * indicate significance at 1%, 5% and 10%, respectively.

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APPENDIX C

Table C.1: VDC results for Panel of industries

Industry	Period	Endogenous variable: ICT			
		ICT	**EMP**	**LP**	**RO**
Panel A	**1**	100.0000	0.000000	0.000000	0.000000
	5	99.07570	0.119636	0.411551	0.393117
	10	99.06321	0.141047	0.549885	0.245862
	15	99.05940	0.148091	0.598578	0.193933
	20	99.05755	0.151543	0.622224	0.168687
		ICT	**EMP**	**LP**	**RO**
Panel B	**1**	100.0000	0.000000	0.000000	0.000000
	5	98.60497	0.366060	0.381088	0.647885
	10	98.67654	0.234395	0.425073	0.663989
	15	98.69507	0.186774	0.437474	0.680683
	20	98.70438	0.163493	0.443519	0.688607
		ICT	**EMP**	**LP**	**RO**
Panel C	**1**	100.0000	0.000000	0.000000	0.000000
	5	96.50434	0.896010	0.144151	2.455498
	10	96.40898	0.933088	0.155004	2.502923
	15	96.40833	0.933347	0.155081	2.503245
	20	96.40832	0.933348	0.155081	2.503247
Endogenous variable: EMP					
		ICT	**EMP**	**LP**	**RO**
Panel A	**1**	0.587730	99.41227	0.000000	0.000000
	5	0.669157	98.44007	0.440115	0.450654
	10	0.780586	98.32705	0.441747	0.450614
	15	0.864186	98.24353	0.442047	0.450235
	20	0.923376	98.18441	0.442250	0.449964
		ICT	**EMP**	**LP**	**RO**
Panel B	**1**	0.979831	99.02017	0.000000	0.000000
	5	2.252189	93.91185	1.964057	1.871900
	10	2.555161	93.60804	1.959739	1.877064
	15	2.804365	93.36540	1.955799	1.874436
	20	2.978350	93.19613	1.953132	1.872387
		ICT	**EMP**	**LP**	**RO**
Panel C	**1**	0.591109	99.40889	0.000000	0.000000
	5	0.728351	97.88947	0.566642	0.815538
	10	0.736782	97.87937	0.566981	0.816862
	15	0.736841	97.87931	0.566982	0.816869
	20	0.736841	97.87931	0.566982	0.816869
Endogenous variable: LP					
		ICT	**EMP**	**LP**	**RO**
Panel A	**1**	0.505490	28.34879	71.14572	0.000000
	5	0.510534	28.95456	64.78593	5.748968
	10	0.541516	28.94681	64.75773	5.753945
	15	0.567504	28.93920	64.74084	5.752451
	20	0.585832	28.93385	64.72894	5.751380
		ICT	**EMP**	**LP**	**RO**
Panel B	**1**	3.835279	35.91509	60.24963	0.000000
	5	3.801509	33.61287	54.91920	7.666417
	10	3.909849	33.58048	54.84995	7.659724
	15	3.916523	33.57809	54.84608	7.659307
	20	3.921344	33.57639	54.84331	7.658956
		ICT	**EMP**	**LP**	**RO**

Panel C	**1**	0.191810	27.57473	72.23346	0.000000
	5	0.552316	29.51432	66.17372	3.759640
	10	0.573108	29.50903	66.15576	3.762100
	15	0.573253	29.50899	66.15564	3.762111
	20	0.573254	29.50899	66.15564	3.762111
Endogenous variable: RO					
		ICT	**EMP**	**LP**	**RO**
Panel A	**1**	0.151119	0.947468	17.55970	81.34172
	5	0.552275	1.722754	16.59683	81.12814
	10	0.561038	1.724715	16.58973	81.12451
	15	0.561302	1.724716	16.58968	81.12430
	20	0.561460	1.724714	16.58965	81.12417
		ICT	**EMP**	**LP**	**RO**
Panel B	**1**	1.188316	2.573352	28.25050	67.98783
	5	3.625216	3.903210	25.21064	67.26093
	10	3.729780	3.901393	25.18517	67.18366
	15	3.741574	3.900951	25.18210	67.17538
	20	3.750099	3.900601	25.17988	67.16942
		ICT	**EMP**	**LP**	**RO**
Panel C	**1**	0.641616	0.298609	18.42137	80.63840
	5	0.656849	0.343231	18.91751	80.08241
	10	0.657214	0.343291	18.91744	80.08206
	15	0.657216	0.343291	18.91744	80.08206
	20	0.657217	0.343291	18.91744	80.08206

