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# ENERGY CONSUMPTION AND FINANCIAL DEVELOPMENT IN SOUTH AFRICA: AN EMPIRICAL INVESTIGATION

*This paper examines the dynamic relationship between energy consumption and financial development in South Africa during the period 1980-2013. In order to address the omission of variable bias, the study has included economic growth as an intermittent variable between financial development and energy consumption. Unlike some previous studies, this study uses three proxies for financial development: i) domestic credit to the private sector as a percentage of GDP as a proxy for financial institutions' depth; ii) bank credit to bank deposits as a proxy for financial institutions' stability; and iii) bank lending-deposit spread as a proxy for financial institutions' efficiency. Using the ARDL bounds testing approach to cointegration and Granger-causality test, the obtained results show that there is a distinct long-run unidirectional causal flow from financial development to energy consumption in South Africa. This applies irrespective of which proxy has been used to measure the level of financial development. The study also finds that there is a long-run unidirectional causality from economic growth to energy consumption, and a unidirectional causality from economic growth to financial development when bank lending-deposit interest rates spread is used as a proxy for financial development. This, therefore, implies that*

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*energy consumption in South Africa is largely driven by the growth-led financial development in the long run.*

*Key words: Financial Development; Energy Consumption; South Africa; ARDL Bounds Testing Approach*

## 1. Introduction

The relationship between financial development and energy consumption has attracted considerable attention in recent years. Currently, there exist four views on the relationship between financial development and energy consumption. The first view argues that there is a unidirectional causal flow from financial development to energy consumption. The second view is in favour of the energy-led financial development hypothesis. This view maintains that it is energy consumption that drives financial development. In contrast to the first two views, the third view takes a middle-ground stance. This view argues in favour of a bidirectional relationship between these two variables. It argues that both financial development and energy consumption Granger-cause each other. Although the majority of the previous studies on this subject are in favour of finance-led energy consumption, energy-led financial development, or a bidirectional causal relationship between energy and financial development, there are a few studies that support a neutrality hypothesis, which posits that there is no causal relationship between financial development and energy consumption.

Unfortunately, the majority of the empirical studies that have been conducted on the relationship between financial development and energy consumption are mainly concentrated in the Asian and Latin-American countries (see Abosedra et al., 2015; Furuoka, 2015; Kakar, 2016; Sbia et al., 2017). Very few empirical studies on this subject exist for the sub-Saharan African countries. The current study, therefore, attempts to examine the causal relationship between financial development and energy consumption in South Africa during the period 1980--2011. In order to address the omission of variable bias, the study has included economic growth as an intermittent variable between financial development and energy consumption, thereby leading to a trivariate causality model. Unlike some previous studies, this study uses three proxies for financial development: i) domestic credit to the private sector as a percentage of GDP as a proxy for financial institutions' depth; ii) bank credit to bank deposits as a proxy for financial institutions' stability; and iii) bank lending-deposit spread as a proxy for financial institutions' efficiency. The findings of this study will shed light on the role of financial sector development in energy infrastructure development, and in particular, whether a well-developed financial sector drives energy demand in South Africa. Previous studies have shown that a well-developed financial system increases the efficiency of the financial sector, which in turn leads to efficient allocation of financial services.

The rest of the paper is organised as follows: Section 2 gives a summary of the empirical literature on the relationship between financial development and energy consumption from both developing and developed countries; while section 3 gives an overview of financial development and energy consumption in South Africa. Section 4 presents the empirical model specification, estimation techniques, and empirical analysis; and Section 5 concludes the study.

## 2. Literature review

Various empirical studies have examined the direction of causality between energy consumption and financial development, but with conflicting findings. These studies can be divided into four groups. The first group of studies argues that there is unidirectional causal flow from financial development to energy consumption. Studies whose findings are consistent with this view include Sadorsky (2010), Ozturk and Acaravci (2013), and Mudakkar *et al*. (2013), amongst others.

Sadorsky (2010), for example, examined the impact of financial development on energy demand for 22 emerging economies (Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Israel, South Korea, Malaysia, Mexico, Morocco, Peru, Philippines, Poland, Russia, South Africa, Thailand, and Turkey). The study employed panel Generalised Method of Moments estimations (GMM) from 1990 to 2006. To measure financial development, the study used stock market variables and FDI, while energy consumption was measured by energy use in kilogram (kg) of oil equivalent per capita energy. The reported results from this study indicated a unidirectional causal flow from financial development to energy consumption. Ozturk and Acaravci (2013) applied an ECM based Granger-causality test to examine the causal relationship between energy consumption and financial development for Turkey for the period 1960 to 2007. The results showed a unidirectional causal flow from financial development to energy consumption. Mudakkar *et al*. (2013) examined the causal link between energy consumption and financial development for Bangladesh, India, Nepal, Pakistan, and SriLanka. Using a Granger- causality test and Toda-Yamamoto-Dolado approach from 1975 to 2011, the study revealed a unidirectional causal flow from financial development to energy consumption in India and SriLanka.

