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Estimating effects of information and communication technology (ICT) on productivity of manufacturing industries in South Africa

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Abstract:

The paper serves to examine whether the growth in labour productivity (LP) in the manufacturing sector following policy reforms after democracy can be attributed to ICT. To achieve this, we examine the link between ICT intensity and LP growth of 23 manufacturing industries for the period 1970-2016 and sub-periods 1970-1995 and 1996-2016. The industries are disaggregated into two groups which are namely 'more ICT intensive' and 'less ICT intensive' using the ICT intensity index. Four dummy variable regression models are applied to test for the relationship between ICT intensity of industries and LP growth. The findings suggest that LP growth of more ICT intensive industries accelerated more than that of their counterparts. The results underscore the need for policy measures to increase ICT use with the aim of improving LP performance of industries.

Keywords: ICT intensity, LP growth, manufacturing industries

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ESTIMATING EFFECTS OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) ON PRODUCTIVITY OF MANUFACTURING INDUSTRIES IN SOUTH AFRICA

1. INTRODUCTION

South Africa is leapfrogging behind comparator countries in the BRICS grouping with respect to total factor productivity (TFP) (World Bank, 2017). Yet, Information and communication technology (ICT) has been, and continues to be credited for its potential to resuscitate productivity. To be specific, the resurgence in productivity performance and growth in the US and other OECD countries in the 1990s has been attributed to both the expansion in the production of ICT and use by other economic sectors (Stiroh, 2002; Strauss and Samkharadze, 2011; Bloom *et al*., 2012). Despite this, there is unclear empirical evidence on the contribution of ICT to the productivity performance of developing countries (Niebel and Mannheim, 2014).

Domestically, empirical evidence by Rankin (2018) indicates that labour productivity in the manufacturing sector grew substantially in the first twenty years of democracy. On this basis, the key question that this paper attempts to answer is: can this growth in labour productivity in the manufacturing sector be linked to ICT? Posing this question is imperative provided that South Africa's ICT sector underwent major policy reviews following democracy in 1994, resulting in various ICT policy frameworks[1] (DTPS, 2014). In view of this, this paper strives to provide empirical evidence on whether these policies contributed to the labour productivity growth in the manufacturing sector.

In empirical analysis, ICT contributes to productivity and economic growth in three ways. First, it increases multi-factor productivity (MFP), or labour and capital productivity in the ICT producing sector. Second, it contributes to capital deepening through productivity gains generated from the use of ICT as capital input in the non-ICT sectors. Third, greater use of ICT throughout the economy contributes to economy-wide total factor productivity (TFP) (van Ark, 2003; Piatkowski, 2004; Farooquie *et al*., 2012; Mefteh and Benhassen, 2015). Thus, ICT contributes directly to the growth of ICT producing industries and indirectly to the productivity growth of non-ICT industries (Abri and Mahmoudzadeh, 2014).

With respect to the levels of analysis, aggregate studies commonly apply the standard growth accounting and regression frameworks to explain the impact of ICT on productivity (Jorgenson and Stiroh, 1996a; Niebel *et al*., 2013; Relich, 2017). An important of note is that most of these studies found a negative or zero impact of ICT on productivity. However, empirical evidence from Stiroh (2002a), Engelbrecht and Xayavong (2006), Abri and Mahmoudzadeh (2014) and Corrado *et al*., (2017) proved

[1] These frameworks include the Telecommunications Act No. 103 of 1996, the Postal Service Act No. 124 of 1998 and the Broadcasting Act No. 4 of 1999

that productivity growth varies according to the extent to which industries use ICT (i.e. ICT intensity).

Previous researchers have outlined reasons why aggregate studies that employed growth accounting and regression models found negative or zero impact of ICT. First, employing growth accounting model cannot provide a deeper explanation of which part of productivity growth can be associated with the network effects of technology (i.e. productivity effects from the use of ICT in the non-ICT sectors) (Stiroh, 2002a; van Ark, 2014). Second, the neoclassical assumptions of constant returns to scale and competitive markets underlying the growth accounting model do not hold and as such the model provides poor estimates of the true relationship between ICT and productivity (Stiroh, 2002b; Engelbrecht and Xayavong, 2006). Third, the growth accounting model does not account for variations in ICT intensity among industries. Based on Stiroh (2002a), by focusing on the aggregate level, studies miss out on the part of the productivity as, in reality, the degree of ICT use and hence productivity growth differs immensely across industries.

To avoid problems associated with these models, we follow methods by Stiroh (2002a), Ark *et al*., (2002), Engelbrecht and Xayavong (2006) and Abri and Mahmoudzadeh (2014) of examining variations in productivity growth across industries. We rank industries with respect to their ICT intensity (i.e. more ICT-intensive and less ICT intensive) using the ICT intensity index developed by Engelbrecht and Xayavong (2006). Disaggregation of industries into intensity clusters is essential as, in many cases; it is not ICT productivity growth per se, but rather the relative productivity performance of more ICT against less ICT intensive industries that embodies the beneficial productivity effects of ICT (Engelbrecht and Xayavong, 2006). We further disaggregate industries into ICT producing and ICT using groups. As per Stiroh (2002a), by examining the relationship between ICT intensity and variation in productivity growth of ICT producing and ICT using industries over time, we can better understand the source of productivity growth.

The rest of the paper is structured as follows. Section 2 discusses the definition and measurement of productivity and literature on the impact of ICT on productivity. Section 3 presents the process and methods of classifying industries by ICT intensity index. The empirical models, variables and parameters of estimates are also described in Section 3. Section 4 presents both the descriptive and empirical results. Section 5 concludes the paper and highlights key implications.

2. REVIEW OF LITERATURE

2.1. Definition and measurement of productivity

An industry's productivity is defined as the efficient use of resources such as land, labour, capital, energy, materials, information and so forth in the production of various goods and services. From this perspective, higher productivity can be attained through production of more output in terms of quantity with the same amount of resources. Therefore, mathematically, productivity is measured as the ratio of output to all inputs used in the production process as follows:

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

Where P= Productivity; Y=Output; X= Inputs

Three types of productivity can be used: (1) productivity with respect labour (i.e. labour productivity), (2) productivity with respect to capital (i.e. capital productivity) and (3) productivity with respect to all inputs (i.e. total factor productivity). The precise measure of productivity is total factor productivity since it accounts for all inputs affecting productivity. However, it is practically difficult to measure total factor productivity due to the problem of determining weights which would reflect scarcity prices of all inputs. In view of this, statisticians have replaced the term “total factor productivity” with “multi-factor productivity” (i.e. output per weighted average of labour and capital inputs) given that other variables are usually excluded in calculating total factor productivity. Using multi-factor productivity as a measure of productivity is crucial for investment purposes since productivity from labour side determines industries’ profitability of using additional labour. At the same time, given the scarcity of capital relative to labour, investment decisions are more likely to be driven by relative productivity of capital in various industries (Sriyani Dias, 1991).

