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Do aggregate domestic consumption spending & technological innovation affect industrialization in South Africa? An application of linear & non-linear ARDL models

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ABSTRACT

The current paper has attempted to measure the effect of the positive and negative shocks of aggregate domestic consumption spending (ADCS) and technological innovation (TINN) on industrialisation in South Africa using the time-series data from 1980 to 2014. The ARDL estimations indicated that the ADCS and TINN determine industrialisation in both the short term and long term, while the NARDL estimations suggested that the positive shocks in ADCS and TINN have a positive effect on industrialisation in both the short run and long run. Our results validated an asymmetrical association between TINN and industrialisation, and between ADCS and industrialisation.

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Aggregate domestic consumption spending (ADCS); technological innovation (TINN); ARDL; NARDL

1. Introduction

Globally, economies are now recognising the need to adapt to changes in industrial technology. Reason being, the high-technology industry has become a critical tool for economic growth as it has enabled both developed and developing economies to manufacture globally competitive goods and services. Over the past few decades, significant advancements in equipment and production techniques have enabled increased productivity, efficient production, and low labor-cost (Tabi, 2011). Broadly, industrialisation not only improves an economy's capacity to convert raw materials, intermediate goods, and other inputs into finished goods more efficiently, but also generates increased varieties and volume of manufactured products. Beyond that, it also improves employment and living standards (Maku, 2015). As a primary aspect of the economic policy in most developing countries (Jelilov, Enwerem, & Isik, 2016), it is considered as an indispensable tool to alleviate poverty and improve economic growth. Despite that, the industrialisation patterns have a profound impact on the benefits that the poor receive from economic activities. Such that, industrial and pro-poor economic policies are often focused on expanding the economic returns to the productive factors possessed by the poor, for example, increasing benefits for labours without skills (United Nations, 2007). In parallel, aggregate consumption and innovation also play a significant role in the

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industrialisation process. Higher aggregate consumption facilitates the industrial sector to produce more goods and services, and expand their business: installing new plants; hiring skilled labours, increasing research and development; and applying innovative and advanced technology. With increased productivity and efficiency, industries can produce goods at low cost without compromising on product quality. Consumers' satisfaction for products increases and enables excessive consumption, thereby forming a continuous cycle between aggregate consumption and manufacture value-added as shown in Figure 1.

That said, the aggregate consumption is not always constant given that it may rise and fall over time due to economic shocks. During recessions, economic activities decline, which in turn, undermines average income and aggregate consumption spending, and the level of industrial production: consequently, leading to the closure of production plants, decreased wages, and lay-offs. In contrast, increased economic activities during the economic boom cause a rise in average income, aggregate consumption spending, and industrial production increases: subsequently, leading to new production plants, increased labour wages and employment. Thus, the negative shock of aggregate consumption spending harms the process of industrialisation, while the positive shock of aggregate consumption spending enhances the process of industrialisation. Equally important, the importance of technological innovation has been widely recognized for attaining economic growth, productivity, and sustainable development of our societies. Technological innovation practices have benefited multiple domains such as, cognitive, cultural, political, technological and scientific. Given that learning abilities are crucial for transforming, solving and leveraging socioeconomic realities, technological innovation enables societies to invent more efficient capital goods and feasible solution for optimal production systems (Adesida, Karuri-Sebina, & Resende-Santos, 2016).

South Africa, as one of the fastest developing economies, recognises the importance of technological innovation and industrialisation. From 1980 to 2014, the average growth in manufacturing value-added (MVA) and average growth in aggregate domestic consumption spending (ADCS) of South Africa were 15.75% and 5.50%, respectively. From 1980 to 2014, South Africa's MVA and ADCS were higher than other African economies, which means that the impact of ADCS on industrialisation was relatively more significant. Even though there is no empirical study that explains the complex interaction between MVA,

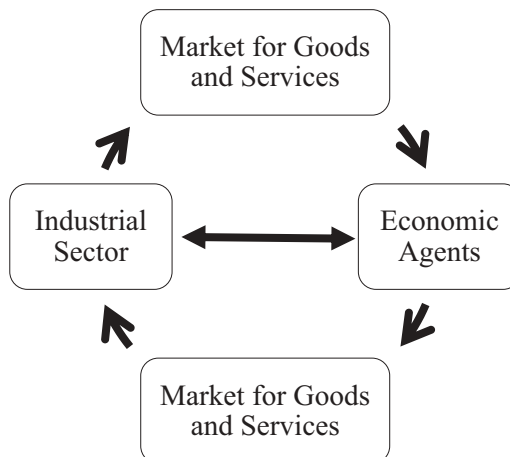


Figure 1. Circular model of ADCS and industrial production.

ADCS and industrialisation, a possible explanation resides in the positive and negative shocks in ADCS and their subsequent impact on industrialisation.

Therefore, the study's purpose is to examine the impact of the positive and negative shocks of ADCS and TINN on industrialisation. The paper contributes to the existing economic literature in many ways. First, to the best of our knowledge, it is the first study on the nexus among ADCS, TINN and industrialisation. Second, the proposed conceptual framework elaborates how ADCS and technological innovation (TINN) contribute to the process of industrialisation under different economic conditions. Third, this empirical study represents an initial attempt to examine potential asymmetrical nexus between ADCS, TINN, and industrialisation using the non-linear ARDL (NARDL).

The rest of the paper is divided into six different parts. Part 2 discusses the conceptual framework. Part 3 outlines the data sources, methodology, and econometric specification. Part 4 elaborates the empirical findings. Part 5 provides the conclusions, followed by policy recommendations and limitations of the study.

2. Conceptual framework

2.1. Industrial development in south africa: an overview

The industrial development across different sectors in South Africa suggests that industrialisation that occurs at the back of protective barrier is far vigorous than traditional scholars admit, and that the investments in the public sector can be robust and incite growth. From 1925 to 1973, the South Africa government followed an “import substitution” strategy to enhance the level of state investment and inland manufacturing across key sectors. This process of industrialisation formed a symbiotic association between the state-owned enterprises, the state, and the mining industry. This relationship led to creation of massive state-owned corporations, local-market and industry protection strategy, labour exploitation and suppression, guaranteed provision for and new companies. Regardless of protectionism, economic growth was remarkable through the 1960s. The expansion of the manufacturing sector was mainly conspicuous, and South Africa remains the most industrialised nation in Sub-Sahara Africa (Schneider, 2000). During the 1980s, South Africa's economic conditions deteriorated as the manufacturing sector lost the ability to either produce employment opportunities or products that could meet the needs of both domestic and global market. Factors that contributed to this adverse situation included the poorly structured protection systems, highly concentrated industrial structure coupled with a concomitantly ineffectual and intimidated micro-enterprise and SME sector, technological backwardness, apartheid's impact on the workforce skills profiling, outmoded and repressive work organisation, and ineffective industrial relations systems (Joffe & Kaplan, 1995). Despite all challenges, South Africa has not only emerged as one of the fastest emerging economies but also ranks in the list of newly industrialised economies. Figure 2 depicts the MVA for the top eight African emerging economies. With almost 20% share, South Africa ranked among the top during vis-a-viz MVA contributions in 2018.

Figure 3 shows the top 10 manufacturing sector during 1998, representing the category-wise (percentage) sales. As shown below, the food category (fruit, fish, meat, etc.) made up about 7.2% of the total manufacturing. While the manufacturing of steel production and basic iron, other food products, parts and accessories, coke, petroleum

Manufacturing value added: Top 8 African Countries

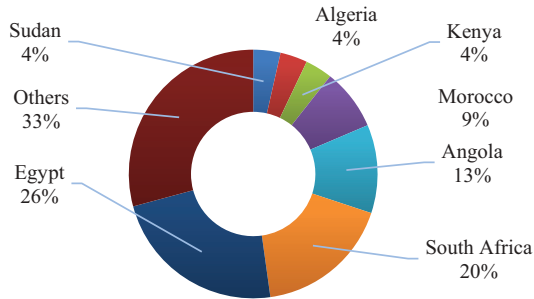


Figure 2. Manufacturing value-added: Top 8 emerging economies in Africa. Source: South Africa Market Insights (2018)

products and nuclear fuel, beverages, non-ferrous metal products, motor vehicles, other chemical products, and basic chemicals made of 6.45%, 5.39%, 3.79%, 7.02%, 6.41%, 5.29%, 6.74%, 6.08%, and 4.32% of total manufacturing, respectively.