The second group, however, argues that there is a unidirectional causal flow from energy consumption to financial development. Studies whose findings support this view include, amongst others, Yandan and Lijun (2009), A-Mulali and Sab (2012), and Islam *et al*. (2013. For example, Yandan and Lijun (2009) employed a Granger-causality test on time series data covering the period 1985 to 2006 in the case of Guangdong province in China. The study found that energy consumption Granger-causes financial development. A-Mulali and Sab (2012) investigated the causal link between energy consumption and financial development in the case of 19 selected countries (Antiguaand, Barbud, Australia, Canada, China, Cyprus, Denmark, Iceland, Japan, South Korea, Malaysia, Malta, New Zealand, South Africa, St. Kitts and Nevis, Sweden, Switzerland, Thailand, United Kingdom, and the United States) using a panel Granger-causality test. The study covered the period 1980 to 2008, and the empirical results revealed a positive unidirectional long-run and short-run causal link running from energy consumption to financial development in all countries under investigation. Islam *et al*. (2013) also tested the causal relationship between energy consumption and financial development in the case of Tunisia using time series data for the period 1971 to 2009. The study applied the Granger-causality test, and the results provided evidence of a unidirectional causal flow from energy consumption to financial development.

The third group supports a feedback relationship between financial development and energy consumption. In other words, this group argues that there is a bidirectional causal relationship between financial development and energy consumption. Studies whose findings are consistent with this theory include, amongst others, Lee *et al*. (2008), Salman and Atya (2014), Abosedra *et al*. (2015), Shahbaz and Lean (2012), Shahbaz *et al*. (2013a), Al-Mulali and Sab (2012), and Khan *et al*. (2014). A study by Lee *et al*. (2008) found evidence of a feedback relationship between financial development and energy consumption in the case of 22 OECD countries after employing a panel causality test on data covering the period from 1960 to 2001. Salman and Atya (2014) employed the ECM based Granger-causality test on time series data in the case of three North African countries, namely Algeria, Egypt, and Tunisia, to examine the relationship between financial development and energy consumption over the period 1980 to 2010. The study found a bidirectional causal link between financial development as measured by stock market indicators and energy consumption in the case of Algeria. Abosedra *et al*. (2015) investigated the relationship between financial development and energy consumption for Lebanon and found a bidirectional causal link between the two variables. The study applied the Vector Error Correction based Granger-causality test on monthly data over the period 2000 to 2010. Shahbaz and Lean (2012) used Autoregressive Distributive Lag (ARDL) test and Granger-causality test to examine the relationship between financial development and energy consumption for Tunisia for the period 1971 to 2008.

The study found bidirectional causality between the two variables. Likewise, Shahbaz *et al*. (2013a), while using a multivariate causality framework, found that financial development and energy use Granger cause each other. Al-Mulali and Sab (2012) used a panel Granger-causality test on a panel of 30 Sub-Saharan African countries to examine the relationship between financial development and energy consumption from 1980 to 2008. The study found a bidirectional relationship between finance and energy.

Unlike the first three groups, the fourth group argues in favour of the neutrality hypothesis, which postulates that there is no causal relationship in either direction between financial development and energy consumption. This view, though unpopular, has been supported by studies such as Dritsaki and Dritsaki (2014) and Shahbaz *et al*. (2013), amongst others. Dritsaki and Dritsaki (2014) investigated the causal link between financial development and energy consumption in the case of Greece using time-series data over the period 1960 to 2009. The study employed a Vector Error Correction based Granger-causality test to empirically test the causal link between the two variables. The study confirmed no causality between the two variables. Shahbaz *et al*. (2013) employed the Granger-causality test to find the direction of causation between financial development and energy consumption in the case of China and Indonesia for the periods 1971 to 2011 and 1975 to 2011, respectively. The study found evidence of no causality between finance and energy in the case of both countries. Table 1 summarizes the literature on the causal link between energy consumption and financial development.