For the purpose of this study, labour productivity is used as a proxy for productivity due to both the economic and technical reasons. Economically, labour productivity is preferred given South Africa’s sluggish growth and high unemployment rate as follows:

- Labour productivity drives economic growth in that a highly productive economy means more outputs are produced with the same amount of resource or the same level of outputs are produced with less resources.
- Increased productivity can results in higher wages and better working conditions for workers. Therefore, workers benefit if increased productivity leads to higher wages.
- Increased labour productivity generates higher profit and creates investment opportunities for firms.
- In the longer term increased productivity increases employment. Increased employment translates to higher tax revenues for government (ILO, 2015).

Technically, labour productivity is preferred for the following technical reasons (Stiroh, 2002a):

- The use of ICT has an effect on labour productivity through the traditional capital deepening effects. Within this vein, ICT is viewed as an intermediate input that firms invest in to raise the productivity of labour.

- The data required to estimate labour productivity growth as well as other measure of labour input are available than data required to correctly measure total factor productivity.

Theoretically and empirically, labour productivity can be measured using either gross output or value added. In this study, we define labour productivity as gross output per hours worked instead of value added following empirical studies by Basu and Fernald (1995, 1997a, 1997b) which showed that value added data results in biased estimates and incorrect inferences regarding production parameters (Stiroh, 2002a).

2.2 Impact of ICT on productivity

The role of ICT in improving productivity is highly acknowledged in literature. Greater use of information increases productivity of knowledge workers, which drives overall efficiency of firms, and thus raises economic growth (Moradi and Kebryaee, 2005). Moreover, ICT use increases labour productivity and efficiency since existing services and activities become more convenient or quicker and cheaper (OECD, 2016; World Bank, 2016). Despite the productivity gains associated with ICT, empirical evidence suggests that the positive link between ICT and productivity is not clear-cut (Kijek and Kijek, 2018).

The limited or no evidence of the positive effects of ICT on productivity is referred to as “productivity paradox”. The term was coined by Solow (1987) to explain limited evidence on the positive effects of ICT. It stems from the evidence that researchers found little proof that ICT significantly contributed to productivity in the US in the 1970s and 1980s. Consequently, various explanations have been put forward to explain productivity paradox at the firm, industrial and aggregate levels. The summary of previous studies on the impact of ICT on productivity is presented in Table 1 of Annexure A.

Kijek and Kijek (2018) provide a summary of previous studies on the impact of ICT and productivity at the firm level. The most conclusive points from these studies are that the earlier studies found either negative or no significant relation between ICT and productivity (Yosri, 1992; Berndt and Morrison, 1995 Loveman, 1996). On the contrary, the latter studies have found evidence of a positive relationship (Stare *et al*., 2006; Arvanitis and Loukis, 2009). As per, Kijek and Kijek (2018), the reason for divergent results is that earlier studies focused mainly on a direct relationship between ICT and productivity, neglecting the indirect effects of ICT.

Stiroh (2002a) added that, as with the firm level studies, earlier studies focusing on aggregate level found no significant impact (Oliner and Sichel, 1996; Jorgenson and Stiroh, 1995; 1999), while industry-level studies found significant impact (Steindel, 1992; Brynjolfsson and Hitt, 1995; Lichtenberg, 1995). Stiroh suggests that the reason for this is that productivity impact could not be observable due to aggregation of both the more ICT-intensive and less ICT-intensive industries at the aggregate level. This assertion is validated by empirical study by McGuckin and Stiroh (2002) which found the estimated elasticity of computers to be high when industries were disaggregated. Thus, the disaggregation of industries according to ICT intensity allows us to identify the differential impacts of ICT across industries with varying intensities of ICT use (Chen *et al*., 2014).

Therefore, regardless of the level of analysis, the disaggregation of industries according to their ICT intensity is crucial in identifying the source of productivity growth. This is affirmed by empirical evidence from Stiroh (2002) which proved that non-ICT intensive industries made no contribution to aggregate productivity in the U.S after 1995, while aggregate productivity originated in those industries that either use or produce ICT most intensively. While it is clear that ICT contributes to productivity, Stiroh (2002) alerts that ICT per se is not the key driver of the great disparities in productivity growth across industries. As an example, firm level evidence from Bresnahan *et al*., (1996) and Brynjolsson and Hitt (1996; 2003) affirmed that investment in ICT alone is not likely to yield a large impact on productivity. From this perspective, productivity gains from ICT can only be fully realised through complementary factors such as favourable regulatory environment, adaptation of workers' skills to the demands of the new economy, the ability of firms effectively use ICT (Edquist, 2005; Yousefi, 2015; World Bank, 2016).

3. RESEARCH METHODS

3.1 Classification of industries by ICT intensity

Various indexes have been developed to rank industries and underlie the impact of ICT on productivity growth. The most common indexes entail grouping of industries into "more ICT intensive" and "less ICT intensive" based on industries' share of ICT capital services (Stiroh, 2002a), industries' direct requirement for ICT (Engelbrecht and Xayavong, 2006) and industries' investment in ICT (Abri and Mahmoudzadeh, 2014). In all cases, the industries ranking below the median value of the index are ranked as "less ICT intensive" while those above are ranked as "more ICT intensive". The indexes by Stiroh (2002a) and Abri and Mahmoudzadeh (2014) require data on ICT capital stock. However, ICT capital stock variable is not available and hence those indexes cannot be adopted for current analysis.

