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# URBANISATION, ENERGY CONSUMPTION AND ECONOMIC GROWTH IN SOUTH AFRICA

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***Abstract***

*The causal relationship between urbanisation, energy consumption, and economic growth was examined for South Africa using annual data from 1990 -2021. The growing need for economies to bounce back after the COVID-19 pandemic and catch up with national economic plans and the Sustainable Development Goals (SDGs) motivated a relook at the important factors that influence economic growth. This study used two measures of energy consumption, namely electricity consumption and total energy consumption. Employing autoregressive distributed lag (ARDL) to cointegration and error correction model (ECM)- based Granger-causality test, the study found unidirectional causal flow from energy consumption to urbanisation in the short run regardless of the energy consumption measure used, and the same causal flow in the long run when total energy consumption was used. The study found a unidirectional causality from urbanisation to economic growth. A bidirectional causality between economic growth and electricity, while no causality was confirmed when total energy consumption was used. The findings from this study confirm the importance of energy consumption and urbanisation in driving economic growth. Policy recommendations are discussed.*

*Keywords: Public debt Malawi; government debt; debt management; sustainability*

**JEL:** F43; O4

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## 1. Introduction

The aftermath of the COVID pandemic was felt across most, if not all, developing and developed countries, of which South Africa is not an exception. COVID-19 slowed economic activities due to restricted trade and other economic activities, especially during the lockdown periods. Like many other signatories to the Sustainable Development Goals, South Africa experienced a slump in economic growth that derailed the national development plans. Governments are currently exploring ways to speed up the economic growth process to catch up with the momentum before the pandemic. For South Africa, economic growth fell to -6,3 percent, and currently, the government is working tirelessly to recover from the sharp decline (World Bank, 2023). Even when the country recorded a recovery, in 2021 a growth of 4,9 percent was recorded, on average, economic growth levels are way below economic growth projected to support the goals outlined in the National Development Plan 2030 (World Bank, 2023). Although South Africa has recorded a gradual increase in the number of people moving to urban areas after the COVID-19 pandemic, more people moved to urban areas in search of greener pastures as the unemployment rate climbed from 24,3 percent in 2020 to 28,7 percent in 2021 (World Bank, 2023). Urbanisation has been associated with an increase in pressure over resources in urban areas, such as electricity and other social services. Unfortunately, slow economic growth and a high rate of urbanisation are currently being experienced at a time when the country is struggling with low energy production. Studies that have examined the causality between energy consumption and economic growth (Ghoshray et al., 2018; Khobai and Roux, 2017; Alshehry and Belloumi, 2015; Ucan, Aricioglu and Yucel, 2014) and those that investigated the causal relationship between economic growth and urbanisation (see, for example, Shaban, Kourtit and Nijkamp, 2022; Nguyen and Nguyen, 2018; Zi, 2017) found mixed results.

Against this background and the mounting pressure to put the economy on a growth trajectory in an environment where energy generation remains depressed, the current study aims to i) establish the causal flow between urbanisation, energy consumption and economic growth; and ii) establish whether energy-led growth or urbanisation-led growth hypothesis holds in South Africa.

In this study, energy consumption is captured by total energy consumption and electricity consumption. Total energy consumption captures renewable energy, oil, gas and electricity. To fully specify the model, trade openness was included as an intermittent variable between energy consumption and urbanisation. This variable was selected because it plays an important role in driving economic growth and has the potential to influence energy consumption and urbanisation. The study used an autoregressive distributed lag (ARDL) approach and error correction model (ECM)- based Granger causality test to examine this linkage. The ARDL approach was adopted due to its numerous advantages. For example, the approach does not require all variables in the model to be integrated of the same order, and the results from the empirical analysis can be tied to short-run and long-run time frames. This is more informative to policy makers as policies can be tailored to cater for short-term and long-term needs.

South Africa is an interesting case study for this study, given the level of its gross domestic product (GDP). It is also one of the most advanced emerging market economies. Several studies have been done on the impact of energy consumption and urbanisation on economic growth in South Africa, with little or no consensus. Given that the National Development Plan 2030 is still on the cards, and there is pressure to put the economy back on the growth path amidst energy challenges, this study will shed light on how to get the economy back on the growth path in time to realise the SDGs and the National Development Plan 2030 objectives.

The rest of the study is divided as follows: Section 2 outlines related literature; section 3 provides the estimation techniques and section 4 discusses data analysis and presents the results. The conclusion is highlighted in Section 5.

