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Can Investing in Information Systems Boost Economic Complexity in South Africa: Movement Towards the Fourth Industrial Revolution?

T Ncanywa
Walter Sisulu University, South Africa

Abstract: Countries need to accelerate the growth and development of their economies by increasing the productive capacity for better living conditions of their citizens. For countries to improve their economies, they need to boost their economic complexity by producing and exporting commodities that embody sophisticated characteristics. The economic complexity index measures how diverse products are and include their ubiquity when they are exported. Economic complexity provides reasons why some countries progress very slowly by studying the characteristics of countries export baskets. This study seeks to find out if the investment in information systems can influence the South African economic complexity. The set objective employs the autoregressive distributive lag (ARDL) methodology. Results of the ARDL bounds test gave an F-statistic of 7.17 greater than the upper bound and this indicated a long run relationship in the series. Furthermore, investment in information systems had a significant positive relationship to economic complexity with a speed of adjustment of 87%. Investing in information system has proved to be innovative and contribute to firm output and labour productivity. Furthermore, information technology improves organizational performance, reduce production cost and improve the production of all personnel and ultimately increase the efficiency of human capital. The positive relationship between information systems and economic complexity is a good indicator that South Africa can enhance its complexity through information systems activities. It is therefore, recommended that the government of South African invest in information systems as this could yield a faster route towards the fourth industrial revolution.

Keywords: Autoregressive distributive lag, Diversity, Economic complexity, Information system, Ubiquity

1. Introduction

South Africa needs to accelerate the growth and development of its economy by increasing the productive capacity for better living conditions of its citizens (Maia & Hanival, 2013). Therefore, it should search for ways to sustain economic development. For countries to improve their economies, one way is to boost their economic complexity which is an economic development phenomenon by producing and exporting commodities that embody sophisticated characteristics (Hidalgo & Hausmann, 2009). Economic complexity index is a knowledge-based indicator in a society indicated by the products it makes and export (Hidalgo & Hausmann, 2009; Hausmann, Hidalgo, Bustos, Coscia, Chung, Jimenez, Simoes & Yildirim, 2014). So, economic complexity is rooted to the country's production and exportation of more diverse and less ubiquitous products. The economic complexity index (ECI) measures how diverse products are and include their ubiquity when they are exported. Economic complexity provides reasons why some countries differ in progress and show different export characteristics (Cristelli, 2013; Desjardins, 2017; Hartmann, Guevara, Jara-Figueroa, Aristarán & Hidalgo, 2017).

Examples of complex products range from machinery, processed metals to chemicals, while un-complex products are agricultural products unprocessed goods like raw gold, textiles and wood (Felipe et al., 2012). The following countries produce the most complex products: Japan, Germany, and Sweden. Countries such as Cambodia, Papua New Guinea, Nigeria and Botswana produce least complex products (Hausmann et al., 2014). Most African countries are found at the bottom section of the economic complexity ranking list and South Africa is rated 55 out of 129 countries (Hausmann et al., 2014). Desjardins (2017) attested those countries in the bottom section have industries that lack sophistication, innovation, and knowledge. It is the desire of each country to move up in the ranking list of ECI.

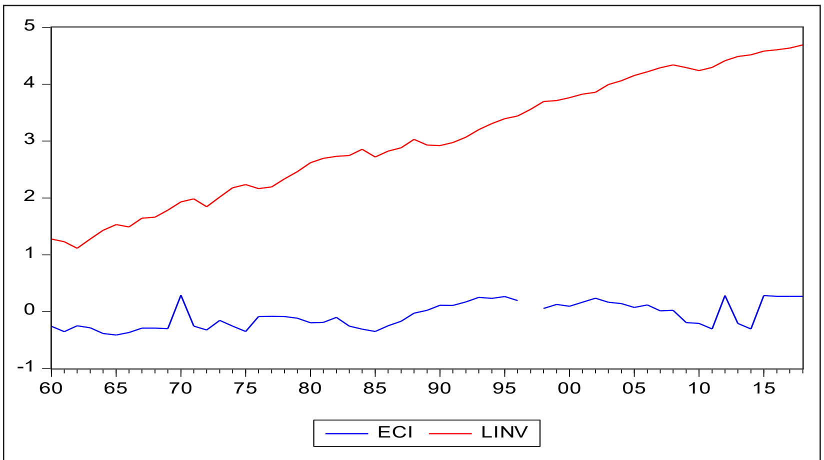
Even though South Africa is a natural resource rich country in agricultural products and minerals, there is a need for structural transformations. South Africa is still trapped in the exportation of unprocessed minerals, and this is echoed by the views of Monga (2018) as a common practice in African economies. Considering this, Yusuf (2017) alluded that the more diversified economies in production, the more the economy can grow. This means to boost economies in countries rich in natural resources requires them to produce and export goods that are sophisticated (Felipe, Kumar, Abdon & Bacate, 2012). Therefore, there should be more understanding on knowledge rather than obvious knowledge to increase complexity.