In view of this, we adopt Engelbrecht and Xayavong (2006)'s method of ranking industries into "more ICT-intensive" and "less ICT-intensive" based on their direct requirements of ICT inputs using Input-Output (I-O) data sourced from Quantec. The I-O data is used due to its ability to account for the nature of ICTs produced by the ICT sector and used by various industries. Thus, using I-O data is critical for segregation of industries into "ICT producing" and "ICT using" groups. Within this vein, it is assumed that innovation firstly occurs in the ICT producing sector and later spreads to other sectors (ICT using sectors) (Abri and Mahmoudzadeh, 2014). Therefore, productivity effects are firstly realised by few industries, particularly producers of those new technologies in the ICT sector. Afterwards, effects become more noticeable in other industries when innovations mushroom across the economy (van Ark, 2014).

In measuring the ICT intensity of industries, we calculated the direct requirements of ICT inputs for each industry (measured in million rand (ZAR)), using I-O data for 23 manufacturing industries for the period 1996. Following, Engelbrecht and Xayavong (2006), the ICT intensity index for industry j's (I_j) is defined as industry j's requirements for ICT intermediate inputs to total requirements by all the 23 manufacturing industries for ICT inputs expressed as follows:

$$I_j = \frac{(\sum_{j=1}^{n} ict_j^*)}{Tj}$$

3.3 Empirical models

Differences-in-Differences (DD) estimation is applied in this paper to estimate the casual relationship between ICT and labour productivity. DD estimation requires two sets of data: the treatment and control groups. For this reason, the more ICT intensive industries are the treatment group while the less ICT intensive industries are the control group. Our time series data comprises of labour productivity for the 23 industries from the period 1970 to 2016, sourced from Quantec. To control for systematic differences between the two groups, we divided our data into two sub-periods: 1970 to 1995 and 1996 to 2016. Thus, the former sub-period accounts for pre-policies era while the latter sub-period represents post-policy era. The rationale for delineating the sub-periods in this way is because various ICT policy frameworks were introduced in the second half of the 1990s (i.e. from 1996) following democracy in South Africa in 1994. Thus, this paper strives to evaluate whether those policies contributed to the labour productivity growth in the manufacturing sector. Consequently, the sample is broken down as follows:

(1) The less ICT intensive industries pre-1996;

(2) The less ICT intensive industries post-1996;

(3) The high ICT intensive industries pre-1996; and

(4) The high ICT intensive industries post-1996.

The ICT intensity of industries is calculated using the I-O data for 23 manufacturing industries for the period 1996. After grouping of industries, we apply similar methodology as Engelbrecht and Xayavong (2006) to calculate labour productivity growth rates for each industry. Afterwards, industries are categorised as more ICT intensive and less ICT intensive using the ICT intensity index.

Moreover, we further extend our analysis to agro-processing industries by assessing the productivity growth of more ICT intensive against less ICT intensive agro-processing industries. Lastly, we estimate four dummy variable regression models as follows (Engelbrecht and Xayavong, 2006):

$$dLnP_{i,t} = \alpha_0 + \alpha_1 D + \varepsilon_{i,t}, \tag{1}$$

$$dLnP_{i,t} = \beta_{L0} + \beta L_1 ICT_L + \varepsilon_{i,t}, \tag{2}$$

$$dLnP_{i,t} = \beta_{M0} + \beta_{M1} ICT_M + \varepsilon_{i,t}, \tag{3}$$

$$dLnP_{i,t} = \delta_0 + \delta_1 D + \delta_2 ICT + \delta_3 D.ICT + X\text{'s} + \varepsilon_{i,t}, \tag{4}$$

The first model is used to examine growth rate of productivity pre-and post-1996. Model two distinguishes the growth rate of productivity of the less ICT-intensive industries pre and post-1996. Model three distinguishes the growth rate of productivity of the more ICT intensive industries pre and post-1996. Model four statistically tests for the effect of ICT on productivity growth industries pre-and post-1996. The description of variables and parameters is presented in Table 2.

Table 2: Description of variables and parameters

Variable	Description
i,t	i= 1, 2……23 industries; t= t = 1,. . ., 46, indexes the annual observations over the period 1970-2016
LP	Labour productivity
$dlnP_{i,t}$	Annual growth rate of productivity (LP) of industry i
D	Dummy variable where D=1 if t ≥1996 and D = 0 otherwise
ICT_L	ICT intensity for the less ICT intensive industries
ICT_M	ICT intensity for the less ICT intensive industries
ICT	Dummy variable equals 1 if the industry is more ICT intensive and 0 otherwise.
α_0	Mean growth rate of LP, pre-1996
$\alpha_0 + \alpha_1$	Mean growth rate of LP, post-1996
α_1	Change in mean growth rate of LP post-1996
β_{L0}	Mean growth rate of LP for less ICT intensive industries, pre-1996
$\beta_{L0} + \beta_{L1}$	Mean growth rate of LP for less ICT intensive industries, post-1996
β_1	Change in mean growth rate of LP for more ICT intensive industries, post-1996
B_{M0}	Mean growth rate of LP for more ICT intensive industries, pre-1996
$B_{M0} + \beta_{M1}$	Mean growth rate of LP for more ICT intensive industries, post-1996

β_{M1}	Change in mean growth rate of LP for more ICT intensive industries, post-1996
δ_0	Mean growth rate of LP for less ICT intensive industries, pre-1996.
$\delta_0+\delta_1$	Mean growth rate of LP for less ICT intensive industries, post-1996.
δ_1	Acceleration of LP for less ICT intensive industries, post-1996.
$\delta_0+\delta_2$	Mean growth rate of LP for more ICT intensive industries, pre-1996.
$\delta_0+\delta_2+\delta_1+\delta_3$	Mean growth rate of LP for more ICT intensive industries, post-1996.
$\delta_1+\delta_3$	Acceleration of LP for more ICT intensive industries, post-1996
δ_3	Differential acceleration (i.e., difference-in-difference) of the LP growth rate for more ICT intensive industries relative to others.
X's	Explanatory variables, namely, unit cost of labour, remuneration, employment and capital to labour ratio.
$\varepsilon_{i,t}$	Random error term

Source: Adapted from Engelbrecht and Xayavong (2006)

This paper departs from Engelbrecht and Xayavong (2006) in that we account for other factors except ICT that might have an effect on labour productivity. By doing this, we avoid "omitted variable bias", a bias that occurs when one or more variables, which we would like to control for, have been omitted in estimating a regression model. Omitting relevant variables introduces a correlation between the error term and explanatory variables, giving rise to biased and inconsistent coefficients of estimates (Wooldridge, 2012). In view of this, we introduced other variables, X's, which are namely, unit cost of labour, remuneration, employment and capital to labour ratio, which account for labour productivity growth besides ICT.