Table C.2: VDC results for Panel B industries

FOOD				
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	90.67428	4.114126	1.272312	3.939278
10	90.23262	4.396315	1.258868	4.112198
15	90.22727	4.403708	1.258202	4.110824
20	90.22685	4.404029	1.258204	4.110916
	Endogenous variable: EMP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	19.06159	80.93841	0.000000	0.000000
5	35.94202	55.30006	2.121557	6.636355
10	39.34388	51.64695	2.118532	6.890639
15	39.35726	51.63825	2.117346	6.887143
20	39.36341	51.63274	2.117308	6.886544
	Endogenous variable: LP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	33.34169	31.90513	20.35790	14.39528
5	33.34169	31.90513	20.35790	14.39528
10	38.65508	29.17661	18.24979	13.91852
15	38.68499	29.22378	18.19702	13.89421
20	38.69463	29.22070	18.19304	13.89163
	Endogenous variable: RO			
Period	**ICT**	**EMP**	**LP**	**RO**
1	29.91517	26.93908	23.99707	19.14868
5	32.40582	26.08981	22.79554	18.70883
10	32.40582	26.08981	22.79554	18.70883
15	32.49572	26.05813	22.75235	18.69381
20	32.49775	26.05733	22.75155	18.69337
BEVERAGES				
Period	**Endogenous variable: ICT**			
	ICT	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	83.89975	12.57163	0.650925	2.877698
10	83.86063	12.61546	0.650181	2.873729
15	83.86052	12.61558	0.650179	2.873717
20	83.86052	12.61558	0.650179	2.873717
	Endogenous variable: EMP			
	ICT	**EMP**	**LP**	**RO**
1	8.518852	91.48115	0.000000	0.000000
5	19.96838	75.86654	1.446045	2.719031
10	20.06314	75.77920	1.444497	2.713168
15	20.06339	75.77897	1.444489	2.713152
20	20.06339	75.77897	1.444489	2.713152
	Endogenous variable: LP			
	ICT	**EMP**	**LP**	**RO**
1	11.11231	10.44154	78.44615	0.000000
5	11.20660	9.608377	66.40780	12.77722
10	11.22114	9.608355	66.38620	12.78430
15	11.22116	9.608375	66.38616	12.78430
20	11.22116	9.608375	66.38616	12.78430
	Endogenous variable: RO			
	ICT	**EMP**	**LP**	**RO**

1	2.352513	0.395270	47.02218	50.23004
5	3.627873	0.479566	44.81546	51.07710
10	3.628956	0.480260	44.81756	51.07322
15	3.628957	0.480260	44.81756	51.07322
20	3.628957	0.480260	44.81756	51.07322
TEXTILE				
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	65.73313	11.45095	4.245666	18.57026
10	63.01964	11.93222	4.859630	20.18851
15	62.58873	12.00741	4.957014	20.44685
20	62.50358	12.02226	4.976257	20.49790
	Endogenous variable: EMP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	4.159175	95.84082	0.000000	0.000000
5	4.200770	87.76688	0.500469	7.531886
10	4.207622	87.75713	0.501382	7.533869
15	4.209026	87.75498	0.501578	7.534420
20	4.209317	87.75453	0.501618	7.534534
	Endogenous variable: LP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.010482	67.75895	32.23056	0.000000
5	2.978168	62.20276	27.90201	6.917071
10	4.051214	61.15996	27.45569	7.333140
15	4.268224	60.94772	27.36514	7.418922
20	4.313076	60.90385	27.34642	7.436652
	Endogenous variable: RO			
Period	**ICT**	**EMP**	**LP**	**RO**
1	1.138097	0.273019	0.283876	98.30501
5	5.820389	9.134389	0.985955	84.05927
10	6.857011	9.233368	1.124934	82.78469
15	7.066720	9.254188	1.152999	82.52609
20	7.110057	9.258491	1.158799	82.47265
PAPER				
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	65.47273	30.32442	1.368751	2.834100
10	65.45813	30.40469	1.388540	2.748645
15	65.09727	30.77509	1.398583	2.729057
20	65.06102	30.81259	1.399915	2.726484
	Endogenous variable: EMP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.033172	99.96683	0.000000	0.000000
5	11.56288	77.95033	0.603178	9.883612
10	16.21411	73.60664	0.986191	9.193065
15	16.63569	73.24424	0.986715	9.133355
20	16.65370	73.23231	0.987392	9.126594
	Endogenous variable: LP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	7.959924	66.62766	25.41241	0.000000
5	14.14958	57.59121	24.06179	4.197414
10	15.14329	57.23593	23.53587	4.084914
15	15.33156	57.12594	23.46573	4.076778