South African industries need to invest in information technology (IT) by adopting innovative technologies with electronic commerce (internet & social networks) in their operations (Anumba & Ruikar, 2002; Seuwou, Banissi & Ubakanma, 2017). Investment in information systems in this study is measured by gross fixed capital formation on information, computer and telecommunications equipment. According to Rai et al. (1997), investing in IT yielded positive contribution to firm output and labour productivity as IT improves organizational performance. Improving IT reduce production cost and improve production of all personnel and ultimately increase efficiency of human capital. Adopting technological operations and enhancing information systems can accelerate the country's movement towards the fourth industrial revolution while promoting a high economic complexity index (Huang, Behara & Goo, 2014).

Information Technology (IT) is required for economic growth and to improve living conditions of citizens (Avgerou, 2003; Aparicio, Urbano & Audretsch, 2016; Halevi, 2018). IT opens opportunities for development as more effective technologies provide a competitive advantage when these countries trade. Industrialized countries such as Singapore have development policies that use IT at the center of their production (Avgerou, 2008). Developing countries have insufficient technical skills that limit them to participate productively in the world economy. Developing countries are denied of these opportunities for growth as there is limited access to internet connectivity. For instance, countries like Germany and Japan have internet connections in public transport (such as buses and trains). Different IT services and prices may also account for the differences in economic complexity of developed and developing countries. IT is meant to improve living conditions and play a development role as a tool for economic and social benefits (Maia & Hanival, 2013). Therefore, technology is an instrument for growth and development.

Looking at the way ECI and information system trend over time (Figure 1), in South Africa information system gradually increases while ECI moves between values of -1 and 0. A question that comes to mind is 'do investment on new technologies lead to economic development?' Hence, it was imperative to find out if investment on information systems (technology) can influence the South African economic complexity. This paper is structured as follows; introduction is followed by literature review, then methodology, results and discussion, finally conclusion and recommendations.

Figure 1: Trends of ECI and Information System in South Africa, 1960-2018



Notes: ECI- Economic Complexity Index; LINV- Logged Investment

Source: Author compilation

2. Literature Review

Theory of the relationship between information systems and economic complexity is adopted from the Neo-classical economic perspective of development. The Neo-classical theory is based on the rational behavior of economic agents (individuals and business organizations) and the capacity of market competition (Avgerou, 2003; Farias, Farias, Krysa & Harmon, 2020). Market competition can eliminate inefficient producers and create equilibria of production and consumption at optimal conditions of full employment and the lowest prices. In this theory, it is believed that development strive to transform socioeconomic agents into free markets (Avgerou, 2003; Halevi, 2018).

It is alluded in Halevi (2018) that there are a number of challenges with the static nature of the Neo-classical development theory. Firstly, free markets tend to lead to market failure. Secondly, imbalances in production, prices and consumption may lead to inflation and unemployment. This could be problematic for South Africa as it needs to maintain stable prices and drop unemployment. Thirdly, the theory works well with rich countries and cannot be fostered in developing countries (Avgerou, 2003; Kodakanchi et al., 2006). This may justify why complex products are found in countries with high income, and less complex products are exported from the low-income countries (Felipe et al., 2012). That been the case, export shares of the more complex products increase with income, while export shares of the less complex products decrease with income (Aparicio, Urbano & Audretsch, 2016). Fourthly, individuals rarely possess complete information about the market. Lastly, intrusion of politics in economic behavior as governments shape development. Governments include conflict, cooperation and negotiations in production and distribution of resources (Farias et al., 2020; Leftwich, 2000). Government policies foster high-tech-industries (Hobday, 1995; Kodakanchi, Kuofie, Abuelyaman & Qaddour, 2006).