## 2. The dynamics of urbanisation, economic growth and energy consumption in South Africa

### 2.1 Urbanisation dynamics in South Africa

The South African population is projected at 57 million, with 63 percent already living in urban areas, which translates to 37,8 million individuals living in urban areas, according to the UNHabitat (2023). The urban population is projected to increase to 80 percent by 2050 (Parliamentary Monitoring Group, 2023; UNHabitant, 2023). The South African government has developed the Integrated Urban Development Framework (IUDF), spearheaded by the Department of Cooperative Governance and Traditional Affairs (CoGTA) (IUDF, 2023). The framework seeks to foster a shared understanding in South Africa of the best way to manage urbanisation and achieve economic development. The IUDF is centred on nine levers:

integrated spatial planning; integrated transport and mobility; Integrated sustainable human settlement, Integrated urban infrastructure; Efficient land governance and management and Inclusive economic development; and Sustainable Finance (IUDF, 2023).

Urbanisation in South Africa is largely associated with seeking greener pastures by individuals from rural areas. One of the factors that have been cited as a contribution to migration is the previous spatial setting and controlled migration and settlement (Coalition for Urban Transitions, 2023). Most of the settlements were alienated from cities, characterised by low economic activities (Coalition for Urban Transitions, 2023). In 2018, for example, South Africa's eight metropolitan municipalities contributed about 58,4% of GDP (Coalition for Urban Transitions, 2023). Most skilled, high-paying jobs are found in cities, making them very attractive to individuals seeking to better their lives (Coalition for Urban Transitions, 2023).

Urbanisation also comes with its own negative effects. According to the Parliamentary Monitoring Group (2023), urbanisation has a negative impact on the environment, unemployment, criminality, and loss of fabric of the society because of changes in living conditions and increase in living cost (Parliamentary Monitoring Group, 2023). To militate against the negative challenges associated with urbanisation, the IUDF was adopted in 2016. Among other objectives, the IUDF aimed to spell out policies, principles, and programmes that lead to the achievement of the National Development Plan 2030. Among such programmes that aim to implement the framework are the Small Towns Regeneration Strategy commissar in 2013/14 and the City Support Programme (Parliamentary Monitoring Group, 2023). Other initiatives include the District Development Model (DDM), Cities Support Programme (CSP) and Intermediate Cities Municipalities (ICM) (Cooperative Governance Traditional Affairs, 2023). The thrust of these programmes is to bring spatial transformation and, at the same time, manage the growing urban population without neglecting the rural poor (Cooperative Governance Traditional Affairs, 2023).

**2.2 Economic growth dynamics in South Africa**

South Africa adopted the National Development Plan (NDP) 2030, rolled out in September 2012, as a blueprint and long-term plan for the country. The main objectives of the plan are to eradicate poverty and inequality; and to accelerate economic growth by 2030 (National Planning Commission, 2023). The NDP draws resources from the public and the private sector to achieve the main objective of the Plan. Public-Private partnership plays centre stage in the National Development Plan, where everyone in society pulls their effort to achieve the National Plan (National Planning Commission, 2023). The five-year NDP implementation roadmap has short-term, medium- and long-term interventions (National Planning Commission, 2023). Five-year medium-term strategic frameworks (MTSF) are used as an implementation vehicle for the NDP. The first MTSF was rolled from 2014-2019, and the main thrust of the framework was to ensure policies are coherent, aligned, and coordinated across all government plans and budget processes (Republic of South Africa, 2023). Some of the highlights in the 2014-2019 MTSF framework are the creation of decent work opportunities, radical economic transformation, access to adequate human settlements, fighting corruption, promotion of investment, and creation of a competitive environment (Republic of South Africa, 2023). The second MTSF spanning from 2019-2024 is a successor to the 2014-2019 MTSF. Its emphasis hinges on picking some of the targets that were missed in the 2014-2019 framework and incorporating the COVID-19 pandemic-unanticipated event since the inception of the NDP. The 2019-2024 MTSF provides a basis for decisions on resourcing and public expenditure; effective programme development; greater accountability; planning for fast-track spatial transformation; and partnership and social compacting (Republic of South Africa, 2023).

From 1990 to 1992, the South African economy experienced negative growth, and the economy only picked up from 1993 (World Bank, 2023). Growth was experienced from 1994 to 2019, with an average of 2.7 percent (World Bank, 2023). During the study period, the biggest slump was recorded in 2020, a negative 6.3 percent (World Bank, 2023). This is a time that coincided with COVID-19 pandemic (World Bank, 2023). The economy recovered in 2021 with 4.9 percent, a huge recovery from a slump recorded in 2020.