Given the above background, the overall aim of the paper is to examine the effect of ICT on labour productivity of manufacturing industries. The objectives of the paper are:

1. To analyse the growth rate of labour productivity of manufacturing industries pre-and post-1996.
2. To distinguish the growth rate of labour productivity between the more ICT intensive and less ICT intensive industries.
3. To statistically test the effect of ICT on labour productivity growth for the two types of industries pre-and post-1996.

4. DESCRIPTIVE AND EMPIRICAL RESULTS

4.1 Descriptive results

4.1.1 Classification of industries according to their ICT intensity

Using ICT intensity index defined as the industries' direct requirements for ICT intermediate inputs, we distinguish industries into two categories (i.e. more ICT intensive and less ICT intensive industries). Akin to previous studies we use the median of the index as the point of reference for ranking industries into the two categories[2]. Within this vein, industries with the ICT intensity index of greater or equal to the median of 0.46% are ranked as more ICT intensive and vice versa for less ICT intensive industries. The ICT intensity of the industries is presented in Table 3. Columns 2 to 5 of Table 3 presents ranking of the respective industries in column 1 by previous studies. Columns 6 and 7 presents the ranking of the industry and the ICT intensity index, consecutively, as found by the current study.

Table 3: ICT intensity of manufacturing industries

Industry	**ICT intensity of the industry**					**ICT intensity index (%)**
	Stiroh (2002)	**Ark *et al*., (2002)**	**Engelbrecht and Xayavong (2006)**	**Abri *et al.* (2015)**	**This study**	
Agro-processing sub-sectors						
1. Food	High/Low[3]	Low	Low	Low	High	2.51
2. Beverages	High/Low	Low	Low	Low	High	1.98
3. Tobacco	High/Low	Low	Low	Low	Low	0.21
4. Textile	High/Low	High/Low	Low	High	Low	0.16
5. Wearing Apparel	High/Low	High/Low	Low	High	High	1.69
6. Leather	High/Low	High/Low	Low	High	Low	0.02
7. Wood	Low[4]	Low	Low	Low	High	0.46
8. Paper	Low	Low	Low	Low	Low	0.14
9. Rubber	Low	Low	Low	N/A	Low	0.14
10. Furniture	High/Low	High/Low	Low	Low	Low	0.41
ICT sub-sectors						

[2] Previous studies include studies by Stiroh (2002a) and Engelbrecht and Xayavong (2006)
[3] High/low implies that other parts of the industry are categorised as high ICT intensive while others are low ICT intensive
[4] Low implies that the industry is low ICT intensive

11. Printing	High[5]	High	High	High	High	8.44
12. Radio,TV instruments	N/A	N/A	N/A	High	High	37.69
13. TV, radio, communication equipment	N/A	N/A	N/A	High	High	35.86
Rest of Manufacturing Industries						
14. Coke and Refined petroleum	Low	Low	Low	Low	Low	0.11
15. Basic chemicals	Low	Low	High	High	Low	0.34
16. Other chemicals	N/A[6]	N/A	High	N/A	High	1.08
17. Other non-metallic products	N/A	N/A	N/A	Low	Low	0.27
18. Glass and Glass Products	N/A	N/A	N/A	N/A	Low	0.04
19. Non-metallic mineral products	Low	Low	Low	Low	Low	0.23
20. Machinery and Equipments	High	High	High	N/A	High	2.12
21. Electrical machinery and Equipments	N/A	N/A	N/A	High	High	3.40
22. Transport equipment	High/Low	Low	High	Low	High	1.92
23. Motor vehicle parts	N/A	Low	N/A	Low	High	0.80

Source: Authors' classification based on previous studies

The findings are that more than half of the industries (52%) are ranked as more ICT intensive while the remaining industries are less ICT intensive. Of the agro-processing industries, four industries, namely, Food, Beverages, Wearing Apparel and Wood ranks as more ICT intensive while the rest are less ICT intensive. This implies that the four industries have the highest share of direct requirements for ICT intermediate inputs. Turning on other sectors, we observe that the ICT industries have the highest ICT intensity index. These industries account for 82% of the share of direct ICT intermediate inputs required by the 23 industries. These results are as expected since the ICT sector is most intensive user of ICT goods and services (OECD, 2016). Amongst the remaining manufacturing industries, four industries which are namely Manufacture of Other chemicals, Machinery and Equipment, Electrical Machinery Equipments, Transport Equipments and Motor Vehicles ranks as more ICT intensive while the remaining industries ranks as less ICT intensive.

4.1.2 Labour productivity growth rates

[5] High implies that the industry is high ICT intensive

[6] N/A implies that the industry was not included in the study under review

Table 3 presents a brief description of the mean growth rate of LP of each of the 23 manufacturing industries for the period 1970 to 2016 and sub-periods 1970 to 1995 and 1996 to 2016. The detailed results are presented in Table 4 of Annexure B. In general, majority of the industries (i.e. 73.9%) have positive LP growth in all periods. Moreover, 86.9% of the industries (i.e. 20 out of 23) show acceleration in labour productivity, suggesting a broad productivity growth. Of the agro-processing industries, the Beverages and Tobacco industries exhibits decelerating LP while rest displays acceleration in LP.

The industries were further grouped into two groups which are namely Category A and Category B. Category A encompasses all the manufacturing industries as presented in Table 3 while Category B comprises of agro-processing industries. We calculated the mean of LP growth rates between the more ICT intensive and less ICT intensive industries for the two Categories for the periods under investigation. The results are presented in Table 5.