Another theory relevant to studies relating to information systems and economic complexity is the Neo-Schumpeterian theory (Avgerou, 2008). This theory acknowledges that investing in information systems need development of appropriate organizational and social structures. This investment can positively influence the country's wealth, infrastructure and wage rate, but with a lag between introducing the new technology information system and achieved productivity (Avgerou, 2008). Organizations need a long period of learning about production and technology to be efficient. The Neo-Schumpeterian theory elucidates that as time goes by, new equipment and methods are adopted, then there will be dynamism of innovation. A socio-technical approach that includes appropriate organizational changes can lead to a beneficial developmental process and increase diversity in economic complexity. In the socio-economic context, knowledge and information drives innovation and this lead to new social relationships and new structure (Bell, 1973).

Studies relating directly to the nexus between information systems and economic complexity are scarce, hence literature is reviewed on economic complexity and information systems separately. For instance, studies of Simoes & Hildalgo (2011) focus on establishment of the Economic complexity index; Ralarala and Ncanywa (2019) on economic complexity and monetary aggregates; Hidalgo and Hausmann (2009) on economic complexity and economic growth. Studies on economic complexity are not yet well researched and its limits are still somewhat blurred, hence the significance of this study to literature gaps. Furthermore, some authors drawing thoughts about complexity from the neo-Schumpeterian evolutionary theory, have contradicting views on which approach to adopt whether it should promote direct interventions or bottom-up process (Hidalgo & Hausmann, 2009; Simoes & Hildalgo, 2011).

There are studies that in their investigation found a positive relationship between complexity and economic growth (Hidalgo & Hausmann, 2009). Bustos, Gomez, Hausmann and Hidalgo (2012) showed that economic growth has been influenced by a sophisticated product mix that countries make. The improvement in growth lead to more sophisticated production output which improve the country's developmental state. A developing state leads to social improvements in respective countries' regions and communities. Hartmann (2014) advocate that if there is economic diversification there could be more social choices and capabilities that could lead to more complex decision processes. This means the process of structural transformation could be adhered to information systems to access information and find social support. Therefore, in expanding production, innovation and economic diversification should be encouraged, focusing on promoting social inclusion and human agency (Bustos et al., 2012). If countries are limited with knowledge and skills, they find it difficult to manufacture complex products especially the technological advanced machines (Yelinmez & Kilic, 2014). This limits these countries to contribute to economic growth and development by increasing complex products. A similar sentiment is shared by Felipe (2014) who concluded that rich country are rich because of the strategies to produce and export products that represent sophisticated and connected characteristics.

Other economic complexity studies relate to product space and inequality. For example, González et al. (2018) used the product space methodology to identify new products. If this methodology combines with the analytic hierarchy process it can assist to identify sectors (such as information systems) that can boost economic complexity with the intention to boost economic development. Hartmann et al. (2017) used this measure together with the network of related products or product space to illustrate how the development of new products is associated with changes in income inequality. Their findings showed that economic complexity captures information about an economy's level of development that is relevant to the ways an economy generates and distributes its income and how a country's productive structure may limit its range of income inequality.

Literature on information systems include studies that look at the quality of information systems. For instance, Kodakanchi et al. (2006) establish that developing countries are challenged by lack of infrastructure to invest on information technology. Kodakanchi et al. (2006) developed an economic model for developing countries that IT is a function of larger foreign investment, government policies supporting IT, social awareness of IT importance, high productivity and investment. In this model it has been found that investment and higher productivity fasten economic growth. In the study by Baroudi, Olson and Ives (1986), it turns out that the user of information system involvement leads to increased user information satisfaction and increased system usage. Successes of information systems depend on system quality, information quality, user satisfaction, individual impact and organizational impact (DeLone & Mclean, 1992; Anumba & Ruikar, 2002; Seuwou et al., 2017).

3. Methodological Approach

This paper adopted the autoregressive distributive lag (ARDL) in order to investigate if information systems can affect economic complexity. The estimated model is based on the dynamic nature of the Neo-Schumpeterian theory (Pesaran et al., 2001; Avgerou, 2008), and is as follows:

$$ECI_t = \alpha + INV(IS)_t + CPI_t + GDP_t + \varepsilon_t \qquad (1)$$

ECI is economic complexity index; INV (IS) is investment in information systems proxy by Gross fixed capital formation on information, computer and telecommunications equipment. The expected a-prior is that investment in information systems can positively influence economic complexity to boost development of the economy in South Africa. Other control variables such as consumer price index (CPI) which measures inflation and GDP for economic growth are added in model. Inclusion of economic growth in the model is supported by some studies reviewed in literature (Hidalgo & Hausmann, 2009; Bustos et al., 2012). Logarithms are used in order to standardize variables such as investment, CPI and GDP.