20	15.34027	57.12643	23.45766	4.075636
	Endogenous variable: RO			
Period	**ICT**	**EMP**	**LP**	**RO**
1	53.73740	0.072677	20.90879	25.28114
5	45.36812	15.60734	15.68094	23.34359
10	45.28266	15.76255	15.68484	23.26994
15	45.28108	15.76445	15.68243	23.27204
20	45.28055	15.76577	15.68216	23.27152
RUBBER				
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	96.50434	0.896010	0.144151	2.455498
10	96.40898	0.933088	0.155004	2.502923
15	96.40833	0.933347	0.155081	2.503245
20	96.40832	0.933348	0.155081	2.503247
	Endogenous variable: EMP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.591109	99.40889	0.000000	0.000000
5	0.728351	97.88947	0.566642	0.815538
10	0.736782	97.87937	0.566981	0.816862
15	0.736841	97.87931	0.566982	0.816869
20	0.736841	97.87931	0.566982	0.816869
	Endogenous variable: LP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.191810	27.57473	72.23346	0.000000
5	0.552316	29.51432	66.17372	3.759640
10	0.573108	29.50903	66.15576	3.762100
15	0.573253	29.50899	66.15564	3.762111
20	0.573254	29.50899	66.15564	3.762111
	Endogenous variable: RO			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.641616	0.298609	18.42137	80.63840
5	0.656849	0.343231	18.91751	80.08241
10	0.657214	0.343291	18.91744	80.08206
15	0.657216	0.343291	18.91744	80.08206
20	0.657217	0.343291	18.91744	80.08206

Table C.3: VDC results for Panel C industries

TOBACCO				
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	83.33909	1.784144	1.466327	13.41044
10	83.21700	1.822937	1.469640	13.49043
15	83.21562	1.823633	1.469589	13.49116
20	83.21559	1.823647	1.469588	13.49118
	Endogenous variable: EMP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.556453	99.44355	0.000000	0.000000
5	3.268582	93.25622	0.034976	3.440221
10	3.399853	93.09507	0.038134	3.466947
15	3.402428	93.09205	0.038177	3.467343
20	3.402478	93.09199	0.038178	3.467351
	Endogenous variable: LP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.096692	67.36824	32.53507	0.000000
5	2.520464	52.72140	26.44044	18.31770
10	2.620592	52.62582	26.39941	18.35418
15	2.622668	52.62453	26.39875	18.35406
20	2.622708	52.62450	26.39873	18.35405
	Endogenous variable: RO			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.420908	2.605095	69.29936	27.67464
5	0.445486	4.185661	52.39537	42.97349
10	0.451175	4.183631	52.36925	42.99595
15	0.451253	4.183630	52.36917	42.99595
20	0.451254	4.183630	52.36917	42.99595
WEARING APPAREL				
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	51.04578	11.16114	20.49475	17.29834
10	49.73045	13.59048	20.27965	16.39942
15	49.56990	13.59529	20.44672	16.38808
20	49.55912	13.59558	20.46028	16.38503
	Endogenous variable: EMP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	16.15241	83.84759	0.000000	0.000000
5	17.05307	57.33111	23.15814	2.457679
10	15.67076	52.86901	28.07117	3.389058
15	15.53322	52.17243	28.83728	3.457066
20	15.50944	52.10244	28.92762	3.460498
	Endogenous variable: LP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	12.20271	44.86227	42.93502	0.000000
5	11.28765	32.71010	53.00684	2.995417
10	9.890707	29.17462	57.37562	3.559053
15	9.779026	28.69319	57.89232	3.635467
20	9.755071	28.64241	57.96098	3.641536
	Endogenous variable: RO			
Period	**ICT**	**EMP**	**LP**	**RO**