From another perspective, technology and innovation not only contribute to the industrialisation process but also enhance the quality of the production process. Over the years, industries have shifted from low-tech and resource-based activities to medium-high and high-tech undertakings. The increasing share of medium-high and high-tech industries signifies ongoing efforts of the government to enhance the technological superiority in manufacturing. Industries have been making significant, in terms of manufacturing the tools and machinery needed by construction, mining livestock, agriculture, manufacturing, and a range of consumer goods companies (UNDP, 2018).

Below, Table 1 indicates the technology-intensity compositions of MVA across developed and developing economies. South Africa is not only dominating among African

South Africa: Manufacturing Categories, 1998

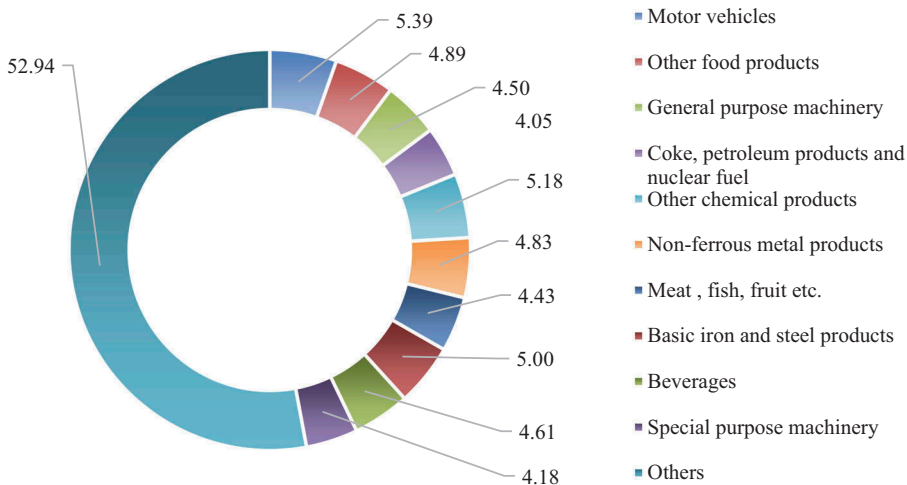


Figure 3. South Africa: the Percentage share of each sector within the manufacturing industry. Source: South Africa Market Insights (2018).

economies in the medium-high and high-tech categories, but it also stands prominent in the Sub-Saharan Africa vis-a-viz competitiveness and innovation.

2.2. Integrating aggregate consumption spending, technological innovation, and industrialisation: a conceptual framework

Generally, the demand in an open economy is often considered to be regulated by four economic agents (i.e. domestic consumers, producers, government, and international consumers) whose total expenditures represent gross domestic demand. The total expenditures on domestic output are equal to the total spending by each of the aforementioned economic agents. Because individuals consume domestic and foreign-produced goods, the total consumption spending is computed as a sum of foreign plus domestically produced goods. The same logic applies to investors and government spending. In other words, the gross domestic product (GDP) reflects the difference between aggregate consumption spending on domestic and foreign-produced goods by the residents of the country. The relationship between aggregate spending on output and the aggregate consumption spending on domestic and foreign-produced goods can be expressed as Equation (1):

$$Y^{\forall} = AC - AC^{\tau} \quad (1)$$

Where: Y^{\forall} = domestic output; AC = aggregate spending on the consumption of goods; AC^{τ} = aggregate spending on the consumption of imported goods; and $AC - AC^{\tau}$ = aggregate domestic consumption spending (ADCS). AC is the sum of total consumption spending on domestically produced goods by consumers, producers, and government, while the AC^{τ} is the sum of the total consumption spending on foreign-produced goods by the same agents. The ADCS includes changes in inventories, household consumption expenditure, final consumption expenditure, general government expenditure, gross capital formation, gross fixed capital formation, and exports. Equation (1) shows that the total spending on domestically produced goods is determined by the difference between aggregate spending on consumption of local plus imported goods. This equation is derived from the national income identity. Besides, gross domestic production reflects the total value-added of production. Many sectors are responsible for the production of goods and services (e.g., agriculture, forestry, fishing, mining, manufacturing), and thus, sum of the value-added of different sectors combines to form the total consumption spending. Therefore, Equation (1) can also be modified as;

$$\begin{aligned} &AHFFVA + MMUVA + MVA + CVA + WRRHVA + TSCVA + OAVA \\ &= AC - AC^{\tau} \end{aligned} \quad (2)$$

Where; AHFFVA = agriculture, hunting, forestry, and fishing value-added; MMUVA = mining, manufacturing, and utilities value-added; MVA = MVA; CVA = construction value-added; WRRHVA = wholesale, retail trade, restaurants, and hotels value-added; TSCVA = transport, storage, and communication; and OAA = other activities value-added. Providing the prime objective is to investigate the possible association between ADCS and industrialisation, we readjusted equation (2) for MVA as follows:

$$MVA = (AC^* - AC^{*\tau}) \quad (3)$$

Table 1. Technology intensity composition of MVA by industrialisation level, development group, region and income, 2005, 2010, and 2015 (per cent).

Grouping	2005			2010			2015		
	Low tech	Medium-low tech	Medium-high tech	Low tech	Medium-low tech	Medium-high tech	Low tech	Medium-low tech	Medium-high tech
World	30.8	27.0	42.2	29.8	26.3	43.9	29.0	26.3	44.7
<i>By industrialisation level</i>									
Industrialized economies	28.6	25.6	45.8	27.4	24.3	48.3	26.1	24.1	49.9
North America	32.8	24.2	43.0	30.9	22.9	46.2	28.7	23.0	48.3
Europe	28.4	27.1	44.4	27.9	25.7	46.4	26.4	25.1	48.5
East Asia	22.1	23.8	54.1	21.2	22.4	56.5	20.8	22.1	57.1
Developing and emerging industrial economies	36.4	30.8	32.8	34.0	29.9	36.1	33.2	29.5	37.3
Other developing economies	45.3	31.4	23.4	43.7	32.6	23.8	46.2	26.9	26.9
Least developed countries	61.4	25.9	12.7	70.2	20.8	9.0	73.3	19.4	7.3
<i>By region (developing and emerging industrial economies)</i>									
Africa	49.4	29.8	20.8	49.6	31.2	19.2	58.2	22.6	19.2
South Africa	42.4	29.9	27.8	43.9	28.6	27.5	44.5	26.8	28.7
Asia and Pacific	32.0	30.8	37.3	29.9	30.1	40.0	29.1	30.1	40.8
China	29.9	30.5	29.6	28.5	30.0	41.5	27.5	30.3	42.2
India	26.5	40.0	33.5	22.8	38.8	38.4	23.9	40.7	35.4
Europe	42.5	27.9	29.6	40.9	27.9	31.2	38.9	27.9	33.2
Poland	41.9	26.1	32.0	37.2	27.9	34.9	36.8	29.2	34.0
Turkey	41.2	27.2	31.6	40.6	27.4	32.0	38.2	26.9	35.0
Latin America	39.9	32.3	27.7	40.0	29.8	30.2	41.4	29.4	29.2
Mexico	33.0	33.7	33.3	34.0	30.9	35.1	32.1	28.1	39.9
<i>By income level</i>									
High income	29.0	25.6	45.4	27.7	24.4	47.9	26.4	24.2	49.3
Upper-middle income	34.7	31.3	34.0	32.4	30.1	37.5	30.8	30.1	39.1
Lower-middle income	38.4	29.6	32.0	36.6	29.5	33.9	39.1	27.1	33.8
Lower income	63.2	24.9	11.8	71.4	20.3	8.3	73.8	19.5	6.7