The annual time series data spanning from 1960 to 2018 is used for the analysis and the choice of this data is based on availability from the sources. Data for investment in information systems, consumer price index and gross domestic product are obtained from the South African Reserve Bank. Data for economic complexity is obtained from the Massachusetts Institute of Technology (MIT) Atlas of economic complexity. Time series data is mainly characterized with non-stationarity meaning that the distribution of the mean does not remain constant as the time progresses (Brooks, 2008). The Augmented Dickey-Fuller (ADF) and the Zivot and Andrew (ZAU) unit root tests are employed to test for stationarity. These tests confirm the order of integration whether the variables are stationary at levels I (0), first order I (1) or second order I (2). Also, the analysis of non-stationary variables results into spurious regressions (Gujarati & Porter, 2009). It should be noted that ARDL model crash if there are variable integrated at I (2) (Asteriou & Hall, 2007; Nkoro & Uko, 2016). ZAU unit root tests confirm presence of structural breaks, and the significance of the break points is tested with linear models of multiple structural changes (Bai & Perron, 1998).

If stationarity results yield different orders of integration at I (0) and I (1), then ARDL is the best estimator to be used for the analysis (Pesaran, Shin & Smith, 2001). ARDL is advantageous as it captures estimates of the short run, long run and error correction model (speed of adjustment) simultaneously; and its ability to incorporate small sample size and yet generate valid results (Nkoro & Uko, 2016). In the ARDL approach the bounds test also called cointegration test indicate the presence of a long run relationship in the series. The bounds test gives the lower bound and the upper bound critical values. If the computed F-statistics lies above the upper critical bounds test, we reject the null hypothesis of no cointegration, indicating that cointegration exists. In case where the computed F-statistic lies in between the two bounds test, the cointegration becomes inconclusive (Pesaran et al., 2001; Nkoro & Uko, 2016). To determine the long run, the short run dynamics and error correction model, equation 1 can be transformed into:

$$\Delta ECI_t = \alpha + \sum_{i=1}^{k} \beta_1 ECI_{t-1} + \sum_{i=1}^{k} \beta_2 \Delta INV(IS)_{t-1} + \sum_{i=1}^{k} \beta_3 \Delta CPI_{t-1} + \sum_{i=1}^{k} \beta_4 \Delta GDP_{t-1} + \delta_1 ECI_{t-1} + \delta_2 INV(IS)_{t-1} + \delta_3 CPI_{t-1} + \delta_4 GDP_{t-1} + \varphi CE_{t-1} + \varepsilon_t \quad (2)$$

Where Δ denoted the first difference operator in the model and α represent the constant and ε represent the error term also known as the white noise disturbance. The short run estimates in the model are represented by $\delta_1 - \delta_4$ coefficients. The long run estimates in the model are represented by $\beta_1 - \beta_2$ coefficients. φ denotes the speed of adjustments coefficient and CE denotes the residual obtained from estimated cointegration in equation. Lastly, diagnostic and stability test are employed to check reliability of the adopted variables and stability of the model.

4. Results and Discussion

This section provides results obtained from the analysis and discussion.

4.1 Unit Root Tests

It is important to note that for time series data, testing for unit roots is a necessary condition to choose the best technique to apply and to avoid possibility of spurious results. Table 1 provides results of unit roots to establish the stationarity of the series.

It can be seen from Table 1 that variables tested for unit root are stationary at different orders of integration at level [I(0)] and after first differencing [I(0)] following both the traditional and structural break (the innovative and additive outlier) unit root tests. It can also be confirmed that there are no variables at second differencing as this would explode the ARDL methodology (Nkoro & Uko, 2016). The different orders of integration pave a way for the study to run the ARDL model. As much as there were some structural breaks found in the unit root testing, they were insignificant. Further tests for

Table 1: Unit Root Test Results

Variables	ADF (Trend and Intercept)		Break With Innovation Outlier (Trend and Intercept)			Break With Additive Outlier (Trend and Intercept)		
	ADF prob.	Order of integration	ADF prob.	Break Date	Order of integration	ADF prob.	Break Date	Order of integration
ECI	0.0055	0	0.0185	1987	0	0.0205	1986	0
LINV_IS	0.1239	1	0.4041	2008	1	0.9999	1990	1
DLINV_IS	0.0000	0	0.0000	1976	0	0.0000	1976	0
CPI	0.0166	0	0.0000	2012	0	0.9335	1972	1
LCPI	-	-	-	-	-	0.0545	1976	0
GDP	0.2779	1	0.2080	1984	1	0.2668	1983	1
LGDP	0.0024	0	0.0000	1992	0	0.0000	1992	0
Notes: ECI-Economic complexity index; LINV_IS- Investment in information systems; CPI- Consumer Price Index; GDP-Gross domestic product								