1	0.138892	4.680988	45.74675	49.43337
5	0.638370	11.60362	38.25514	49.50287
10	0.788628	11.41822	39.36625	48.42690
15	0.796853	11.41230	39.46913	48.32173
20	0.796906	11.41226	39.48613	48.30471
	LEATHER			
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	91.13398	2.442882	1.351360	5.071773
10	91.12628	2.445238	1.353769	5.074708
15	91.12628	2.445239	1.353769	5.074709
20	91.12628	2.445239	1.353769	5.074709
	Endogenous variable: EMP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	0.214830	99.78517	0.000000	0.000000
5	0.214830	99.78517	0.000000	0.000000
10	7.255039	92.11889	0.137902	0.488170
15	7.255040	92.11889	0.137902	0.488170
20	7.255040	92.11889	0.137902	0.488170
	Endogenous variable: LP			
Period	**ICT**	**EMP**	**LP**	**RO**
1	3.509557	21.92817	74.56228	0.000000
5	9.591890	24.21778	61.59222	4.598116
10	9.594435	24.21763	61.58436	4.603577
15	9.594436	24.21763	61.58436	4.603578
20	9.594436	24.21763	61.58436	4.603578
	Endogenous variable: RO			
Period	**ICT**	**EMP**	**LP**	**RO**
1	6.507920	0.702014	6.704514	86.08555
5	7.639261	2.137434	11.01414	79.20917
10	7.639267	2.137463	11.01413	79.20914
15	7.639267	2.137463	11.01413	79.20914
20	7.639267	2.137463	11.01413	79.20914
	WOOD			
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	95.14793	3.350604	0.807559	0.693907
10	95.13678	3.349601	0.807786	0.705834
15	95.13678	3.349601	0.807786	0.705838
20	95.13678	3.349601	0.807786	0.705838
	Endogenous variable: EMP			
	ICT	**EMP**	**LP**	**RO**
1	0.116066	99.88393	0.000000	0.000000
5	1.711412	95.67950	1.605629	1.003455
10	1.711748	95.67837	1.605644	1.004235
15	1.711748	95.67837	1.605644	1.004235
20	1.711748	95.67837	1.605644	1.004235
	Endogenous variable: LP			
	ICT	**EMP**	**LP**	**RO**
1	15.48619	35.77845	48.73536	0.000000
5	10.12958	31.02318	34.72787	24.11936
10	10.13057	31.02216	34.72689	24.12038
15	10.13057	31.02216	34.72689	24.12038

20	10.13057	31.02216	34.72689	24.12038
	Endogenous variable: RO			
	ICT	**EMP**	**LP**	**RO**
1	13.88205	18.55663	22.60757	44.95375
5	13.57178	18.01343	22.60945	45.80534
10	13.57269	18.01310	22.60928	45.80492
15	13.57269	18.01310	22.60928	45.80492
20	13.57269	18.01310	22.60928	45.80492
FURNITURE				
	Endogenous variable: ICT			
Period	**ICT**	**EMP**	**LP**	**RO**
1	100.0000	0.000000	0.000000	0.000000
5	95.55949	0.997169	3.268455	0.174886
10	95.53545	1.013591	3.265384	0.185576
15	95.53531	1.013679	3.265357	0.185657
20	95.53531	1.013679	3.265357	0.185658
	Endogenous variable: EMP			
	ICT	**EMP**	**LP**	**RO**
1	7.263916	92.73608	0.000000	0.000000
5	13.11004	57.32506	11.12077	18.44413
10	13.36634	57.11738	11.08074	18.43555
15	13.36781	57.11638	11.08051	18.43530
20	13.36782	57.11637	11.08051	18.43530
	Endogenous variable: LP			
	ICT	**EMP**	**LP**	**RO**
1	6.481762	27.55241	65.96582	0.000000
5	8.953192	24.69073	60.49369	5.862387
10	9.059525	24.66332	60.40068	5.876475
15	9.060143	24.66321	60.40016	5.876488
20	9.060147	24.66321	60.40016	5.876488
	Endogenous variable: RO			
	ICT	**EMP**	**LP**	**RO**
1	13.16313	0.724595	28.32091	57.79136
5	17.90209	8.804905	23.84689	49.44612
10	18.08579	8.830138	23.77655	49.30752
15	18.08703	8.830141	23.77609	49.30673
20	18.08704	8.830141	23.77609	49.30673