Note. Manufacturing value-added is in constant 2010 USD. Source: UNDP (2018)

Where: AC^* = aggregate consumption spending on manufactured products; and, $AC^{*\tau}$ = aggregate consumption spending on imported manufactured products. Equation (3) indicates that the economic agents consume and are willing to buy the entire produce of the manufacturing sector, depending on individual choices, taste, prices, and quality. Thus, it is safe to assume that any change in ADCS will cause a significant change in the MVA. This situation, to some extent, occurs as high consumption spending often encourages the manufacturing sector to allocate additional capital for the instalmentsof new plants, tools, machinery, and to hire more labours. Manufacturers adopt innovative, sophisticated and advanced technology to produce more goods at a lower cost; consequently, increasing the industrialisation process in developing economies. Assuming that ADCS is an essential factor of MVA, any change in ADCS will also affect industrialisation. Based on such assumption, the changes in ADCS and MVA can be stated in the following form:

$$\Delta MVA = (\Delta AC^* - \Delta AC^{*\tau}) \quad (4)$$

Where: ΔMVA = change in MVA; ΔAC^* = change in aggregate consumption spending; and, $\Delta AC^{*\tau}$ = change in aggregate spending on imported goods; and $\Delta AC^* - \Delta AC^{*\tau}$ = change in ADCS. The ADCS-related changes in MVA are called aggregate domestic consumption spending to manufacturing value-added (ADCS-MVA), which are presented below in the mathematical form as equation (5):

$$ADCS - MVA = \frac{\Delta MPV}{\Delta (AC^* - AC^{*\tau})} = \frac{\Delta MPV}{\Delta ADCS} \quad (5)$$

The ADCS-MVA estimates the variations in the manufacturing value-added due to changes in the aggregate domestic consumption spending. The association between ADCS and MVA is depicted in [Figure 4](#).

The MVA_0 and $ADCS_0$ represent the starting points of the MVA and ADCS. As ADCS increases from $ADCS_0$ to $ADCS_1$, the MVA concurrently increases from MVA_0 to MVA_1 . The curve formed by joining the orange and blue points can be described as the ADCS curve, which depicts the positive association between ADCS and MVA. The slope of ADCS curve is called the ADCS to manufacturing value-added intensity (ADCSP-MVA). The ADCS-MVA is represented by the ADCS line, a sloped line created by plotting change in MVA (Y-axis) and ADCS (X-axis). Given the data on ADCS and MVA, the ADCS-MVA can be easily computed. This computation is crucial as the ADCS-MVA is not constant and varies due to changes in the level of ADCS: higher the ADCS, the higher will be ADCS-MVA. With an increase in domestic demand, the industrial production will rise, and further increase the MVA. The main concept behind the ADCS-MVA is that higher ADCS expands the aggregate domestic demand, industrial production, economic growth, and MVA. Using the value of ADCS-MVA, the impact size of an increase in ADCS on industrialisation can be easily estimated.

Furthermore, economic situation is inconsistent given that it experiences economic shocks in both the short and long-run as a process of the economic cycle. Recessions, as a negative shock, lead to a decline in economic activities and exert pressure on living-costs and savings of people. This shock in ADCS causes a change in the level of poverty, real income, public debt, tax collection, economic growth while decreasing MVA in the short term. With the declining level of ADCS, manufacturers attempt to follow consumer's demand and cut down the cost of production to avoid potential losses: subsequently, decreasing the MVA. An extreme negative shock in ADCS can even cause high unemployment and significant reduction in the industrial production. As illustrated in [Figure 5](#), the

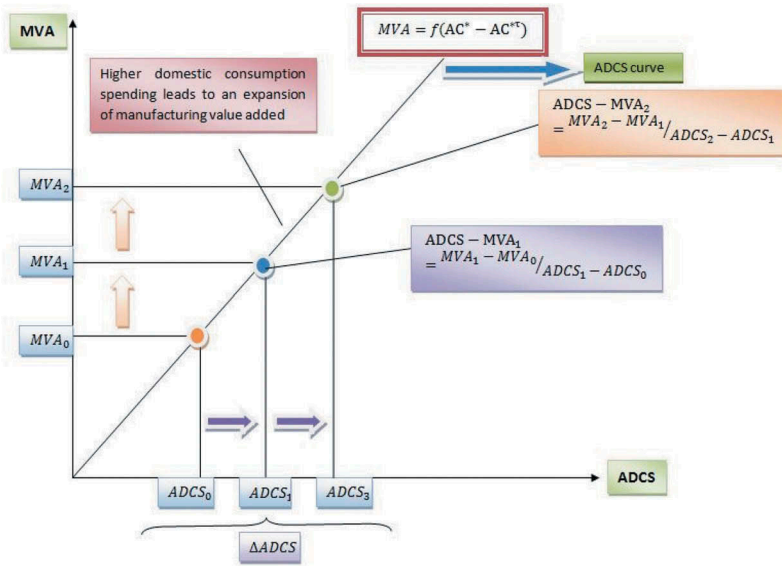


Figure 4. Relationship between ADCS and MVA.

MVA is prone to decline as an economy recovers from a negative shock in the short-run. E_0 depicts the initial point of equilibrium where the short-run MVA curve meets the ADCS curve at $ADCS_0$ and MVA_0 . At this point, it is assumed that the aggregate consumption spending is higher than the aggregate consumption spending on foreign-produced goods. Despite this surplus aggregate consumption spending, it is presumed to be a good sign for the domestic industry given that the domestic manufacturing sector is capable of producing at least those products that consumers are willing to consume. Moreover, it enables the manufacturers to use more innovative and high-tech methods to produce goods at a lower cost to increase consumer's satisfaction. After experiencing the negative shocks in ADCS, the equilibrium position in an economy changes from E_0 to E_1 . At this new point of equilibrium (E_1), the ADCS and MVA plunge to $ADCS_1$ and MVA_1 , respectively, i.e. the ADCS curve moves from right to left. If the decline in economic activities prevails for a long time, the economic situation is more likely to worsen. The long-run period is uncertain, and thus, it is probable that some exogenous shocks may further deteriorate the economic environment, causing a further decline in the ADCS and MVA. For an economy that needs an extended period (long-run) to revert to the initial equilibrium point, the ADCS and MVA must follow the same direction.

Contrary to above, an economy on a path of sustainable growth with moderate inflation and the low unemployment rate is expected to cause an increase in the income per capita and ADCS. The positive shock in ADCS is characterised by a significant positive change in MVA and economic growth in the short term. With increasing ADCS, manufacturers tend to increase production and employ more skilled labours, which contributes to MVA. Thus, it is rational to assume that a positive shock is more likely to enhance the industrialisation process if an economy is capable of taking less time (short-run) to revert to the initial equilibrium point. The effect of a positive shock of ADCS on MVA is depicted in Figure 6.