*Table 1.*

THE CAUSAL LINK BETWEEN ENERGY CONSUMPTION AND FINANCIAL DEVELOPMENT

| Author(s) | Period | Countries | Methodology | Data | Empirical findings |
|---|---|---|---|---|---|
| Islam *et al*. (2013) | 1971-2009 | Malaysia | Causality test based on ECM | Time series | EC→FD |
| Salman and Atya (2014) | 1980-2010 | Three North African countries (Algeria, Egypt, and Tunisia) | Causality test based on ECM | Time series | FD↔EC (Algeria) |
| Shahbaz and Lean (2012) | 1971-2008 | Tunisia | Granger causality based on ECM | Time series | FD↔EC |
| Shahbaz *et al*. (2013a) | 1971–2011 | China | Multivariate Granger causality model | Time series | FD↔EC |
| Shahbaz *et al*. (2013) | 1971-2011 | China | Granger causality | Time series | FD≠EC |
| Shahbaz *et al*. (2013) | 1975-2011 | Tunisia | Granger causality | Time series | FD≠EC |
| Yandan and Lijun (2009) | 1985-2006 | China (Guangdong province ) | Granger causality based on ECM | Time series | EC→FD |
| A-Mulali and Sab (2012) | 1980-2008 | 19 selected countries[1] | Granger causality based on ECM | Panel data | EC→FD |
| Abosedra. *etal*. (2015) | 2000$M_2$-2010$M_{12}$ | Lebanon | Granger causality test based on ECM | Time series | FD ↔EC |
| Lee *et al*. (2008) | 1960-2001 | 22 OECD countries | Panel causality test | Panel data | FD ↔EC |
| Ozturk and Acaravci (2013) | 1960-2007 | Turkey | Granger causality based on ECM | Time series | FD→EC |
| Dritsaki and Dritsaki (2014) | 1960-2009 | Greece | Granger causality test based on ECM | Time series | FD≠EC |
| Mudakkar *etal*. (2013) | 1975-2011 | Bangladesh, India, Nepal and Pakistan and SriLanka | Granger causality and Toda-Yamamoto-Dolado approach | Time series | FD→EC (India)<br>EC→FD(Nepal)<br>EC↔FD(Pakistan)<br>FD→EC(Sri Lanka)<br>FD≠EC (Bangladesh) |
| Sadorsky (2010) | 1990-2006 | 22 emerging economies | Generalised Method of Moments | Panel data | FD→EC |

## 3. An overview of financial development and energy consumption in South Africa

South Africa's financial sector is considered to have one of the most developed and sophisticated financial systems, not only by the standards of African countries, but also by the standards of emerging economies. For example, the Johannesburg Stock Exchange (JSE), which was formed in 1887, is currently ranked as the 18th largest stock exchange in the world in terms of market capitalization (see Bureau of Africa Affairs, April, 2000). The South African Reserve bank is also considered to be independent; and it operates in the same way as do Western central banks. In fact, the South African Reserve Bank is one of the oldest central banks in the world. The Bank relies entirely on indirect instruments of monetary policy, namely: open market operations, reserve requirements, and credit facilities, among others.

South Africa was not only one of the first developing countries to implement interest rate liberalisation in the 1980s; but it is also one of the first countries to have successfully implemented an inflation-targeting policy. The financial sector reforms in South Africa were initiated shortly after the De Kock Commission reports of 1978 and 1985. Interest and credit controls were virtually removed in 1980; while the bank's liquidity ratios were reduced substantially between 1983 and 1985. Inflation-targeting, on the other hand, was implemented in February 2000. This move was made, in order to improve the co-ordination between monetary policy and other macroeconomic policies, as well as to make monetary policy more transparent and accountable.

By any standard and measure, South Africa has one of the most stable financial institutions in Africa. Its financial sector is wide and broad; and it comprises a number of financial institutions. By 1997, South Africa had about 51 licensed banks. In addition, there were five mutual banks. Of the 51 licensed banks, 8 were branches of foreign banks; while 11 were subsidiaries of foreign banks. Currently, the country has about 26 locally controlled banks, seven (7) internationally controlled banks, 43 foreign bank representatives, 15 branches of foreign banks, three (3) mutual banks, three (3) co-operative banks, and three (3) development-related banks, amongst others.

On the energy front, it is worth noting that South Africa is considered to be the largest electricity producer and consumer in Africa (see Odhiambo, 2009). According to the current estates, more than half of the electricity generated in Africa comes from South Africa. Eskom, which supplies approximately 96% of South Africa's electricity, also supplies more than 45% of Africa's electricity. Some of the importers of South Africa's electricity include Swaziland, Botswana, Mozambique, Lesotho, Namibia, Zambia and Zimbabwe.