APPENDIX D

Impulse response functions

Figure D.1: IRFs for Panels A

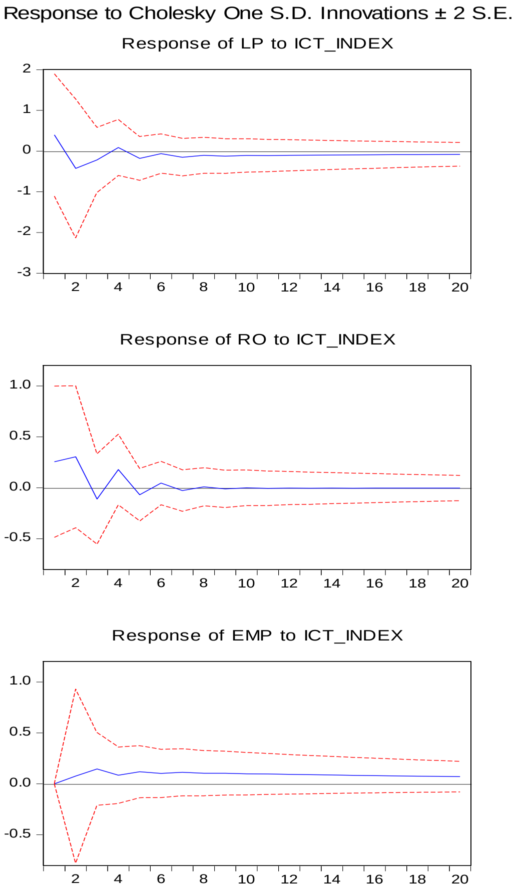

Figure D.2: IRFs for Panels B

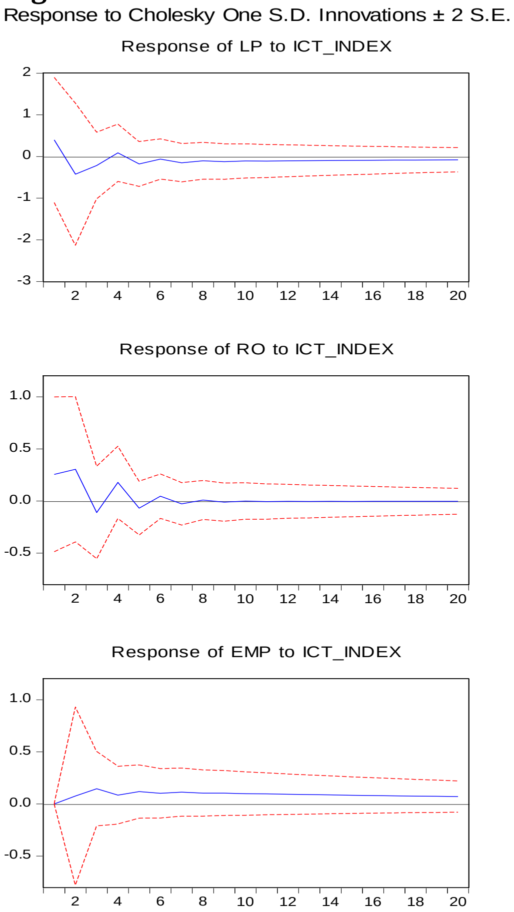

Figure D.3: IRFs for Panels C