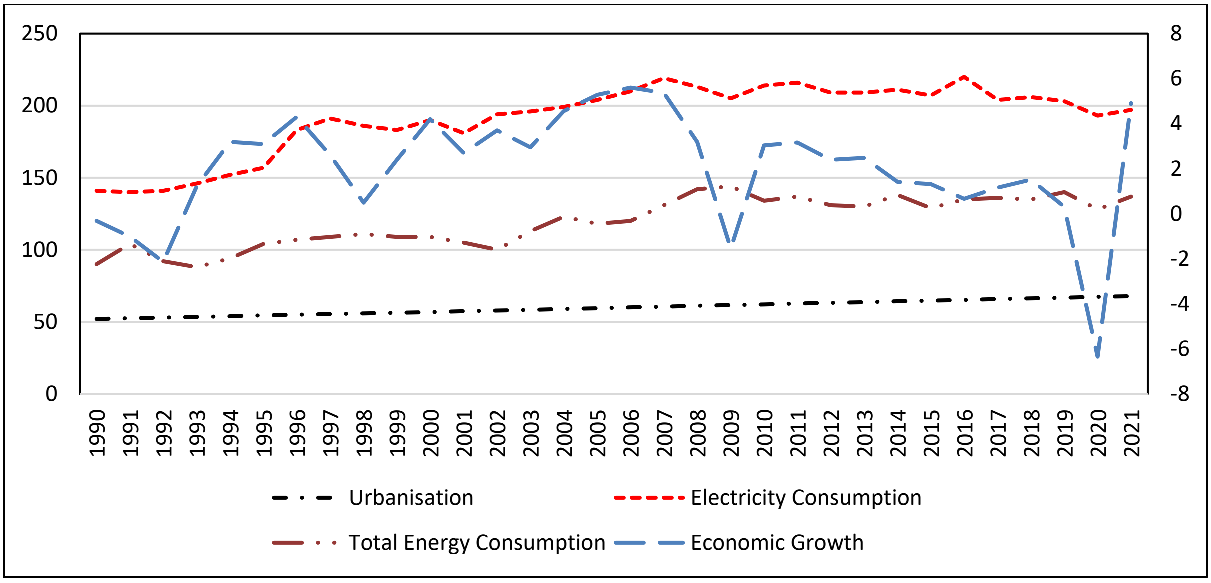
**2.3 Energy Consumption Dynamics in South Africa**

South Africa drafted the White Paper on the Energy Policy in 1998. The main objectives of the White Paper include, among others, increasing access to affordable energy, managing energy-related environmental impact and governance of energy (Department of Mineral Resources and Energy, 2022). The White Paper on the Energy Policy is complemented by the White Paper on Renewable Energy and the Nuclear Energy Policy (Department of Mineral Resources and Energy, 2022). The Integrated Resource Plan 2010-30, which came into effect in 2011, is an electricity development plan that aims to consider the environment and cost of supplying energy to South Africans. The Integrated Resource Plan 2010-30 helps investors to plan investment in the energy sector, a road map to meet the country's electricity demand (Energy Department, 2023). Apart from White Papers and Integrated Resources Plan 2010-2030, there are some acts that regulate energy in South Africa, such as the National Energy Act of 2008; the Petroleum Products Act of 1977; The Gas Act of 2001; the Nuclear Energy Act of 1999. The main thrust of the National Energy Act includes ensuring that diverse energy is made available to South Africans at an affordable process and emphasises the increase in the use of renewable energy.

South Africa is a highly energy-intensive country, and it has one of the most developed infrastructures in Africa. Although recently, South Africa has struggled with the production of sufficient electricity to meet its high daily demands, the country has invested in alternative energy sources, especially renewable energy, as part of sustainable energy production. The most popular energy used in both urban and rural areas is electricity, although other sources of energy are also available.

The energy supply in South Africa is dominated by coal, which comprised 65 percent of the primary energy supply in 2018 (Mineral Resource and Energy, 2021). Renewable energy only claims 18 percent of the energy supply (Mineral Resource and Energy, 2021). Electricity and energy consumption have maintained an upward trend during the study period, showing the general increase in energy demand in the country. What is not clear, however, is whether the rise in energy consumption is influenced by urbanisation or economic growth. The trends in economic growth, urbanisation and energy consumption are reported in Figure 1.

**Figure 1: The trends in Urbanisation, Energy Consumption and Economic Growth**




Source: World Bank (2023) and Enerdata (2023)

Figure 1 reports total energy consumption maintaining an upward trend during the study period. Urbanisation has also maintained an upward trend mimicking the trends in electricity consumption and total energy consumption. Economic growth maintained an upward growth from 1990 to 2008. However, the economy took a downward trend from 2009 and recovered in 2010, but the growth rates that were experienced did not reach the pre-financial crisis growth rates.