E_0 represents the initial equilibrium position where SRMVA intersects the ADCS curve with $ADCS_0$ and MVA_0 . Because of the negative shocks in ADCS, the equilibrium position shifts from E_0 to E_1 . Due to the adverse shocks, the ADCS and MVA move to

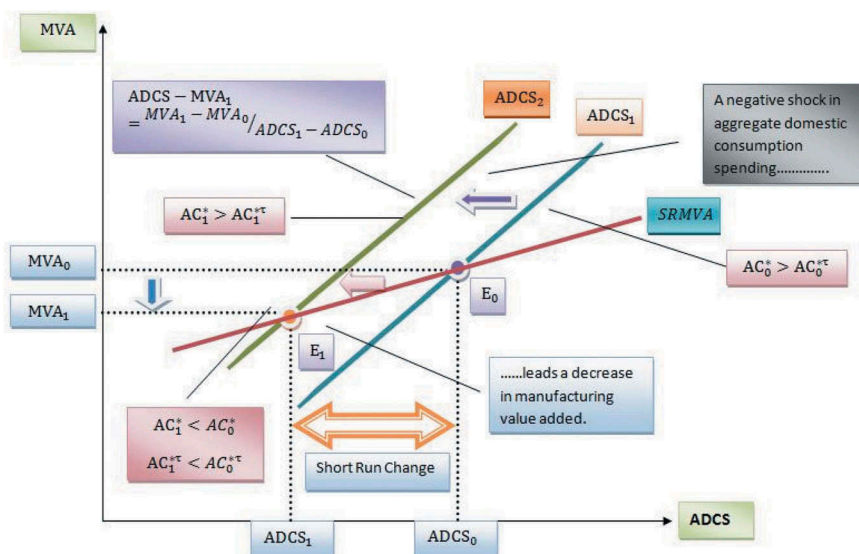


Figure 5. Shifts of ADCS: Short-run ADCS negative shock.

ADCS₁ and MVA₁, i.e. the ADCS curve moves from left to right. If the rise in economic activity continues for an extended period, the persistent increase in income is predicted to cause an expansion in the ADCS. In this situation, manufacturers are more likely to boost the production of goods; consequently, increasing economic growth and MVA. For an economy that needs an extended period (long-run) to return to the initial equilibrium position, the ADCS and MVA must follow a similar path for a long time.

In the same context, the market-size and household income have been identified as the critical factors in the big push theory of industrialisation (Murphy, Shleifer, & Vishny, 1989b; 1989a). Several studies have empirically validated the positive and significant influence of these factors on industrialisation, often using GDP per capita as a proxy for aggregate income (Dong, Song, & Zhu, 2011; Kang & Lee, 2011; Kaya, 2010). One factor of the big push industrialised, as suggested by Murphy et al. (1989b) and Rosenstein-Rodan (1943), is elaborated in this statement: “simultaneous investment by many firms can become profitable even when each lost money investing in isolation”. Simultaneous investments are expected to raise the aggregate demand through the level of market-size and income for all firms. In addition, Rowthorn and Ramaswamy (1997) and Kaya (2010) have found a positive nexus between investments and industrialisation for both developing and the OECD economies. Rowthorn and Ramaswamy (1997) defended their rationale using the demand for manufactured goods as a basis for this positive relationship, but Kaya (2010) argued that the reinvestment of returns from inward investments in the home country appears to be the rationale for the investment-industrialisation nexus.

From a contextual perspective, the reported estimates for MVA across many economies in Africa reflect signs of de-industrialisation, which is often attributed to low level of international trade and diminishing income. Theoretically, although a positive correlation between income and industrialisation exists, it can be negative if the level of income reaches a certain threshold. This phenomenon is also known as the inverted-U theory of industrialisation. The same concept advocates that de-industrialisation is a natural course of action along with

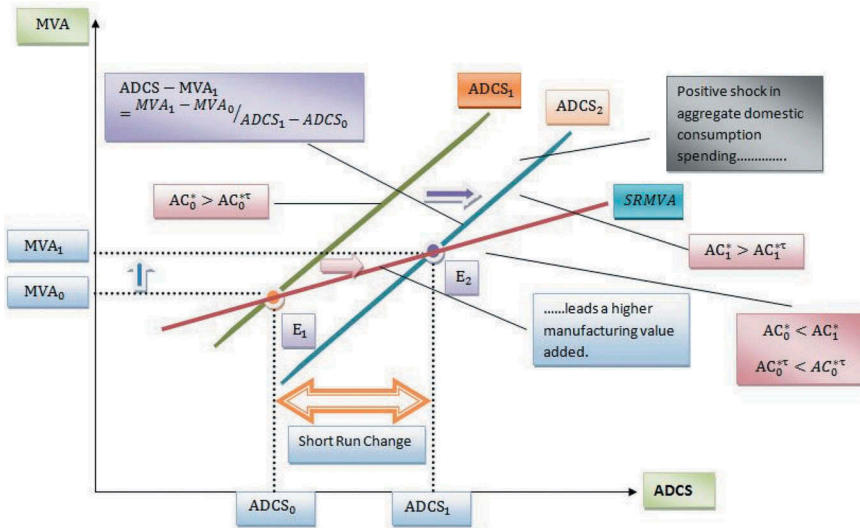


Figure 6. Shifts of ADCS: Short-run ADCS positive shock.

development given than an increase in the level of income generates a shift in patterns of consumption from non-processed products to manufactured products (industrialisation). Rowthorn and Ramaswamy (1997) argued that the differences between exports and imports are important factors of industrialisation and found that a negative nexus between imports of products and industrialisation. Kaya (2010) also studied the linkage between the square of gross domestic product per capita and industrialisation. Gui-Diby and Renard (2015) asserted that agricultural value-added and FDI are essential factors of industrialisation. Many scholars have also concluded that innovation and technology have boosted the industrialisation process in developing economies (Delfino & Gillespie, 2008; Greif, Kiesling, & Nye, 2015; Rasiah, Lin, & Sadoi, 2013; Scott & Storper, 1992). To summarise, most studies mentioned above have recognised that gross domestic products, net exports, imports, foreign direct investment, agriculture value-added, and technological innovation are imperative factors of industrialisation. Thus, the current empirical model, derived from the national income identity, integrated the effects of net exports, FDI and agricultural value-added. Based on the previous discussion, a new variable (TINN) was added in equation (3) to examine the nexus between technological innovation and industrialisation:

$$MVA = (AC^* - AC^{*\tau}) + TINN \quad (6)$$

where TINN represents technological innovation. In equation (6), the MVA depends not on both the ADCS and TINN. A possible explanation is that higher aggregate demand for manufactured goods provides a space for new investors to establish firms to fill the demand-supply gap, while simultaneously technological innovation in capital goods enables the existing firms to manufacture products at low cost. These two parallel developments enhance the industrialisation, and thus, any changes in these two factors are predicted to bring a variation in MVA, as shown in equation (7):

$$\Delta MVA = (\Delta AC^* - \Delta AC^{*\tau}) + \Delta TINN \quad (7)$$

Where: ΔMVA = change in manufacturing value-added; $\Delta AC^* - \Delta AC^{*\tau}$ = change in ADCS; $\Delta TINN$ = change in technological innovation. The TINN-related change in MVA is called aggregate technological innovation to manufacturing value added (TINN-MVA), presented in the following mathematical equation:

$$ADCS - TINN = \frac{\Delta MPV}{\Delta TINN} \quad (8)$$

TINN-MVA estimates variations in MVA due to changes in the aggregate TINN. Technological innovation is vital for firms because it: enhances the production process; enables the entrepreneur to produce goods in large quantity within a short time period; decreases the cost of production that further increases the total revenues. Technological innovation relies on different factors including, innovation budget, number of graduates, firm size, and economic condition. Economic recessions usually follow financial crisis, in which both governments and firms often struggle to either conduct or support innovation activities. Since any changes in these factors bring a change in technological innovation and industrial value-added, it is estimated that the positive and negative shocks in technological innovation and industrialisation process must follow the same path in the long and short run.

3. Methods and measures

3.1. Data sources, variables, and software

The data (in the constant USD) for all variables were compiled from the United Nations Statistics Divisions (UNSD) for the period 1980–2016. These variables included the imports of goods, final consumption expenditures, household consumption expenditures, general government final expenditures, gross fixed capital formation, changes in inventories, exports of goods, construction value-added, wholesale, retail trade, restaurants and hotels value-added, construction value-added, transport, storage and communication value-added, mining, manufacturing, and utilities value-added, agriculture, hunting, forestry and fishing value-added, and MVA. The data for patent applications were taken from the World Bank Data Base. All the variables were converted into a logarithmic form to be analysed using the Eviews10 software.