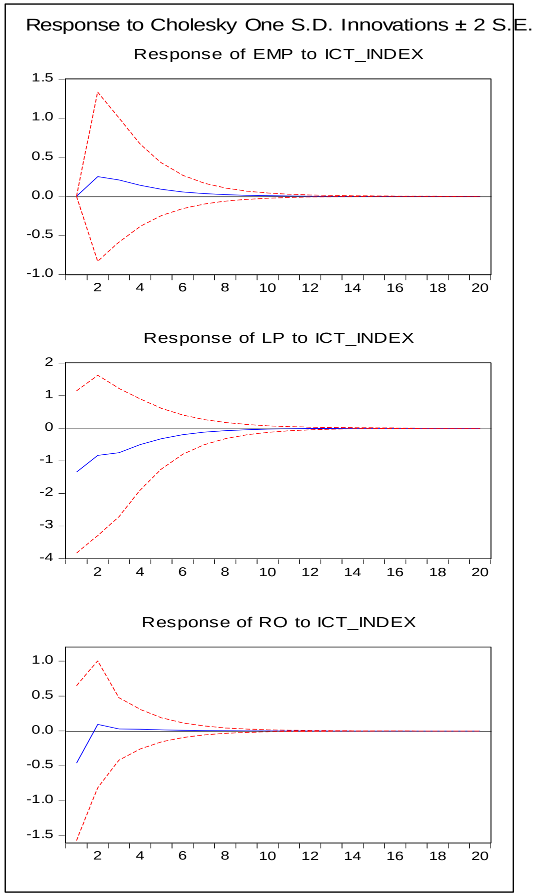

Figure D.4: IRFs for food

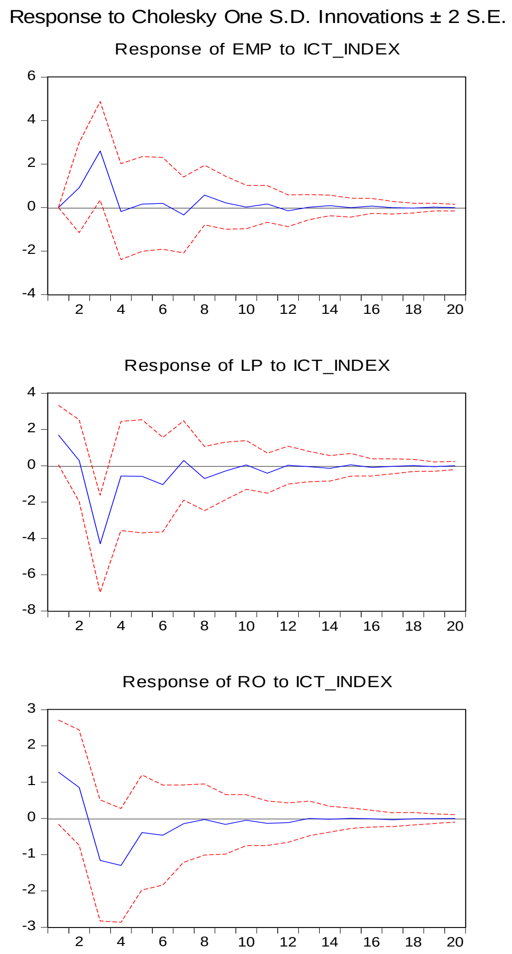

Figure D.5: IRFs for beverages

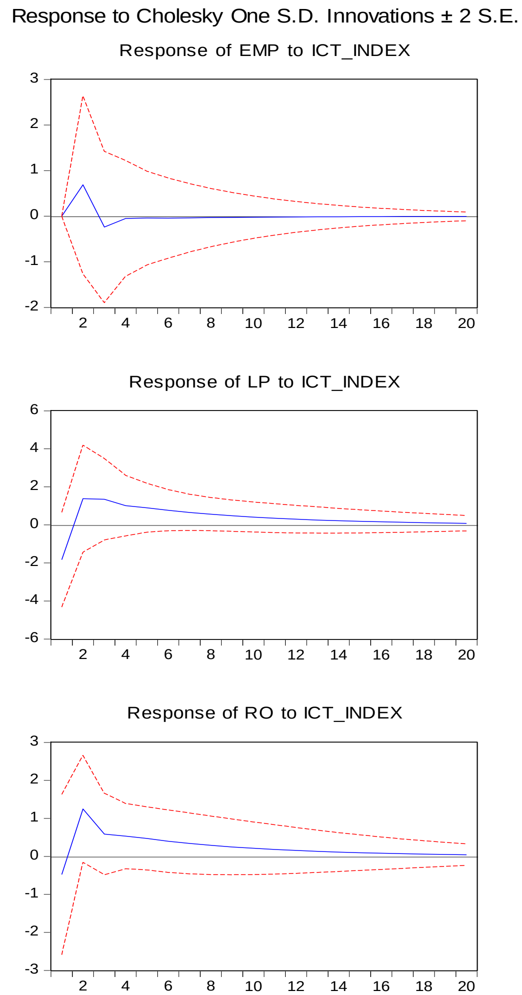

Figure D.6: IRFs for textile

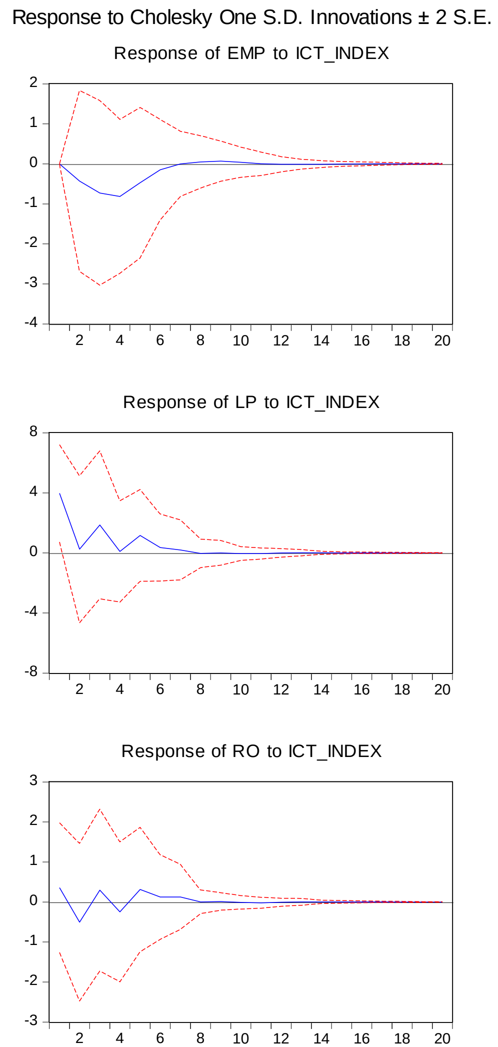