## 3. Review of related literature

Several models tried to explain the main reason or patterns of migration. Among such models are: the Stouffer Theory of mobility, the gravity theory, and the Ravenstein Law of Migration. Over the years, an attempt has been made to integrate different migration theories into social, spatial, behavioral, and economic theory (Statistic South Africa 'StatsSA', 2006). These theories try to explain the patterns and reasons why there is migration. Out of all the models, the most important reason for migration is economic reasons, seeking better services and opportunities. Economic growth, on the other hand, is explained by the growth models where authors like Schumpeter, Solow, and Swan postulate economic growth to depend on investment ability supported by savings in a nation. According to these theories, as long as a nation can save and invest in capital accumulation, growth will be experienced. Although several studies have been done on the impact of urbanisation and energy consumption on economic growth, the literature on the causal relationship between the two is still limited. Due to limited studies that have examined the causality between economic growth, energy consumption, and urbanisation, studies that have explored the causality between economic growth and energy consumption, economic growth and energy consumption, and urbanisation and energy consumption will be reviewed.

**3.1 Economic growth, urbanisation and energy consumption**

Nathaniel and Bekun (2021) analysed the causal link between economic growth, electricity consumption, and urbanisation in Nigeria using data from 1971 -2014. The study found that electricity consumption increases economic growth. A 1% percent increase in electricity consumption led to a 0,16 percent increase in growth, assuming other influencing factors are constant. Urbanisation was found to have a negative effect on economic growth, thereby inhibiting economic growth by 2.38 percent. Using the vector error correction model and Granger causality test, the study found bidirectional causality between economic growth and electricity consumption and between economic growth and urbanisation. In the same vein, Odugbesan and Rjoub (2020) examined the causality between economic growth, energy consumption, urbanisation, and carbon dioxide emission in Mexico, Nigeria, Turkey, and Indonesia, using annual data from 1993 to 2017. The study found a unidirectional causal flow from energy consumption to economic growth for Nigeria and Indonesia and a bidirectional causality between the two for Mexico and Turkey. All the countries in the study show a long-run relationship from economic growth, carbon dioxide and energy consumption to urbanisation.

Sbia, Shahbaz and Ozturk (2017) investigated the relationship between economic growth, financial development, urbanisation and electricity consumption in United Arab Emirates using data from 1975-2011. Employing the autoregressive bound test approach (ARDL), the study found an inverted U-shaped relation exists between economic growth and electricity consumption and between urbanisation and electricity consumption. This means that urbanisation increases electricity consumption up to a certain threshold. The causality analysis found a bidirectional causality between economic growth and electricity in the long run and a unidirectional causal flow from electricity consumption to economic growth in the short run, and another bidirectional between urbanisation and economic growth in the long run. Zhao and Wang (2015) examined the causal relationship between urbanisation, energy consumption and economic growth in China using data from 1980 to 2012. The study found consistent results as Sbia, Shahbaz and Ozturk (2017), i.e., bidirectional causality between energy consumption and economic growth. The study also found a unidirectional causal flow from urbanisation to energy consumption and a unidirectional causal flow from economic growth to urbanisation. Solarin and Shahbaz (2013) examined the causality between energy consumption, economic growth and urbanisation in Angola using data from 1971-2009. Applying the Lee and Strazicich unit root test and ARDL bounds test, the study found a bidirectional causality between urbanisation and economic growth, urbanisation and electricity consumption, and between electricity consumption and economic growth.

### 3.2 Economic growth and urbanisation

Shaban, Kourtit and Nijkamp (2022) examined the causal relationship between economic growth and urbanisation in the Indian States using data from 1971 to 2020. The study used the boostrap panel Granger-causality test and found a unidirectional causal flow from economic growth to urbanisation in most of the states - ten out of fifteen states. Only two states show bidirectional causality between income and urbanisation. Nguyen and Nguyen (2018) examined the relationship between economic growth and urbanisation for ASEAN countries using data from 1993-2014. Using Granger causality for static and dynamic data, the study found a bidirectional causality between urbanisation and economic growth for Brunei, Vietnam and Cambodia, while a one-way causality from urbanisation to economic growth was confirmed. Another unidirectional causality from economic growth to urbanisation was found in Malaysia and Indonesia. In the same spirit, Zi (2017) investigated the causality between urbanisation and economic growth in China using time series data from 1982-2014. Using the VAR model, the study found a unidirectional causal flow from urbanisation to economic growth in the long run. Moomaw and Shatter (1996) examined the causality between economic growth and urbanisation using panel data for 1960, 1970, 1980, and 1990 for 90 countries and found GDP per capita and sectorial incomes to have a positive impact on urbanisation. The study found the casual flow running from urbanisation to economic growth.