3.2. Model specifications

To analyse the impact of positive and negative shocks (in ADCS and TINN) on industrialization, the NARDL model was used. NARDL, introduced by Shin, Yu, and Greenwood-Nimmo (2014), is an extended version of the traditional ARDL model (Pesaran, Shin, & Smith, 2001). The method includes a dynamic error-correction description that allows for capturing the positive and negative shocks in both the short and long-run (Mensi, Hammoudeh, Shahzad, & Shahbaz, 2017), irrespective of regardless of whether [or not] the series is I (0), I (1) or mixed (Ahmad, Khan, Ur Rahman, & Khan, 2018; Ahmad et al., 2019; Rahman & Ahmad, 2019; Rahman, Wu, & Manzoor, 2019). Before proceeding to the complete NARDL model, the linear relationship is presented in the following equation (9):

$$\Delta MVA_t = \alpha_0 + \sum_{i=1}^m \alpha_{1i} \Delta MVA_{t-i} + \sum_{i=0}^m \alpha_{2i} \Delta ADCS_{t-i} + \sum_{i=0}^m \alpha_{3i} \Delta TINN_{t-i} + \alpha_{4i} MVA_{t-i} + \alpha_{5i} ADCS_{t-i} + \alpha_{6i} TINN_{t-i} + v_t \quad (9)$$

Where: MVA = manufacturing value added; ADCS = aggregate domestic consumption spending; TINN = technological innovation; $\alpha_1, \alpha_2, \alpha_3$, = short-run coefficients; $\alpha_4, \alpha_5, \alpha_6$ = long-run coefficients; and, v_t = error term. The error-correction model for equation (9) is presented below in equation (10):

$$\Delta MVA_t = \beta_0 + \sum_{i=1}^m \beta_{1i} \Delta MVA_{t-i} + \sum_{i=0}^m \beta_{2i} \Delta ADCS_{t-i} + \sum_{i=0}^m \beta_{3i} \Delta TINN_{t-i} + \lambda ECT_{t-i} + \mu_t \quad (10)$$

Where ECT signifies the error correction term and its value can be obtained from the residuals of equation (9), while λ refers to the speed of the adjustment coefficient.

As the main objective of this paper is to test the asymmetric effect of ADCS and TINN on industrialisation, two different equations have been estimated. The nonlinear association between ADCS and industrialisation is presented in the following asymmetric long-run regression equation:

$$MVA_t = \varpi_0 + \varpi_1 ADCS_t^+ + \varpi_2 ADCS_t^- + \varpi_3 TINN_t + \varepsilon_t \quad (11)$$

Where: MVA = manufacturing value added integrating of order one; TINN = technological innovation (order one); ADCS = aggregate domestic consumption spending; $\varpi = (\varpi_0, \varpi_1, \varpi_2, \varpi_3)$ = vector of long-run unknown parameters; $ADCS_t = ADCS_0 + ADCS_t^+ + ADCS_t^-$; $ADCS_t^+$ = partial sum process of positive in ADCS_t; and, $ADCS_t^-$ = partial sum of negative variation in ADCS_t. The nonlinear association between TINN and industrialization is presented in the following asymmetric long-run regression equation:

$$MVA_t = \varrho_0 + \varrho_1 TINN_t^+ + \varrho_2 TINN_t^- + \varrho_3 ADCS_t + \varepsilon_t \quad (12)$$

Where: MVA = manufacturing value added (integrating of order one); INNT = technological innovation (order one); ADCS = aggregate domestic consumption spending; $\varrho = (\varrho_0, \varrho_1, \varrho_2, \varrho_3)$ = vector of long-run unknown parameters; $TINN_t = TINN_0 + TINN_t^+ + TINN_t^-$; $TINN_t^+$ = partial sum process of positive in TINN_t; and, $TINN_t^-$ = partial sum of negative variation in TINN_t. The partial sum of variation in each variable is depicted in the following equations:

$$\begin{aligned} ADCS_t^+ &= \sum_{j=1}^t \Delta ADCS_j^+ = \sum_{j=1}^t \max(\Delta ADCS_j, 0), \quad ADCS_t^- = \sum_{j=1}^t \Delta ADCS_j^- \\ &= \sum_{j=1}^t \min(\Delta ADCS_j, 0) \end{aligned} \quad (13)$$

$$\begin{aligned} \text{TINN}_t^+ &= \sum_{j=1}^t \Delta \text{TINN}_j^+ = \sum_{j=1}^t \max(\Delta \text{TINN}_j, 0), \text{TINN}_t^- = \sum_{j=1}^t \Delta \text{TINN}_j^- \\ &= \sum_{j=1}^t \min(\Delta \text{TINN}_j, 0) \end{aligned} \quad (14)$$

By integrating equation 11 and 1 in the ARDL, we obtain the following equations.

$$\begin{aligned} \Delta \text{MVA}_t &= \Gamma_0 + \varsigma_1 \text{MVA}_{t-1} + \Gamma_2 \text{TINN}_{t-1} + \Gamma_3 \text{ADCS}_{t-1}^+ + \Gamma_4 \text{ADCS}_{t-1}^- + \sum_{i=1}^p \Gamma_5 \Delta \text{MVA}_{t-i} \\ &+ \sum_{i=1}^a \Gamma_6 \Delta \text{TINN}_{t-i} + \sum_{i=0}^m (\zeta_i^+ \Delta \text{ADCS}_{t-i}^+ + \zeta_i^- \Delta \text{ADCS}_{t-i}^-) + \epsilon_t \end{aligned} \quad (15)$$

$$\begin{aligned} \Delta \text{MVA}_t &= \Gamma_6 + \Gamma_7 \text{MVA}_{t-1} + \Gamma_8 \text{ADCS} + \Gamma_9 \text{TINN}_{t-1}^+ + \Gamma_{10} \text{TINN}_{t-1}^- + \sum_{i=1}^p \Gamma_{11} \Delta \text{MVA}_{t-i} \\ &+ \sum_{i=1}^a \Gamma_{12} \Delta \text{ADCS}_{t-i} + \sum_{i=0}^m (\vartheta_i^+ \Delta \text{TINN}_{t-i}^+ + \vartheta_i^- \Delta \text{TINN}_{t-i}^-) + \epsilon_t \end{aligned} \quad (16)$$

Where a and m are lag orders. The hidden cointegration issue may arise in the estimated equations (11 and 12) and fail to provide the accurate interpretations of the estimated asymmetric coefficients (Lardic & Mignon, 2008). Following Shin et al. (2014), we thus imposed a restriction on the coefficients of equation 11 and 12 i.e. $\varpi_2^+ = -\Gamma_3^+/\varsigma_1$, $\varpi_3^- = -\Gamma_4^-/\varsigma_1$, $\varrho_1^+ = -\Gamma_9^+/\Gamma_7$ and $\varrho_2^- = -\Gamma_{10}^-/\Gamma_7$.

$\sum_{i=0}^m \zeta_i^+$ and $\sum_{i=0}^m \vartheta_i^+$ estimate the short-run possible response of ADCS and TINN to an increase in industrialisation, while $\sum_{i=0}^m \zeta_i^-$ and $\sum_{i=0}^m \vartheta_i^-$ measure the short-run response of ADCS and TINN to industrialisation. Therefore, as the next step, we captured the asymmetric short-run impact of variations in ADCS and TINN on industrialisation along with asymmetric long-term association. The error-correction models (ECM) for the previous equations are depicted as:

$$\begin{aligned} \Delta \text{MVA}_t &= \sum_{i=1}^p A_i \Delta \text{MVA}_{t-i} + \sum_{i=1}^a B_i \Delta \text{TINN}_{t-i} + \sum_{i=1}^m (\eta_i^+ \Delta \text{ADCS}_{t-i}^+ + \eta_i^- \Delta \text{ADCS}_{t-i}^-) \\ &+ Y_i \text{ECT}_{t-1} + \vartheta_t \end{aligned} \quad (17)$$

$$\begin{aligned} \Delta \text{MVA}_t &= \sum_{i=1}^p E_i \Delta \text{MVA}_{t-i} + \sum_{i=1}^a H_i \Delta \text{ADCS}_{t-i} + \sum_{i=1}^m (I_i^+ \Delta \text{TINN}_{t-i}^+ + I_i^- \Delta \text{TINN}_{t-i}^-) \\ &+ O_i \text{ECT}_{t-1} + \vartheta_t \end{aligned} \quad (18)$$

Where: A_i and B_i = short-run coefficients; η_i^+ , η_i^- , I_i^+ and I_i^- signify short-run adjustment symmetry; and Y_i and O_i = coefficient of error correction term.