Table 5: Labour productivity growth rates, Categories

Annual growth rate (%)				
	1970-2016	1970-1995	1996-2016	Acceleration [(1996-2016)-(1970-1995)]
Category A[7]				
Mean growth rate for high ICT intensive industries	0.74	0.19	0.60	0.41
Mean growth rate for low ICT intensive industries	1.13	0.42	0.73	0.31
Category B[8]				
Mean growth rate for high ICT intensive industries	0.87	0.31	0.60	0.29

[7] Category A= All industries as outlined in Table 3

[8] Category B= Agro-processing industries

Mean growth rate for low ICT intensive industries	1.10	0.52	0.60	0.08
Category C[9]				
Mean growth rate for high ICT intensive industries	0.87	0.32	0.58	0.26
Mean growth rate for low ICT intensive industries	1.13	0.42	0.73	0.31

Source: Authors' calculations

With respect to Category A, it is observed that both the more and less ICT intensive industries experienced acceleration in LP. However, LP growth rate of the more ICT intensive industries is slightly higher than that of the less ICT intensive industries (i.e. 0.41% relative to 0.31%) as presented on Figure 1. It also noted that less ICT intensive industries display a stagnant but positive trend in LP growth across the entire period while their counterparts exhibit downwards and upwards trend.

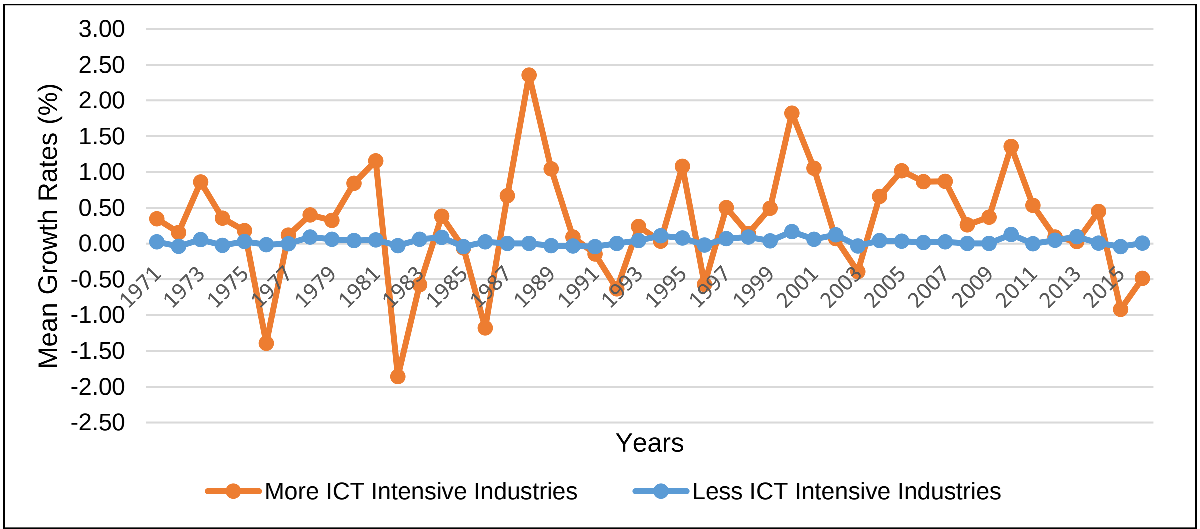

Figure 1: Mean growth rates industries, Category A

Equally, both the more and less ICT intensive industries in Category B exhibits acceleration in LP growth. However, in general, the more ICT intensive industries experienced slightly higher acceleration in LP as displayed on Figure 2.

[9] Category C= All industries in category A excluding the ICT industries

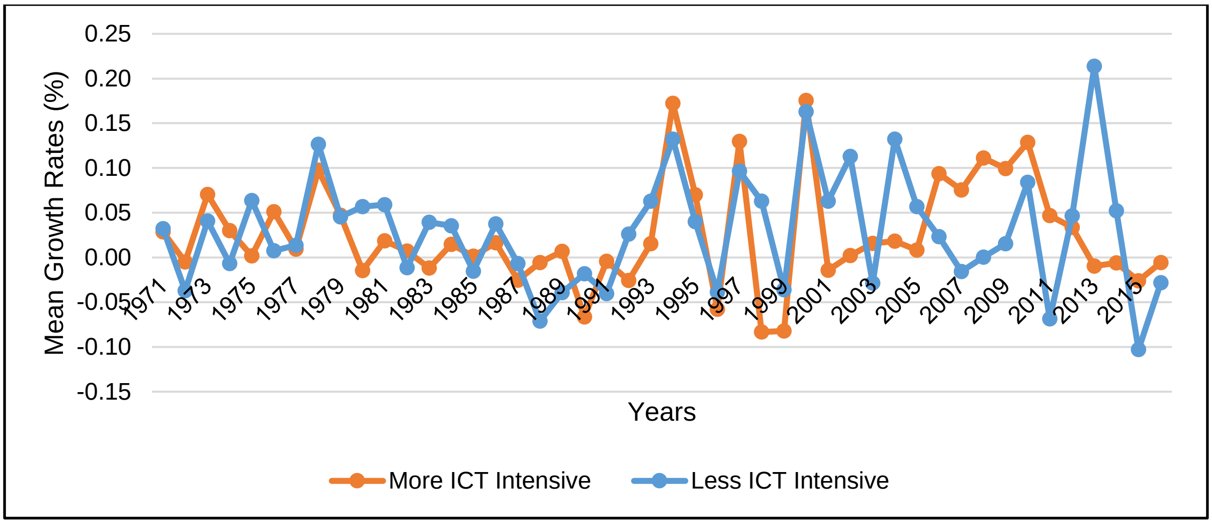

Figure 2: Mean growth rates of industries, Category B

In general, the findings suggest that the more ICT intensive industries are slightly outperforming the less ICT intensive industries in terms of LP growth, irrespective of the Category. Our general findings are in line with those observed in previous studies in other countries such as New Zealand (Engelbrecht and Xayavong, 2006) and Iran (Abri and Mahmoudzadeh, 2014). However, there is conflicting international evidence with regards to whether the ICT producing industries contributes more or less to LP compared to other industries categorised as ICT using. As for an example, empirical evidence by Ark *et al*., (2002) proved that in the US, the wholesale and retail industries exhibited stronger productivity growth in the second half of the 1990's while the telecommunications sector displayed weaker growth.

Contrarily, Engelbrecht and Xayavong (2006) with the focus on New Zealand found lower LP growth for the wholesale and retail industries but higher growth for the communications services. On the other hand, in Iran, Abri and Mahmoudzadeh (2014) found that there is no significant difference in labour productivity growth between IT producing and IT using industries. In view of this conflicting evidence, we deleted the three ICT manufacturing industries[10] from Category A and re-calculated the mean growth rates for all periods. We then defined the industries excluding the ICT manufacturing industries as Category C and included the results in Table 5.