Source: Own compilation from SARB and MIT Atlas of economic complexity

multiple break point tests are performed, and it turns out that the structural breaks are insignificant as the Schwarz criterion selected breaks and LWZ criterion selected breaks show a value of zero (Bai & Perron, 1998). However, two models are run, one without a dummy and another with a dummy to control for structural breaks.

4.2 Autoregressive Distributive Lag (ARDL) Results

The chosen autoregressive distributive lag (ARDL) is an efficient and consistent estimator adopted as unit root test results demonstrated different orders of integration (Nkoro & Uko, 2016). Furthermore, since this annual data that span from 1962 to 2018 contains structural breaks, the ARDL usage is more efficient (Okorie, Akpanta, Ohakwe, Chikezie, Onyemachi & Ugwu, 2019). This is re-enforced when incorporated dummies for structural breaks indicated similar results with standard ARDL estimates but the one with dummies has better estimates (see Table 3). The first step in the ARDL cointegration analysis is the bounds test to find out if there is long run relationship in the series. In Table 2 ARDL bounds test results are reported.

Results of Table 2 indicate the F-statistics of 7.7, which is the value above the upper bound at 1%. This implies that in this series of economic complexity and investment in information system there is cointegration. It's long been established that if there is cointegration there is a long dynamic relationship in the series (Pesaran et al., 2001; Wanjau, 2014; Ncanywa, 2019). This is in line with the Neo-classical theory of Avgerou (2003) and Farias et al. (2020) that information system can influence the economy if the adopted model is dynamic in nature.

The next step is to find estimates for the short and long run economic complexity series. Table 3 shows that investing in information system can strongly and positively influence economic complexity both in the short and long run. Results of table 3 indicate that both in the short and long run, investment in information systems is a significant factor to influence economic complexity. It turns out that in the long run, 1% increase of information system can increase economic complexity by 20% and significant at 1%. This study reinforces the ideas of Kodakanchi et al. (2006), Felipe et al. (2014) and Hartman (2014) that information systems can steer economic advances and create an environment for countries to produce complex products. Furthermore, as addressed by Avgerou (2008) and Halevi (2018) that information system affects development after a lag, it can be shown in table 3 that investment in information system can influence economic system after lagged thrice. It has been found that the error correction model in the ECI-IS series averaged around 87%, demonstrating the speed of adjustment that the system can diverge faster to equilibrium at that rate.

4.3 Diagnostic and Stability Results

The ARDL results undergo the Breusch-Pagan-Godfrey for heteroscedasticity and Breusch-Godfrey Serial Correlation LM Test and was found insignificant to both. The Kurtosis of 3.6 indicate a normal distribution in the series. The Cusum and the cusum of squares prove a stable adopted model (Figure 2).

Table 2: ARDL Bounds Test, 1964-2017

Null hypothesis: No long-run relationship exist		
Test statistics	**Value**	**k**
F-statistics	7.711289	2
Critical Value Bounds:		
Significance	**Lower Bound**	**Upper Bound**
10%	2.63	3.35
5%	3.1	3.87
2.5%	3.55	4.38
1%	4.13	5