### 3.3 Economic growth and energy consumption

Ghoshray et al. (2018) studied the causality between energy consumption and economic growth in the United States using data from 1949-2014. Using a flexible Frontiers analysis, the study found no causality between the two confirming the neutrality hypothesis. In the same vein, Khobai and Roux (2017) examined the relationship between energy consumption, economic growth and carbon dioxide emission in South Africa using data from 1971 to 2013.

Using the vector error correction model (VECM), the study found a bidirectional causality between energy consumption and economic growth. Alshehry and Belloumi (2015) studied the causal relationship between economic growth, energy consumption and carbon dioxide emission in Saudi Arabia. Using Johnsen's multivariate cointegration approach and incorporating carbon dioxide emission as an intermittent variable, the study found a long-run unidirectional causality from energy consumption to economic growth. Ucan, Aricioglu and Yucel (2014) examined the causal relationship between real GDP, renewable and non-renewable energy for a panel of fifteen European Union countries using data from 1990-2011. Employing a panel vector error correction model, the study found a unidirectional causality from non-renewable energy to economic growth. Gelo (2009) examined the causal relationship between primary energy consumption and Gross Domestic Product (GDP) in Croatia using data from 1953-2005. Employing the vector error correction model, the study found a unidirectional causal flow from GDP to energy consumption for Croatia.

Guttormsen (2007) investigated the causal relationship between energy consumption and economic growth for nine countries using data from 1960 to 2002. Using the error-correction model and Granger-causality, the study found that energy consumption and economic growth influence each other. Paul and Bhattacharya (2004) examined the causality between energy consumption and economic growth in India using data from 1950 to 1996. Using the Granger-causality test, the study found a bidirectional causality between the two. The findings of this study are contrary to a unidirectional causality that Cheng (1999) found for India using a different data set. This shows the mixed results on the causal flow between the two variables, meriting a separate study for South Africa. Cheng (1999) analysed the causal relationship between economic growth and energy consumption in India using data from 1952 to 1959. Using Granger-causality test, the study found a unidirectional causal flow from economic growth to energy consumption in the short and long run.

### 3.4 Urbanisation and energy consumption

Wang, Fu and Wang (2021) examined the causality between energy consumption, urbanisation and economic growth in China using data from 2000 to 2017. Using heterogeneous panel data techniques, the study found the Granger causality results to **vary across Western, Eastern, and Central China.** The study found no causality between urbanisation and electricity consumption. Bakirtas and Akpolat (2018) carried out a study on the causal relationship between urbanisation, energy consumption and economic growth for Emerging-Market countries (Mexico, Kenya, Colombia, India, Indonesia and Malaysia) using data from 1971-2014. Employing the Dumitrescu-Hurlin panel Granger causality, the study found a unidirectional causal flow from urbanisation to energy consumption when a bivariate causality framework was used. The same study found a unidirectional causal flow from energy consumption to urbanisation when a multivariate framework was used. The inconclusive results from the same study, based on the methodology, point to the importance of another study that examines the nature of the relationship in south Africa to inform policy.

Faisal et al. (2018) studied the relationship between electricity consumption, urbanisation, economic growth and trade in Iceland using data from 1965-2013. Using Granger causality test under the Vector error correction model, the study found a bidirectional causality between urbanisation and electricity consumption in the long run. Khan, Amin, Rahman (2018) found contrasting results from Faisal et al. (2018) in a study on Bangladesh. Employing data from 1980 to 2015, a unidirectional causal flow from urbanisation to energy consumption was confirmed. Brantley and Sidney (2013), in a study on 105 countries using panel data from 1971 to 2009, found the same results as Khan, Amin and Rahman (2018). The study could not reject a unidirectional causal flow from urbanisation to electricity consumption. In the same spirit, Liu (2009) examined the causality between urbanisation and energy consumption in China using data from 1978 to 2008. Using an autoregressive distributed lag and error correction model, the study found a unidirectional causal flow from urbanisation to total energy consumption. These results are consistent with the findings by Faisal et al. (2018) in the case of Bangladesh.

The literature reviewed on the causal relationship between energy consumption, economic growth and urbanisation indicates variation in the results, depending on the methodology used. The inconclusive results on the causal relationship warrants another study on South Africa that explores the nature of the relationship. Although Khobai and Roux (2017) investigated the causality between energy consumption and economic growth in South Africa, the link between urbanisation and energy consumption was not fully explored, leaving a gap that this study would like to fill.

## 4. **Estimation Techniques**

The study employs the autoregressive distributed lag (ARDL) approach to cointegration and error correction model-based Granger causality test to investigate the causal relationship between energy consumption, urbanisation and economic growth in South Africa. This approach has the advantage of allowing analysis of variables integrated of order zero and one. The approach also allows results to be interpreted for the short run and the long run timeframes.