Figure D.7: IRFs for paper

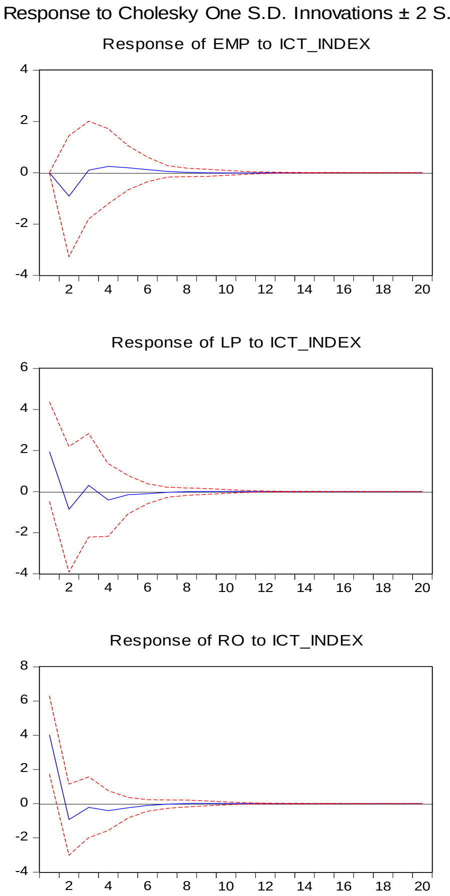

Figure D.8: IRFs for rubber

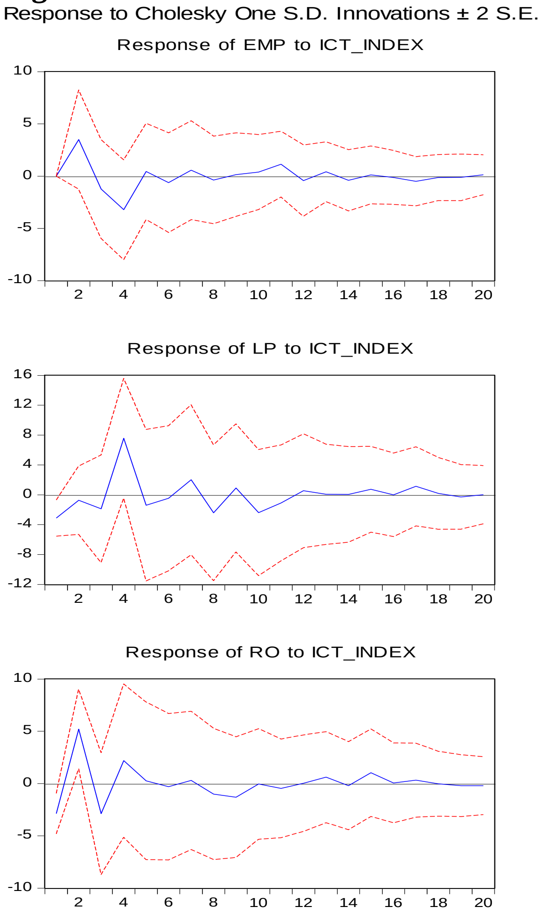

Figure D.9: IRFs for tobacco

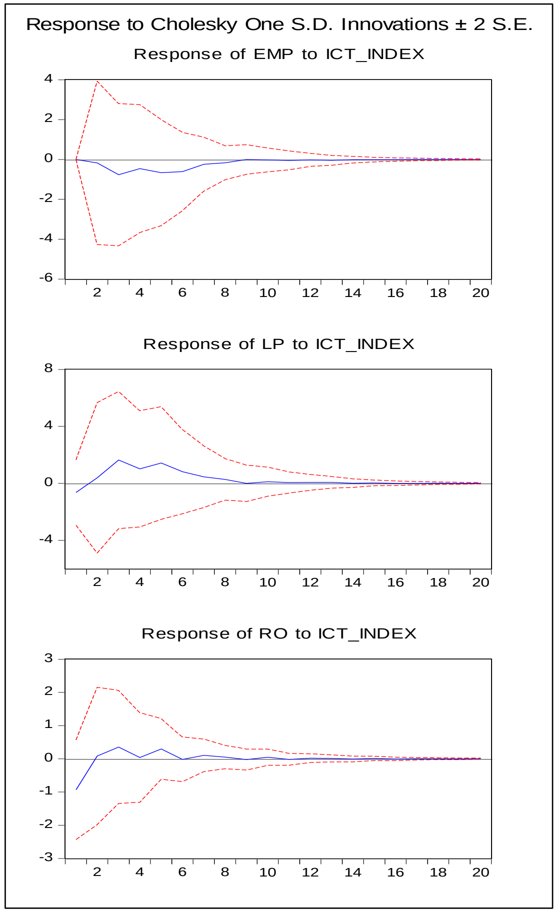