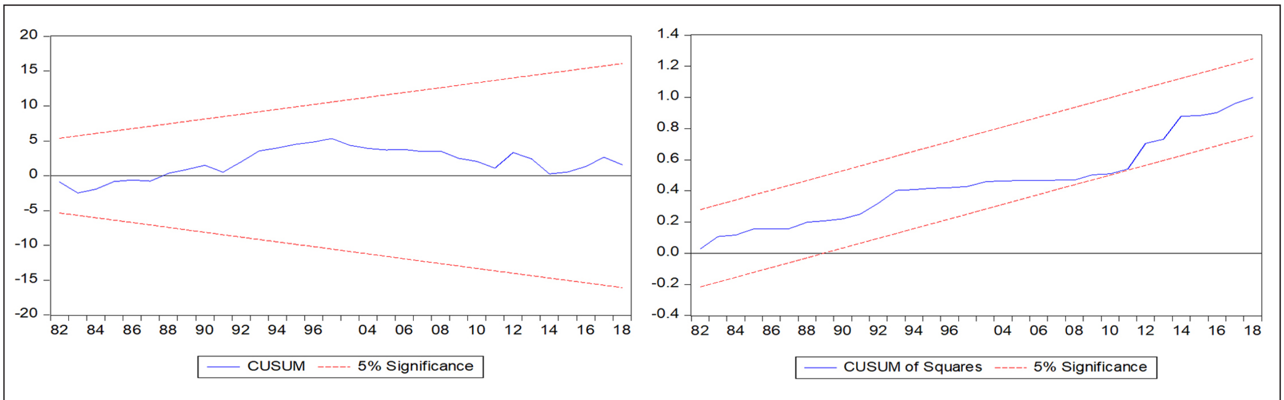
Source: Own compilation from SARB and MIT Atlas of economic complexity

Table 3: Autoregressive Distributive Lag (ARDL) Estimates, 1960-2018

Original dep. variable: ECI Selected Model: ARDL (1, 1, 4)					
Model 1			**Model 2**		
Variable	**Coefficient**	**Prob**	**Variable**	**Coefficient**	**Prob**
Short run coefficients					
D(LINV)	1.233324	0.0011	D(ECI(-1))	0.147647	0.5054
D(LINV(-1))	0.524841	0.1223	D(ECI(-2))	0.069281	0.6953
D(LINV(-2))	0.186051	0.5037	D(ECI(-3))	0.344492	0.0232
D(LINV(-3))	1.030340	0.0009	D(LINV)	1.108640	0.0005
D(LGDP)	-7.464627	0.0209	D(LINV(-1))	0.361270	0.1759
D(LGDP(-1))	-2.763830	0.3405	D(LINV(-2))	-0.198841	0.4073
D(LGDP(-2))	1.677148	0.5407	D(LINV(-3))	0.803379	0.0025
D(LGDP(-3))	-7.009806	0.0048	D(LGDP)	-8.645840	0.0019
D(LCPI)	0.523259	0.7341	D(DUMMY)	-0.002638	0.9635
D(LCPI(-1))	-3.879458	0.0157	D(DUMMY(-1))	-0.089024	0.1814
			D(DUMMY(-2))	-0.081827	0.2257
			D(DUMMY(-3))	-0.129856	0.0204
CointEq(-1)	-0.770708	0.0000	CointEq(-1)	-0.866117	0.0006
Long run Coefficients					
LINV	-0.210044	0.6021	LINV	0.196623	0.0000
LGDP	-0.073242	0.9728	LGDP	-2.224552	0.0269
LCPI	0.515445	0.3380	DUMMY	-0.121132	0.4078
C	0.381323	0.9678	C	9.653782	0.0350
D(LINV) differenced logged investment; D(LGDP) differenced logged gross domestic product; D(LCPI) differenced logged consumer price index; CointEq cointegration equation					

Source: Own compilation from SARB and MIT Atlas of economic complexity

Figure 2: Cusum and Cusum of Squares for ECI-Information System Series, 1960-2018



Source: Own compilation from SARB and MIT Atlas of economic complexity

5. Conclusion and Recommendations

Even though South Africa is a rich country in natural resources such as agricultural products and minerals, it has been observed that these products are exported as raw products. This resulted to South Africa rated 55 out of 129 countries in the Atlas of Economic Complexity list. Therefore, the study aimed to investigate if information systems can influence economic complexity in South Africa. The annual data spanning in the period 1960 to 2018 was obtained from the South African Reserve Bank and MIT Atlas of economic complexity. The autoregressive distributive lag (ARDL) was used to investigate the set aim.

Results of the ARDL bounds test gave an F-statistic of 7.17 greater than the upper bound and this indicated a long run relationship in the series. Furthermore, investment in information systems had a significant positive relationship to economic complexity with a speed of adjustment of 87%. This implies that information system is a faster route to be considered to enhance economic complexity. Investing in information system has proved to be innovative and contribute to firm output and labour productivity. Furthermore, information technology improves organizational performance, reduce production cost and improve production of all personnel and ultimately increase efficiency of human capital. The positive relationship between information systems and economic complexity is a good indicator that South Africa can enhance its complexity through information systems activities. It is therefore, recommended that the South African government should invest in information systems or digital platforms as this could yield a faster route towards the fourth industrial revolution, especially in the post-COVID-19 era.

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