**Variable Definition**

Variables of interest are urbanisation measured by the percentage of the population living in urban areas, energy consumption captured by electricity consumption in Model 1 and total energy consumption in Model 2. Total energy consumption includes gas, oil, renewable energy and electricity consumption. To fully specify the model, an intermittent variable was added- Trade openness (TOP) to form a multivariate causality model.

The ARDL model specification is given in Equations 1-4

Equations 1 to 4 below provide the ARDL model specification.

$$\Delta ECO_t = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta ECO_{t-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta\, ENE_{mt-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\,\Delta TOP_{t-i} + \beta_1 ECO_{t-1} + \beta_2 ENE_{mt-1} + \beta_3 URB_{t-1} + \beta_4 TOP_{t-1} + \mu_{1t} \dots\dots \quad (1)$$

$$\Delta ENE_{mt} = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\,\Delta ECO_{t-i} + \sum_{i=1}^{n} \varphi_{2i}\Delta\, ENE_{mt-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\,\Delta TOP_{t-i} + \beta_1 ECO_{t-1} + \beta_2 ENE_{mt-1} + \beta_3 URB_{t-1} + \beta_4 TOP_{t-1} + \mu_{2t} \dots\dots \quad (2)$$

$$\Delta URB_t = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\,\Delta ECO_{t-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta\, ENE_{mt-i} + \sum_{i=1}^{n} \varphi_{3i}\,\Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\,\Delta TOP_{t-i} + \beta_1 ECO_{t-1} + \beta_2 ENE_{mt-1} + \beta_3 URB_{t-1} + \beta_4 TOP_{t-1} + \mu_{3t} \dots\dots \quad (3)$$

$$\Delta TOP_t = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\, \Delta ECO_{t-i} + \sum_{i=0}^{n} \varphi_{2i} \Delta\, ENE_{mt-i} + \sum_{i=0}^{n} \varphi_{3i}\, \Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\, \Delta TOP_{t-i} + \beta_1 ECO_{t-1} + \beta_2 ENE_{mt-1} + \beta_3 URB_{t-1} + \beta_4 TOP_{t-1} + \mu_{4t} \ldots \ldots (4)$$

Where ECO = economic growth measured by the rate of change in real GDP.

ENE = is energy consumption measured by ELEC = electricity in Model 1, and total energy consumption (measured by renewable energy), oil, gas and electricity in Model 2. The rest of the variables remain unchanged, and they enter each model one at a time.

URB=urbanisation captured by the percentage of the population living in urban areas

TOP= trade openness measured by the sum of exports and imports as a percentage of GDP.

$\varphi_0$ is a constant; $\varphi_1 - \varphi_4$; $\beta_1 - \beta_4$ are coefficients; and $\mu_1 - \mu_4$ are error terms. The other variables remain the same as specified in Equation 1.

Equation 5 -8 below specify the ECM model.

$$\Delta ECO_t = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\, \Delta ECO_{t-i} + \sum_{i=0}^{n} \varphi_{2i} \Delta\, ENE_{mt-i} + \sum_{i=0}^{n} \varphi_{3i}\, \Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\, \Delta TOP_{t-i} + \vartheta_1 ECM_{t-1} + \gamma_{1t} \ldots \ldots (5)$$

$$\Delta ENE_{mt} = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\, \Delta ECO_{t-i} + \sum_{i=1}^{n} \varphi_{2i} \Delta\, ENE_{mt-i} + \sum_{i=0}^{n} \varphi_{3i}\, \Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\, \Delta TOP_{t-i} + \vartheta_2 ECM_{t-1} + \gamma_{2t} \ldots \ldots (6)$$

$$\Delta URB_t = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\, \Delta ECO_{t-i} + \sum_{i=0}^{n} \varphi_{2i} \Delta\, ENE_{mt-i} + \sum_{i=1}^{n} \varphi_{3i}\, \Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\, \Delta TOP_{t-i} + \vartheta_3 ECM_{t-1} + \gamma_{3t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (7)$$

$$\Delta TOP_t = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\, \Delta ECO_{t-i} + \sum_{i=0}^{n} \varphi_{2i} \Delta\, ENE_{mt-i} + \sum_{i=0}^{n} \varphi_{3i}\, \Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\, \Delta TOP_{t-i} + \vartheta_4 ECM_{t-1} + \gamma_{4t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$

ECM = Error correction term

$\vartheta_1 - \vartheta_4$ are the error correction term coefficients and $\gamma_1 - \gamma_4$ are error terms.

The rest of the variables remain the same as defined in Equations 1-4.