For data analysis, the estimation of the equations above involved the following procedures. First, although the NARDL approach can be used, irrespective of the integration of order, it very crucial to conduct unit-root tests to ensure that no variable is integrated order of two. Thus, the Augmented Dicky Fuller (ADF) and Phillips-Perron (PP) unit root were utilised, in addition to, a unit root test with structure break. Second, equation (8) and (9) were estimated to examine the long and short-run relationship between ADCS, TINN, and industrialisation. Third, the ARDL Bound test was used to check the co-integration among variables, in which we tested the null hypothesis of no long-run association ($H_0 : \alpha_4 = \alpha_5 = \alpha_6 = 0$) against the alternative hypothesis ($H_1 : \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq 0$). Fourth, equation (15) and (17) were estimated to test possible impact of the positive and negative impact of ADCS on industrialisation. Fifth, the null hypothesis of no long-run association ($H_0 : \varsigma_1 = \Gamma_2 = \Gamma_3 = \Gamma_4 = 0$) was tested against the alternative hypothesis ($H_1 : \varsigma_1 \neq \Gamma_2 \neq \Gamma_3 \neq \Gamma_4 \neq 0$) after validating the long-run relationship among variables. Sixth, the next step was to confirm the possible long-run asymmetric association between ADCS and industrialisation by testing the null hypothesis of no long-run asymmetrical relationship between ADCS and industrialisation ($H_0 : -\Gamma_3^+/\varsigma_1 = -\Gamma_4^-/\varsigma_1$) against the alternative hypothesis ($H_1 : -\Gamma_3^+/\varsigma_1 \neq -\Gamma_4^-/\varsigma_1$). The short-run asymmetric relationship between ADCS and industrialisation was tested: the null hypothesis of no short-run asymmetrical relationship between ADCS and industrialisation ($H_0 : -\zeta_i^+/\Gamma_5 = -\zeta_i^-/\Gamma_5$) against the alternative hypothesis ($H_1 : -\zeta_i^+/\Gamma_5 \neq -\zeta_i^-/\Gamma_5$).

In the same way, equation (16) and (18) were estimated to compute the possible impact of positive and negative components on TINN and industrialisation. After estimating the long-run coefficients of positive and negative components of TINN, the bound testing method was applied to detect the co-integration among variables, in which the null hypothesis of no long-run association ($H_0 : \Gamma_7 = \Gamma_8 = \Gamma_9 = \Gamma_{10} = 0$) against the alternative hypothesis ($H_1 : \Gamma_7 \neq \Gamma_8 \neq \Gamma_9 \neq \Gamma_{10} \neq 0$). The next was to confirm the possible long-run asymmetric association between TINN and industrialisation by testing the null hypothesis of no long-run asymmetrical relationship between TINN and industrialisation ($H_0 : -\Gamma_9^+/\Gamma_7 = -\Gamma_{10}^-/\Gamma_7$) against an alternative hypothesis ($H_1 : -\Gamma_9^+/\Gamma_7 \neq -\Gamma_{10}^-/\Gamma_7$). Likewise, the short-run asymmetric relationship between TINN and industrialisation was tested: the null hypothesis of no short-run asymmetrical relationship TINN and industrialisation ($H_0 : -\vartheta_i^+/\Gamma_{11} = -\vartheta_i^-/\Gamma_{11}$) against the alternative hypothesis ($H_1 : -\vartheta_i^+/\Gamma_{11} \neq -\vartheta_i^-/\Gamma_{11}$).

Finally, we computed the asymmetric cumulative dynamic multiplier effects of 1% variation in $ADCS_{t-i}^+$, $ADCS_{t-i}^-$, $TINN_{t-i}^+$ and $TINN_{t-i}^-$, respectively, follow as:

$$K_{1b}^+ = \sum_{j=0}^b \frac{\partial MVA_{t+j}}{\partial ADCS_{t-1}^+}, \quad K_{2b}^- = \sum_{j=0}^b \frac{\partial MVA_{t+j}}{\partial ADCS_{t-1}^-}, \quad b = 1, 2, 3 \dots \dots$$

$$K_{3b}^+ = \sum_{j=0}^b \frac{\partial MVA_{t+j}}{\partial TINN_{t-1}^+}, \quad K_{4b}^- = \sum_{j=0}^b \frac{\partial MVA_{t+j}}{\partial TINN_{t-1}^-}, \quad b = 1, 2, 3 \dots \dots$$

where $b \rightarrow \infty$, $K_{1b}^+ \rightarrow \varpi_1^+$, $K_{2b}^- \rightarrow \varpi_2^-$, $K_{3b}^+ \rightarrow \omega_1^+$, $K_{4b}^- \rightarrow \omega_1^-$.

All the econometric expressions were integrated into three specifications to develop a better understanding of the equations above. Specification 1, including equation (9) and (10), to examine the linear association between ADCS, TINN, and industrialization. Specification 2, comprising of equation (15) and (17), to investigate the non-linear nexus between ADCS & industrialization; and Specification 3, comprising of equation (16) and (18), to examine the non-linear linkage between TINN & industrialization.

4. Results and discussion

Table 2 demonstrates the results of unit root tests conducted to assess the stationarity at the level and first difference. The t-statistics for MVA were found to be statistically insignificant at the level (ADF = -1.9850, PP = -1.8551), but became significant at first difference (ADF = -5.9370, PP = -6.5441 at 1% level). The t-statistics for ADCS were found to be statistically insignificant at the level (ADF = -2.9644, PP = 2.1345), but became significant at first difference (ADF = -4.3717, PP = -4.1788 at 5% level). The t-statistics for TINN were found to be statistically insignificant at the level (ADF = -1.9487, PP = -2.0396), but became significant at first difference (ADF = -5.4010, PP = -5.6937 at 1% level). Thus, the results (without and without structure breaks) indicated that the MVA, ADCS, and TINN were non-stationary at the level but became stationary after taking the first difference, allowing for conducting the ARDL and NARDL model. As a pre-requisite, it was considered necessary to select the lag order and model selection criteria for further analysis. Based on the AIC results reported in Tables 3 and 1 was selected as the maximum lag order along with the ARDL (1, 1, 0), NARDL (1, 0, 1, 0) and NARDL (1, 0, 1, 0) as model specification.

Tables 4 and 5 indicate the outcomes of the estimated long and short-run coefficients for specification 1, 2 and 3.

As seen in Table 4, the ARDL estimates (Specification 1) show that the long-run ADCS has a positive and significant effect on industrialisation, where a 1% rise in ADCS increased industrialisation by 0.59%. In contrast, a positive and significant connection was observed between ADCS and industrialisation in the short run, where a 1% upsurge in ADCS increased industrialisation by 0.65%. This implies that the expansion of domestic consumption has led to an increase in the aggregate demand, which in turn, generated massive industrial production. It appears that high domestic consumption has enabled the industrial sector to expand its

Table 2. Outputs of the Unit-root tests.