With the exclusion of ICT producing industries, LP growth of the more ICT intensive industries declines from 0.41% to 0.26%. Moreover, less ICT intensive industries are outperforming the more ICT intensive industries in terms of acceleration in LP growth rates as shown on Figure 3. These findings suggest that the mean growth rate of labour productivity of the more ICT intensive industries is slightly confined to the ICT producing manufacturing industries.

[10] ICT-producing industries consist of Manufacture of Printing, Publishing and Recorded Media, Manufacture of Radio, TV instruments and Manufacture of TV, radio, communication equipment.

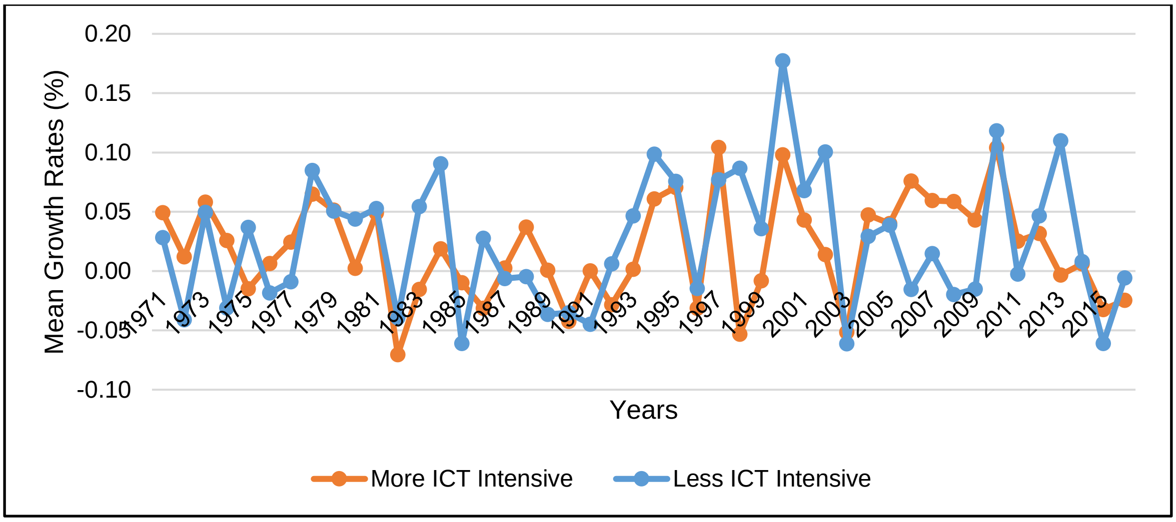

Figure 4: Mean Growth Rates of More vs. Less ICT Intensive Industries, Category C

4.2 Empirical results

Through the descriptive analysis, we established that, in general, the mean growth rates for more ICT intensive industries are greater than those of the low ICT intensive industries. Moreover, the LP growth rate of the more ICT intensive industries is slightly driven by the ICT manufacturing industries. The purpose of this section is therefore to formally test whether the differences in the mean growth rates for more ICT intensive and less ICT intensive are statistically significant. In other words, we test formally whether those differences in LP growth rates of industries between the two groups can be associated with ICT intensity of the industries. To achieve this, we analysed data using the models (1)-(3) specified in the empirical models subsection for Categories A, B and C. Table 6 highlights the model results.

Table 6: Estimates of the relationship between LP growth and ICT intensity: Models (1)-(3)

Model 1	**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	0.098 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		2.7767		0.9642		2.2142
No of Obs		1058		460		920
Model 2						
βL_0	0.208 (0.006)	Pr(T<t)= (0.962)	0.023 (0.082)	Pr(T<t) =(0.755)	0.098 (0.004)	Pr(T<t) =0.987
$\beta L_0 + \beta L_1$	0.411** (0.103)	Pr(T>t)= (0.030)	0.035 (0.016)	Pr(T>t)= 0.245	0.036 (0.006)	Pr(T>t) = 0.014
βL_1	0.203 (0.114)	Pr(|T|>|t|) = 0.070	0.012 (0.017)	Pr(|T|>|t|)= 0.489	0.016* (0.007)	Pr(|T|>|t|) =0.027
T-statistic		1.7761		0.6926		1.7761
No of Obs		1046		276		506
Model 3						
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) = 0.989
$\beta_0 + \beta M_1$	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)= 0.011
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|) =0.023
T-statistic		2.2852		0.7193		1.334
No of Obs	1046		184		414	

Notes: Figures in parenthesis are standard errors. * P < 0.01, ** P < 0.05, *** P < 0.001

For Category A and using model 1, the results reveal that the estimate for the mean growth rate of LP, pre-1996 is not statistically significant. Moreover, the LP growth rates estimate post-1996 is larger than the pre-1996 estimate and statistically significant. This implies that post-1996, the LP growth rates of industries accelerated more relative to the pre-1996 period. Of importance, the DD estimator (α_1) is statistically significant which confirms that the growth rate of LP of manufacturing industries increased post-1996.

For Category A and using model 2, the results also reveal that the estimate for the mean growth rate of LP, pre-1996 is not statistically while the post-1996 estimate is significant. The implication is that post-1996, the LP growth rates of the less ICT industries accelerated more relative to the pre-1996 period. However, the DD estimator (βL_1) is not significant which suggest that the LP growth of the less ICT intensive industries did not increase post-1996.

Akin to the less ICT intensive industries, the estimate for the mean growth rate of LP of the more ICT intensive industries pre-1996 is not statistically while the post-1996 estimate is significant. However, the difference between the two groups is that the DD estimator (βM_1) for the more ICT intensive industries is significant which proves that the LP growth of the more ICT intensive industries increased post-1996.

However, with the exception of the ICT manufacturing industries (Category C), all the parameters of estimates are not statistically significant. This suggests that the LP growth of the more ICT intensive industries is driven by the ICT manufacturing industries.

We further applied models (1) to (3) to industries in Category B to test for the contribution of ICT to ICT using industries. The rationale for doing this is that ICT contributes directly to the growth of ICT producing industries and indirectly to the productivity growth of ICT using industries (Abri and Mahmoudzadeh, 2014). Therefore, in accordance with van Ark (2014), we assume that productivity effects of ICT are firstly realised by ICT producing industries and later other industries as technology mushrooms across the economy.