Figure D.10: IRFs for wearing apparel

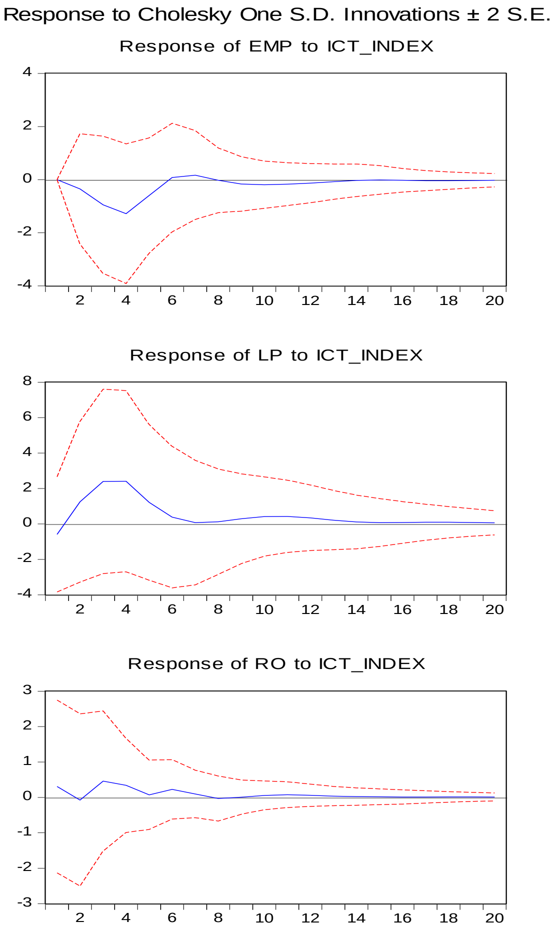

Figure D.11: IRFs for leather

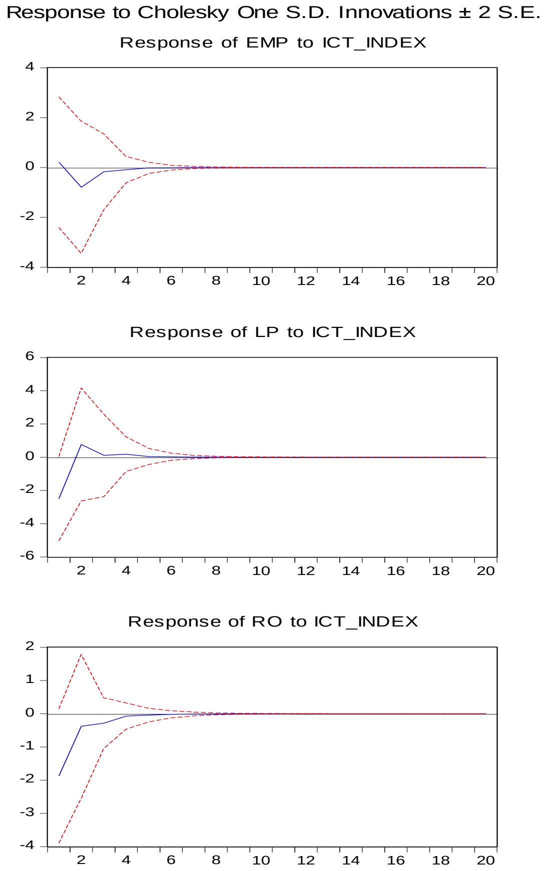

Figure D.12: IRFs for wood

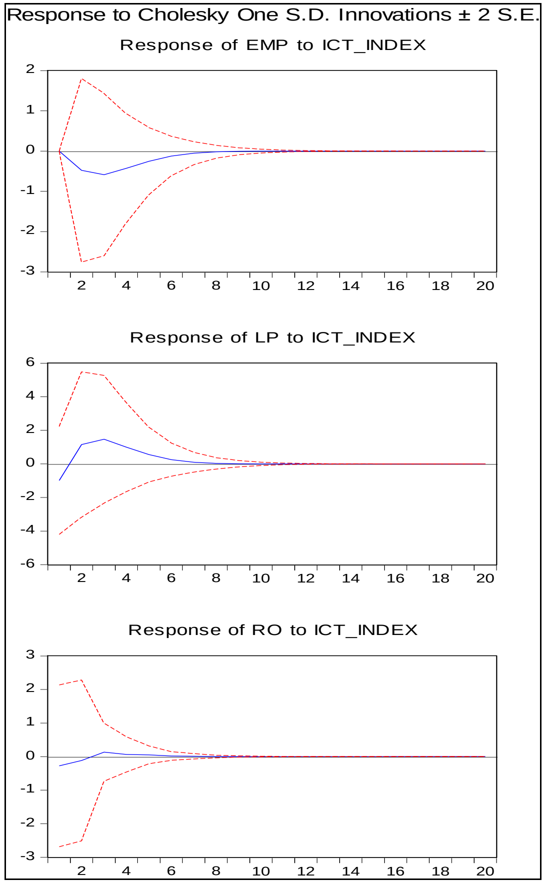

Figure D.13: IRFs for furniture