Variables	Level		First Difference	
	ADF	PP	ADF	PP
MVA	-1.9850	-1.8551	-5.9370***	-6.5441***
ADCS	-2.9644	-2.1345	-4.3717**	-4.1788**
TINN	-1.9487	-2.0396	-5.4010***	-5.6937***

Note: ** and *** depict significance at 5% and 1%, respectively. BD = the break date. ADF = Augmented Dickey-Fuller; PP = Phillips-Perron

Table 3. Optimal lag selection and model selection criteria.

Model	AIC*	BIC	HQ	Adj. R-sq	Specification
ARDL	−5.9356	−5.7111	−5.85900	0.9799	ARDL (1, 1, 0)
NARDL 1	−5.9621	−5.6899	−5.8705	0.9811	NARDL (1, 0, 1, 0)
NARDL 2	−6.0231	−5.7510	−5.9316	0.9822	NARDL (1, 0, 1, 0)

final production using new plants and machinery. Such advancement in domestic consumption has, to some extent, contributed to the process of industrial development. From 1980 to 1997, there was surplus aggregate consumption spending (ADCS minus ADCS on foreign goods) in South Africa. This means that people have spent more money on the purchase of domestic goods, indicating the progress and growing capabilities of the South African industrial sector to produce almost all the consumer goods. Furthermore, the long-run coefficient of TINN supported that the technological innovation has a positive and significant effect on industrialisation in South Africa, where a 1% increase in TINN increased industrialisation by 0.0422%. The short-run coefficient of TINN, however, revealed that a 1%

Table 4. Long-run coefficients.

Variables	Specification 1	Specification 2	Specification 3
ADCS ⁺	-----	0.6059*** (19.0963)	-----
ADCS [−]	-----	0.6582* (4.0272)	-----
INNT ⁺	-----	-----	0.0594*** (4.3877)
INNT [−]	-----	-----	0.0437*** (5.0697)
ADCS	0.5908*** (21.8401)	-----	0.5629*** (11.7417)
TINN	0.0422*** (4.0468)	0.04619*** (3.9181)	-----
C	3.7106*** (11.3342)	10.3350*** (236.5989)	4.16687*** (11.7417)
ARDL-Bound Test	4.7785**	9.7958***	13.7237***

Note: ** and *** depict significance at 5% and 1%, respectively.

Table 5. Short-run coefficients.

Variables	Specification 1	Specification 2	Specification 3
C	2.3161*** (3.7477)		3.5281*** (5.4897)
MVA(−1)	−0.6242*** (−4.0692)	−0.62551*** (−4.6042)	−0.8467*** (−7.1875)
TINN	0.0264*** (3.2406)	0.0289* (1.9539)	-----
D(ADCS)	0.6732*** (4.9295)		-----
ADCS ⁺	-----	0.3790*** (4.7602)	-----
ADCS [−]	-----	0.4117* (1.9539)	-----
INNT ⁺	-----	-----	0.0503*** (4.1257)
INNT [−]	-----	-----	0.0361*** (4.1257)
ECT(−1)	−0.6242***	−0.6255***	−0.8467***

Note: * and *** depict significance at 10% and 1%, respectively.

increase in the technological innovation increased industrialisation by 0.0264%. Despite the small value of TINN-MVA, it remains an effective tool for industrialisation in both the long term and short term. Dutta, Lanvin, and Wunsch-Vincent (2018) reported that South Africa ranked 58th among the most innovative nations and 7th among middle-income economies, which remains unimpressive to this date. Based on technological innovation, South Africa is still behind other developing nations like China and India. Beyond that, it was equally important to check whether [or not] a co-integration exists among ADCS, TINN, and industrialisation. First, the F-statistics were computed with the lower and upper critical value, which was found to be 4.7785 and statistically significant at the level of 5%. Thus, the hypothesis of no co-integration was firmly rejected, offering empirical evidence that the ADCS, TINN, and industrialisation have a long-term relationship. Second, the coefficients and sign of error correction term (ECT) were examined to validate possible long-run linkage between among ADCS, TINN, and industrialisation. As seen in Table 5, the negative and significant (at 1%) coefficient of the ECT for the Specification (1) confirmed the existence of long-run association among variables.

Moreover, the long-run estimates of NARDL model (Specification 2) inferred that the positive and negative components are positive. The elasticity values for ADCS towards industrialisation were 0.6059 (increase) and 0.6582 (decrease). This means that a 1% increase (decrease) in ADCS causes an upsurge (decline) in industrialisation by 0.61% (0.66%). The long-run negative component of ADCS was found to be statistically significant at 10% level of significance but the positive component at 1%. The negative component of ADCS was concluded to be statistically insignificant. Based on the different statistical significance and the magnitude of the computed elasticities, variations in the ADCS reflected an asymmetric effect on industrialisation in the long-run in South Africa. In addition to the above, the results of NARDL (short-run) demonstrated that positive and negative components are positive. The elasticity values for ADCS towards industrialization were 0.3790 (increase) and 0.4117 (decrease), suggesting that 1% increase (decrease) in ADCS increases (decreases) industrialization by 0.38 (0.41) percent. Also, the positive component of ADCS was found to be statistically significant at 1% level of significance, but the negative component was found to be insignificant. Based on the statistical significance and magnitude of elasticities, variations in the ADCS changes appear to have an asymmetric effect on industrialisation in the short-run in South Africa. Table 6, showing the outcome of the Wald test, indicated that the null hypothesis of asymmetrical effects for both long-run and short-run was accepted, providing strong support for both the long and short-term asymmetric effects.

Congruent with above, the nature of data demonstrated that the ADCS (on average) expanded by 5.50% during 1980–2014. With the ADCS values showing 44.79% (highest) and –17.17% (lowest), it was concluded that the positive shocks in ADCS have a significant impact on industrialisation. Specification 3 results depicted that the positive and negative components of TINN were found to be positive. The elasticity of TINN-industrialization increased (decreased) by 0.0594 (0.0437), suggesting that a 1% increase and decrease in TINN increased and decreased industrialisation by 0.0594% (0.0437%), respectively. The long-run positive and negative components of TINN were found to be statistically significant at 1% level of significance. In the same way, the short-run estimates of NARDL (Specification 3) showed that the positive and negative components of TINN were positive and significant (at 1% level of significance). The elasticity values of TINN- industrialisation indicated that a 1% increase

Table 6. Testing Hypothesis of an asymmetrical effect.

Null Hypothesis	Alternative Hypothesis	F-Statistic	Decision
$-\Gamma_3^+/\zeta_1 = -\Gamma_4^-/\zeta_1$	$-\Gamma_3^+/\zeta_1 \neq -\Gamma_4^-/\zeta_1$	4.7602***	Long-run asymmetric relationship between ADCP and industrialisation
$-\zeta_1^+/\Gamma_5 = -\zeta_i^-/\Gamma_5$	$-\zeta_1^+/\Gamma_5 \neq -\zeta_i^-/\Gamma_5$	4.2772***	Short-run asymmetric relationship between ADCP and industrialisation
$-\Gamma_9^+/\Gamma_7 = -\Gamma_{10}^-/\Gamma_7$	$-\Gamma_9^+/\Gamma_7 \neq -\Gamma_{10}^-/\Gamma_7$	5.3013***	Long-run asymmetric relationship between TINN and Industrialization
$-\vartheta_i^+/\Gamma_{11} = -\vartheta_i^-/\Gamma_{11}$	$-\vartheta_i^+/\Gamma_{11} \neq -\vartheta_i^-/\Gamma_{11}$	4.3087***	Short-run asymmetric relationship between TINN and industrialisation

Note: *** depict significance 1%, respectively.

Table 7. Validation test.