**Data sources**

This study investigated the causal relationship between urbanisation, energy consumption and economic growth in South Africa using annual data from 1990-2021. Data used for the following variables ECO, TOP and URB was retrieved from the World Bank Development indicators, while electricity and total energy consumption was extracted from Enerdata.

## 4.Data Analysis and discussion of results

### 4.1 Unit root test

The study used the Augmented Dickey Fuller-GLS test and the Phillip-Perron (PP) test and establish the stationarity of the variables included in the model. The results of the stationarity test are presented in Table 1.

**Table 1: Unit root results**

| **Dickey-Fuller-GLS Unit Root Test** | | |
|---|---|---|
| Variable | Stationarity of all Variables in Levels | Stationarity of all variables in First Difference |

| | Without Trend | With Trend | Without Trend | With Trend |
|---|---|---|---|---|
| ECO | -2.284 | -2.661 | $-6.752^{***}$ | $-6.142^{***}$ |
| ELEC | -1.097 | -1.261 | $-5.841^{***}$ | $-6.551^{***}$ |
| TEC | -0.988 | -2.802 | $-4.554^{***}$ | $-6.042^{***}$ |
| URB | -2.465 | -2.491 | $-4.847^{***}$ | $-8.621^{***}$ |
| TOP | -1.400 | -1.060 | $-6.168^{***}$ | $-6.171^{***}$ |
| **Phillip-Perron Test** | | | | |
| Variable | Stationarity of all Variables in Levels | | Stationarity of all variables in First Difference | |
| | Without Trend | With Trend | Without Trend | With Trend |
| ECO | -1.633 | -2.902 | $-6.5416^{***}$ | $-6.445^{***}$ |
| ELEC | -2.184 | -2.328 | $-5.901^{***}$ | $-8.501^{***}$ |
| TEC | -1.582 | -2.082 | $-8.121^{***}$ | $-8.166^{***}$ |
| URB | -1.042 | -2.131 | $-4.996^{***}$ | $-5.784^{***}$ |
| TOP | -1.432 | -2.825 | $-9.136^{***}$ | $-8.631^{***}$ |

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

All the variables included in the study for Model 1 (where electricity is used as a measure of energy and in Model 2 (where total energy consumption is used a s a measure of energy consumption) are stationary at first difference. This confirms that the study can proceed and use the ARDL approach. The next step is to test for a long run relationship among the variables in each model. The cointegration results are reported in Table 2.

## 4.2 Cointegration Test

### Table 2: Cointegration Results

| Dependent Variable | Function | F-Statistic | Cointegration Status |
|---|---|---|---|
| **Model 1: Energy measured by electricity consumption** | | | |
| ECO | F (ECO\|ELEC, URB, TOP) | $9.314^{***}$ | Cointegrated |
| ELEC | F (ELEC\|ECO, URB, TOP) | $5.586^{**}$ | Cointegrated |
| URB | F (URB\|ECO, ELEC, TOP) | 2.345 | Not cointegrated |
| TOP | F (TOPI\|ECO, ELEC, URB) | $7.817^{***}$ | Cointegrated |
| **Model 2: Energy measured by total energy consumption** | | | |

| | | | |
|---|---|---|---|
| ECO | F (ECO\|TEC, URB, TOP) | 7.683*** | Cointegrated |
| TEC | F (TEC\|ECO, URB, TOP) | 4.963** | Cointegrated |
| URB | F (URB\|ECO, TEC, TOP) | 5.726*** | Cointegrated |
| TOP | F (TOPI\|ECO, TEC, URB) | 5.915*** | Cointegrated |

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

The results reported in Table 2 confirm cointegration in three out of four functions in Model 1, where energy consumption is measured by electricity, while cointegration was confirmed in all functions in Model 2. In all the functions in Models 1 and 2 where cointegration was confirmed, causality was estimated for the long-run and short-run timeframes. The analysis for model F(URB|ECO, ELEC, TOP) was only conducted in the short run since no long-run relationship was found to exist among the variables in the function. Table 3 reports the causality results.

## ECM-Granger causality Results

### Table 3: Granger-causality Results

| **Panel 1** | **Model 1: Electricity as a measure of energy consumption** | | | | |
|---|---|---|---|---|---|
| | **ECM t-statistics** | | | | **ECM (t-stat)** |
| | ΔECO | ΔELEC | ΔURB | ΔTOP | |
| ΔECO | - | 7.151** [0.013] | 8.610*** [0.001] | 1.872 [0.182] | -0.431*** [-6.525] |
| ΔELEC | 6.969*** [0.005] | - | 1.087 [0.309] | 1.936 [0.141] | -0.550*** [-5.075] |
| ΔURB | 0.006 [0.938] | 4.016** [0.056] | - | 0.206 [0.654] | - |
| ΔTOP | 4.314** [0.048] | 1.385 [0.250] | 5.172** [0.031] | - | -0.587*** [-5.906] |
| **Panel 2** | **Model 2: Total energy consumption as a measure of energy** | | | | |
| | ΔECO | ΔTEC | ΔURB | ΔTOP | **ECM (t-stat** |
| ΔECO | - | 0.037 | 3.227* | 5.999** | -0.932*** |