The findings are that coefficient for mean growth rate of LP post-1996 is greater than that of the pre-1996 era. However, all the parameters of estimates are not statistically significant implying that we fail to link the LP growth of the agro-processing industries. Moreover, we fail to link the difference in the LP growth of the more ICT intensive and less ICT intensive agro-processing industries to ICT.

We further applied model (4) to test whether the difference in LP growth between the two groups of industries pre-and post-1996 can be linked to ICT. We estimated the model for each category of industries with and without controls. Model 4 is further split into two wherein model (4) a represents the regression without control variables while model (4) b includes the controls. The results are presented in Table 7.

Table 7: Estimates of the relationship between LP growth and ICT intensity: model 4

Model (4)a	**Category A**		**Category B**		**Category C**	
δ_0	0.208 (0.006)	Pr(T<t)= 0.962	0.023 (0.082)	Pr(T<t) =0.755	0.021 (0.006)	Pr(T<t) = 0.962
$\delta_0 + \delta_1$	0.411** (0.103)	Pr(T>t)= 0.030	0.035 (0.016)	Pr(T>t)= 0.245	0.041 (0.010)	Pr(T>t)= 0.038
δ_1	0.203 (0.114)	Pr(|T|>|t|) =0.070	0.012 (0.017)	Pr(|T|>|t|) =0.489	0.020 (0.011)	Pr(|T|>|t|) =0.076
$\delta_0 + \delta_2$	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) = 0.989
$\delta_0 + \delta_2 + \delta_1 + \delta_3$	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)= 0.011
$\delta_1 + \delta_3$	0.0172** (0.008)	Pr(|T|>|t|) =0.023	0.011 (0.015)	Pr(|T|>|t|) =0.473	0.012 (0.009)	Pr(|T|>|t|) =0.023
δ_3	0.054 (0.015)	Pr>| t |= 0.728	0.551 (0.282)	Pr>| t |= 0.052	0.022 (0.172)	Pr>| t |= 0.898
R^2	0.042		0.081		0.045	
No. of Obs	1058		260		533	

Model (4)b						
δ_0	0.208 (0.006)	Pr (T<t)= 0.962	0.023 (0.082)	Pr(T<t) =0.755	0.021 (0.006)	Pr(T<t) = 0.962
$\delta_0 + \delta_1$	0.411** (0.103)	Pr(T>t)= (0.030)	0.035 (0.016)	Pr(T>t)=0.245	0.041 (0.010)	Pr(T>t)= 0.038
δ_1	0.203 (0.114)	Pr(|T|>|t|) = 0.070	0.012 (0.017)	Pr(|T|>|t|)= 0.489	0.020 (0.011)	Pr(|T|>|t|) =0.076
$\delta_0 + \delta_2$	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) = 0.989
$\delta_0 + \delta_2 + \delta_1 + \delta_3$	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)= 0.011
$\delta_1 + \delta_3$	0.0172** (0.008)	Pr(|T|>|t|) =0.023	0.011 (0.015)	Pr(|T|>|t|) =0.473	0.012 (0.009)	Pr(|T|>|t|) =0.023
δ_3	0.0774 (0.148)	Pr(T>t)= 0.601	0.5107 (0.270)	Pr(T>t)=0.060	0.0551 (0.164)	Pr(T>t)= 0.737
Unit cost	-0.021*** (0.004)	Pr(T>t)= 0.000	-0.028*** (0.008)	Pr(T>t)=0.000	-0.0227*** (0.005)	Pr(T>t)= 0.000
Remuneration	0.043*** (0.005)	Pr(T>t)=0.000	0.0431*** (0.009)	Pr(T>t)=0.000	0.0441*** (0.006)	Pr(T>t)= 0.000
Employment	-0.0076 (0.008)	Pr(T>t)=0.321	-0.0093 (0.016)	Pr(T>t)=0.549	-0.0001 (0.008)	Pr(T>t)= 0.992
Capital: labour ratio	0.001 (0.005)	Pr(T>t)= 0.816	-0.0051 (0.009)	Pr(T>t)=0.555	0.0033 (0.005)	Pr(T>t)= 0.539
R^2		0.167		0.183		0.158
No. of Obs		1058		260		533

The DD estimator (δ_3) without controls is higher than the estimator with controls, irrespective of the category group. For example, the model suggests that the more ICT intensive industries account for a larger share of the LP productivity improvements without controls and a smaller share with the inclusion of the control variables. That is, without the controls, the DD estimator is overestimating the contribution of the more ICT intensive industries to LP growth.

The DD estimator for the more ICT intensive industries (i.e. all industries as per category A) is significant while that of the less ICT intensive industries is insignificant. This suggests that the difference in the LP growth of the more ICT intensive industries pre and post 1996 can be attributed to ICT and contrary for the less ICT intensive industries. Overall, irrespective of the category, we fail to link the difference in the LP growth between two groups to ICT as the DD estimator (δ_3) is statistically insignificant.

Taking into account that other factors except ICT, we estimated model (4) with four selected control variables, namely, unit cost of labour, remuneration per employee, and capital to labour ratio. The findings are that, irrespective of the category, the unit cost and employment negatively influence LP growth and vice versa for remuneration and capital to labour ratio. Of these controls, unit cost and remuneration are statistically significant while others are not.

5. CONCLUSION

The paper serves to provide empirical evidence on whether the growth in LP in the manufacturing sector after ICT policy reforms which occurred from 1996 can be attributed to ICT. The findings suggest that LP growth of more ICT intensive industries has increased relative to that of other industries following policy reforms. However, this only applies with the inclusion of ICT manufacturing industries. This suggests that the ICT producing industries are the driver of growth in LP in South African manufacturing sector. Therefore, our findings are in conformity with findings that the LP growth of industries is driven by ICT producing industries (Engelbrecht and Xayavong, 2006). The results are not as expected but not surprising given that the ICT manufacturing industries account for a larger share of the direct requirements for ICT intermediate inputs. This implies that the ICT sector is feeding more ICT goods and services into self, relative to other sectors. It would therefore be interesting to simulate how much would LP of the ICT using industries change if their ICT intensity indexes were to be increased.