Test	Specification 1	Specification 2	Specification 3
LM Test	0.2223 (0.8948)	2.1113 (0.3480)	0.9200 (0.6313)
BPG	1.6564 (0.7673)	1.6564 (0.7673)	3.2169 (0.6666)
RESET Test	0.0030 (0.9566)	0.7225 (0.4031)	0.5743 (0.4553)

(decrease) in TINN caused an upsurge (decline) in industrialisation by 0.0503% (0.0361%). Table 6, demonstrating the results of the Wald test, proved that the null hypothesis of asymmetrical effects in both the long and short-run was accepted, providing strong support of long and short-term asymmetric effects of TINN changes on industrialisation, respectively.

As a final step, several diagnostic tests were utilised to validate the computed outcomes of Specification 1, 2 and 3. Table 7 exhibits the results of validation tests, comprising of the LM test of Serial correlation, Breusch-Pagan Godfrey test of Heteroskedasticity, and Ramsey Reset test. All these tests suggested that the computed model was error-free. As shown in Figure 7, 8, and 9, the CUSUM test further validated the stability of the model for the years 1980–2014.

5. Conclusion and policy recommendations

Consumption expenditures and technological innovation are important components of economic growth and development. Any changes in consumption expenditures and technological innovation not only bring a change in economic growth but also affects the industrialisation process in developing economies. These two factors are not always constant given that they are highly responsive to economic shocks. In response, the current study was conducted to analyse the possible symmetrical & asymmetrical relationship among ADCS, TINN, and industrialisation using various econometric techniques. The results of the unit-root tests suggested that industrialisation, TINN, and ADCS were I(1) order integrations, while the ARDL bound test validated the existence of long-run linkage between ADCS and industrial value-added (industrialisation). The long-run value of ADCS-MVA revealed that a 1% upsurge in ADCS causes an increase in MVA by 0.59% in the long run. The error-correction term value was found to be negative and statistically significant at 1% level. The short-run value of ADCS-MVA indicated that a 1% upsurge in ADCS leads to an increase in MVA by 0.67% in the short run. Furthermore, the impact of positive and negative components of ADCS and TINN on industrialisation were analysed through non-linear ARDL model. The empirical model revealed that the positive shock in

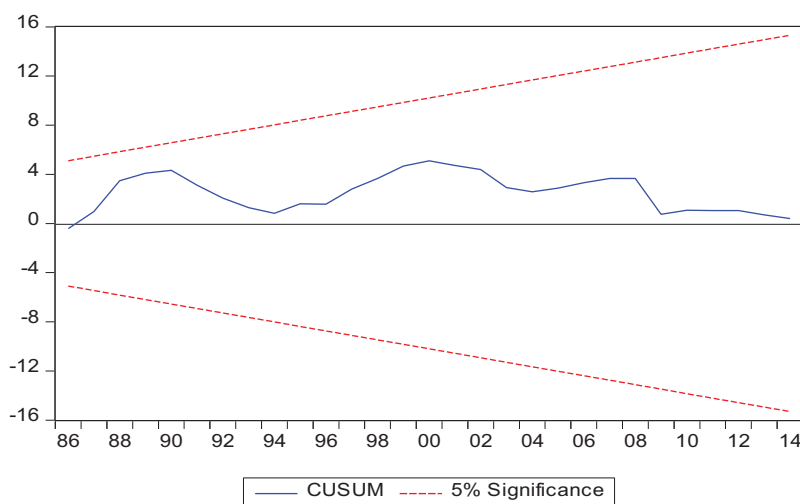


Figure 7. CUSUM Plot for Specification 1.

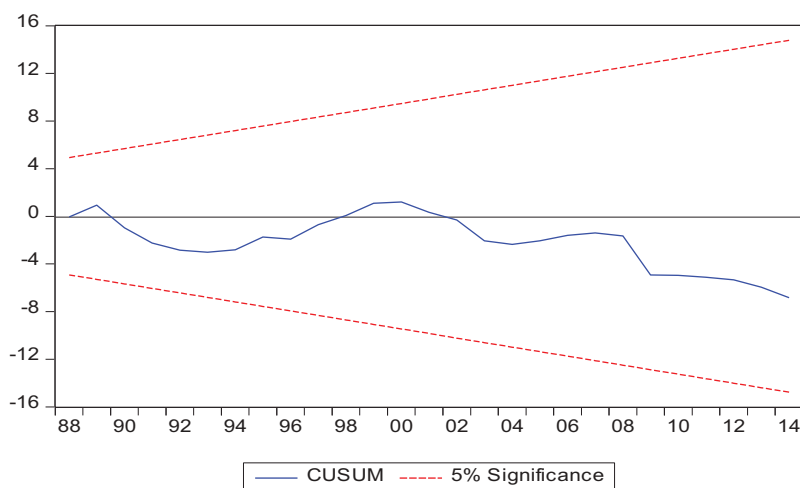


Figure 8. CUSUM Plot for Specification 2.

ADCS has a positive and statistically significant influence on industrialization in both the short run and long run, while the negative shock in ADCS has a positive and statistically significant impact on industrialization in both the short run and long run, while the results also showed that the positive and negative shock of TINN have a positive and statistically significant influence on industrialization in both the short run and long run. The Wald test confirmed that an asymmetrical relationship between ADCS and industrialisation, and between TINN and industrialisation.

Given the current findings, this study offers some important policy implications. First, ADCS is an imperative factor of industrialisation in both the short run and long run, and thus, the government should formulate policies and strategies to enhance sustainable household consumption to enhance the development of the industrial sector. For this purpose,

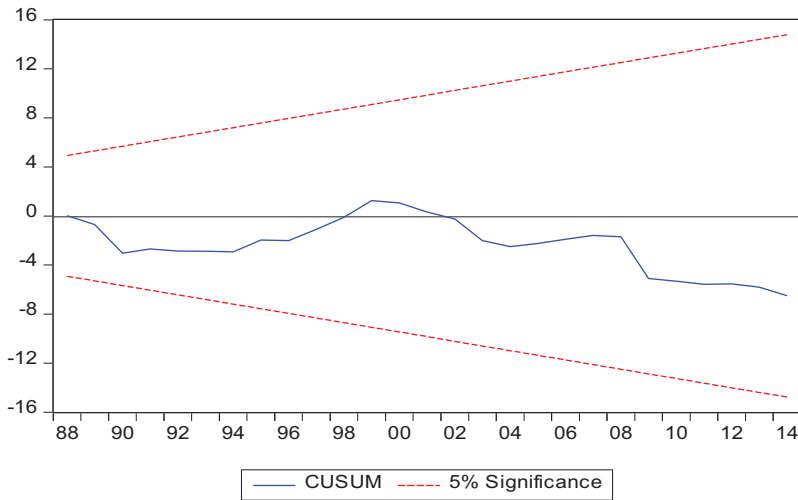


Figure 9. CUSUM Plot for Specification 3.

governments are expected to play an instrumental role in accelerating household activities by supporting the commercial initiatives of the private sector, enhancing the uniformity and coordination of policies, and guaranteeing the provision of infrastructure, and strengthening existing policies. Second, the present finding showing the positive associations between TINN and industrialisation implies that the government should focus on promoting and funding innovative activities. That said, such initiatives would require a sound financial system, supported by banks and other financial institutions. The banking sector, a primary source of financing along with payment agents of the government, should be encouraged to support innovation-financing. Third, the results also call for supporting technological-based firms through comprehensive tax incentives and innovation-financing programs. Fourth, the role of positive and negative components of TINN in the process of industrialisation cannot be underestimated given the asymmetrical association between TINN and industrialisation. Thus, government is expected to formulate their policies in such a way that institutions can provide financial support to firms and entrepreneurs, irrespective of economic situation.

The current study entails the following limitations. First, the current study is limited to South Africa only. Perhaps, a similar study can be conducted for other developing economies, especially for the newly industrialised nations. Second, this study used patent applications as a proxy of technological innovation. However, researchers are encouraged to incorporate research and development expenditures as a proxy for innovation. Third, this study is based on the aggregate level analysis, but future research can be conducted at the firms-level for more in-depth insight.

Disclosure statement

No potential conflict of interest was reported by the authors.

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