| | | | | | |
|---|---|---|---|---|---|
| | | [0.847] | [0.084 | [0.021] | [-5.894] |
| ΔTEC | 2.144<br>[0.156] | - | 1,531<br>[0.227] | 3.465** <br>[0.087] | 2.144<br>[0.156] |
| ΔURB | 0.293<br>[0.594] | 6.541** <br>[0.018] | - | 8.233*** <br>[0.009) | -0.004*** <br>[-4.234] |
| ΔTOP | 8.718*** <br>[0.000] | 0.033<br>[0.857] | 5.116** <br>[0.032] | - | -0.467*** <br>[-5.632] |

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

The results reported in Table 3 confirm a unidirectional causal flow from energy consumption to urbanisation in the short run, irrespective of the energy consumption measure used. However, only a unidirectional causal flow from total energy consumption to urbanisation was recorded in the long run. This finding confirms energy-led urbanisation for South Africa. These results are not unique to South Africa alone. Bakirtas and Akpolat (2018) found the same result in a study on emerging markets. The study also found bidirectional causality between electricity consumption and economic growth in the short run and the long run. This confirms that South Africa follows the feedback hypothesis. This result points to the mutually reinforcing effect between economic growth and electricity consumption. The higher the electricity consumption, especially in the manufacturing sector, the more the economy grows. This implies that a reduction in energy consumption has a negative effect on economic growth. The study also found no causality between economic growth and total energy consumption. A unidirectional causal flow from urbanisation to economic growth was confirmed regardless of the energy consumption proxy used. This finding confirms the positive contribution that urbanisation has on economic growth. As more people move to cities, more labour is supplied to produce goods and services, consequently increasing the demand for goods and services from wages received. This results in an expansion in production in every sector to meet the increase in demand, resulting in economic growth. This is also supported in the theoretical literature, where an increase in labour supply results in a shift in the production possibility frontier (Parkins et al. 2021).

Other results reported in Panel A, Model 1, where electricity consumption is used as a measure of energy consumption, found a unidirectional causal flow from economic growth to trade openness in the short and long run. Another unidirectional causal flow from urbanisation to trade openness was confirmed in the long and short run. This finding confirms the importance of urbanisation in increasing resources needed to produce more exports and, at the same time, increase the demand for imports. No casualty was found between trade openness and electricity consumption in the short and long run.

Other results presented in Panel B, Model 2, where total energy consumption was used as a measure of energy consumption, confirmed a bidirectional causality between trade openness and urbanisation. This means that as more people migrate to towns and cities, a new demand for goods and services is triggered, which consequently results in an increase in demand for imports as well as an increase in labour supply for those companies that manufacture exports. Another bidirectional causality was confirmed between trade openness and economic growth in the long and short run. The study found a unidirectional causal flow from trade openness to total energy consumption in the long and short run. This implies that an increase in trade openness results in an increase in demand for total energy consumption in South Africa.

## 5 Conclusion

This study examined the causal relationship between urbanisation, energy consumption and economic growth in South Africa using data from 1990 to 2021. The study was motivated by the need to establish which variables influence each other with the ultimate objectives of achieving economic growth and improving living standards in the studied country. The study used two energy measures – electricity consumption captured in Model 1 and total energy consumption captured in Model 2. To fully specify the model, trade openness was added as an intermittent variable. Employing the autoregressive distributed lag approach to cointegration and ECM-based Granger causality, the study found a unidirectional causality from energy consumption to urbanisation in the short run irrespective of the energy consumption used, and a unidirectional causal flow from total energy consumption to urbanisation in the long run. A unidirectional causal flow from urbanisation to economic growth in the short and long run across all energy consumption measures was also found to exist. When electricity was used as a measure of energy consumption, a bidirectional causality was confirmed in the short and long run. However, no causality was found to exist between total energy consumption and economic growth. Based on these findings, it can be concluded that energy consumption and urbanisation play an important role in economic growth. It also implies that South Africa follows the energy-led growth when energy is measured by electricity. It is, therefore, recommended that South Africa should continue to design programmes that alleviate energy shortage, particularly electricity, to achieve high economic growth. This may be complemented with policies that facilitate the development of rural areas to minimise urbanisation which puts a lot of pressure on social service in urban areas.

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