However, we fail to link the difference in the LP growth between two groups to ICT as the DD estimator (δ_3) is insignificant. These results serve as a confirmation to the general acknowledgment by previous researchers that the ICT induced productivity and growth are confined to the developed world (Joseph, 2002; Niebel and Mannheim, 2014). Previous studies attribute this to numerous challenges including late introduction of ICT in developing countries, insufficient capital investment and knowledge, lack of absorptive capacities such as low levels of human capital and research and development (R&D) expenditure.

However, all the parameters of estimates are not significant implying that we fail to link the LP growth of the agro-processing industries to ICT. Again, this results are not surprising given that the agro-processing industries account for a smaller share of direct requirements for ICT intermediate inputs (i.e. 7.72%). Moreover, we fail to link the difference in the LP growth of the more ICT intensive and less ICT intensive agro-processing industries to ICT. This implies that the productivity effects of ICT on agro-processing sector are yet to be observable. Given the strategic importance of the agro-processing sector to South African economy, he results calls for policy measures to increase the use of ICT in the sector.

In terms of the effect of the controls on LP growth, findings valid that LP declines with an increase in the cost of labour while LP growth increases with an increase in the remuneration per employee. Therefore, policy measures aimed at reducing the cost of labour in South Africa are imperative if government is to prioritise LP growth. Moreover, firms aiming to improve LP should consider increasing remuneration of their employees. This is critical considering that ICT is not the sole driver of LP growth.

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Annexure A

Table 1: Review of previous studies on the impact of ICT on productivity

Author (s)	**Sampling frame**	**Approach**	**Main finding (s)**
Firm level studies			
Yosri (1992)	31 food firms, United States 1987-1990	Production function	There is no significant correlation between IT investment and productivity.
Loveman (1994)	United States	Production function	The output elasticity of IT is negative.
Berndt and Morrison (1995)	US manufacturing industries 1968-1986 period	Regression framework	A negative correlation between total factor productivity and ICT
Stare *et al*., (2006)	Service firms, Slovenia	Production function approach	There is a positive effect of ICT use on productivity.
Arvanitis and Loukis (2009)	Switzerland and Greece firms 2005	Production function	There is a positive effect of ICT on labour productivity.

Industry level studies			
Engelbrecht and Xayavong (2006)	New Zealand, 29 industries 1988-2003	Difference-in-difference models	Labour productivity growth is higher for those industries that are more ICT intensive.
Bloom *et al.*, 2012	Europe and the US multinational firms	Standard production function framework, fixed effects.	US productivity growth accelerated after 1995, relative to Europe's, particularly in high-ICT intensive sectors.
Niebel *et al.*, 2013	Ten European Union (EU) countries.	Production function and growth accounting frameworks.	The contribution of ICT intangible assets to labour productivity is highest in finance and manufacturing sectors.
Abri and Mahmoudzadeh (2014)	23 Iranian manufacturing industries. 2002-2006	Extended Cobb-Douglas, DEA and panel regression model.	Productivity is higher in ICT-intensive industries. There is no significant difference in labour productivity growth between IT-producing and IT-using industries.
Corrado *et al.*, (2017)	10 EU member states	Cross-country Production function framework	Returns to a country's investments in intangible capital are stronger in the ICT-intensive industries.
Aggregate studies			
Khan and Santos (2002)	Canada 1988-2000	Growth accounting framework	There was no acceleration in the impact of ICT use output growth in the late 1990s. There was no acceleration in the impact of ICT use (capital deepening) on labour productivity growth.
Mačiulytė - Šniukienėa and Gaile-Sarkane (2014)	27 EU states	Correlation analyses	The relationship between ICT development and labour productivity was not found in some of the high and medium productivity countries.
Edquista and Henrekson (2017)	50 industries in Sweden	Augmented Cobb-Douglas Production function and	There is no significant short-run relationship between ICT and TFP (positive relationship found with a lag of seven to

	1993-2013.	Growth Accounting Framework	eight years).
Relich (2017)	28 EU countries (EU 15 countries and 13 CEE countries) 2007-2015	A neoclassical framework of growth accounting and a translog production function	Moreover, the impact of ICT (ERP, e-commerce and CRM software) on labour productivity is higher in CEE countries (transition economies) than in the EU countries (developed economies).

Annexure B

Table 4: Labour productivity growth rates of industries

Annual growth rate (%)					
Industry	1970-2016	1970-1995	1996-2016	Acceleration [(1996-2016)-(1970-1995)]	Is the acceleration in LP?
	Agro-processing sub-sectors				
1. Food	1.32	0.44	0.91	0.47	Yes
2. Beverages	1.57	1.36	0.19	-1.18	No
3. Tobacco	1.57	1.36	0.19	-1.18	No
4. Textile	0.93	0.33	0.78	0.45	Yes
5. Wearing Apparel	1.28	0.15	1.34	1.19	Yes

6. Leather	2.40	0.59	1.72	1.13	Yes
7. Wood	0.44	0.05	0.42	0.37	Yes
8. Paper	0.86	0.45	0.47	0.02	Yes
9. Rubber	0.86	0.45	0.47	0.02	Yes
10. Furniture	1.12	0.26	0.92	0.66	Yes
ICT sub-sectors					
11. Printing	-0.11	-0.21	0.10	0.31	Yes
12. Radio,TV instruments	0.91	0.11	0.93	0.83	Yes
13. TV, radio, communication equipment	1.48	0.18	1.50	1.31	Yes
Rest of Manufacturing Industries					
14. Coke and Refined petroleum	2.0	0.95	1.02	0.07	Yes
15. Basic chemicals	1.70	0.65	0.92	0.32	Yes
16. Other chemicals	1.20	0.90	0.25	-0.65	No
17. Other non-metallic products	1.02	-0.00	1.07	1.07	Yes
18. Glass and Glass Products	1.82	0.85	1.01	0.16	Yes
19. Non-metallic mineral products	0.94	-0.09	1.07	1.16	Yes
20. Machinery and Equipments	0.58	0.09	0.45	0.36	Yes
21. Electrical machinery and Equipments	1.13	0.60	0.67	0.07	Yes
22. Transport equipment	0.76	-0.06	0.84	0.90	Yes
23. Motor vehicle parts	1.46	0.54	0.98	0.44	Yes

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