Although Eskom is currently exploring various forms of energy sources, in order to expand its current plant mix, coal-fired base load power stations, which use coal as their energy source, remain the largest portion of its plant mix. Given the fact that South Africa is one of the largest coal producers in the world, this trend is likely to continue for some time. In fact, South Africa is currently ranked as the seventh largest producer of coal in the world (IEA, 2014). Other leading coal producers include China, which ranked no. 1; the USA, which is ranked no. 2; India, which is ranked no. 3; Indonesia, which is ranked no. 4; Australia, which is ranked no. 5; and Russia, which is ranked no. 6[1].

Currently, Eskom's Generation Division has about 14 coal-fired power stations; and these stations have an installed capacity of 38 548 MW. Koeberg Power Station, which is Africa's first nuclear power station, currently ranks amongst the safest of its kind; and it is considered to be Eskom's most reliable power station. Although South Africa's electricity is dominated by coal, the country's long-term goal is to diversify its energy sources, as far as possible. For example, according to the country's White Paper on Renewable Energy (2003), about 10 000GWh of energy were supposed to be produced from renewable energy sources, such as biomass, wind, solar and small-scale hydro by 2013.

The energy consumption in South Africa has increased significantly in recent years. The energy use (kg of oil equivalent per capita), for example, increased from 2196.95 in 1980 to 2460.16 in 1995, and later to 2466.51 in 1996 and 2489.17 in 1997. Although the energy use per capita decreased somewhat between 1998 and 2002; it later increased to 2469.21 in 2003 and 2913.13 in 2008. Although there was a consistent decrease in energy use per capita during the period 2009-2013, it later increased to 2695.73 in 2014. Table 2 shows the trends of financial development and energy use in South Africa during the period 1980-2014.

[1] See IEA(2014)

*Table 2.*

THE TRENDS OF FINANCIAL DEVELOPMENT AND ENERGY USE IN SOUTH AFRICA DURING THE PERIOD 1994-2014

| Year | Domestic credit to private sector (% of GDP) | Energy use (kg of oil equivalent per capita) |
|---|---|---|
| 1980 | 53.96716593 | 2196.953805 |
| 1981 | 58.77268545 | 2355.561994 |
| 1982 | 60.56956302 | 2496.503364 |
| 1983 | 64.75551905 | 2477.990466 |
| 1984 | 67.76914043 | 2622.881682 |
| 1985 | 71.13091983 | 2561.508921 |
| 1986 | 70.46040223 | 2608.805477 |
| 1987 | 71.08864416 | 2646.544167 |
| 1988 | 72.92548791 | 2696.955789 |
| 1989 | 75.4416385 | 2528.561684 |
| 1990 | 78.47245719 | 2421.586599 |
| 1991 | - | 2471.021497 |
| 1992 | 99.37615963 | 2250.649075 |
| 1993 | 105.0228762 | 2355.770961 |
| 1994 | 111.0089414 | 2381.635527 |
| 1995 | 116.0001419 | 2460.158551 |
| 1996 | 116.7189034 | 2466.510033 |
| 1997 | 113.3613609 | 2489.169143 |
| 1998 | 115.1679271 | 2433.052995 |
| 1999 | 131.0482394 | 2424.933368 |
| 2000 | 130.3122229 | 2384.548086 |
| 2001 | 138.7925028 | 2417.852592 |
| 2002 | 110.7183677 | 2339.763072 |
| 2003 | 115.8622017 | 2469.205547 |
| 2004 | 126.9323461 | 2662.483456 |
| 2005 | 138.1594291 | 2626.981372 |
| 2006 | 156.9762122 | 2579.245622 |
| 2007 | 160.1247848 | 2732.917941 |
| 2008 | 140.3498765 | 2913.130072 |
| 2009 | 145.9411555 | 2824.464363 |
| 2010 | 148.9813957 | 2748.363501 |
| 2011 | 139.6023093 | 2703.178887 |
| 2012 | 146.4797628 | 2628.44834 |
| 2013 | 149.2336824 | 2598.95973 |
| 2014 | 151.1178858 | 2695.733764 |

Source: World Development Indictors (2016)

## 4. Estimation techniques and empirical analysis

### 4.1. Estimation techniques

In order to overcome the traditional weaknesses associated with many cointegration techniques, the current study uses the recently introduced ARDL-bounds testing approach to examine the long-run relationship among energy consumption, financial development proxies, and economic growth. The ARDL-bounds testing approach – based on Perasan and Shin (1999), and Perasan *et al*. (2001) – can be expressed as follows (see Odhiambo, 2010):

**Model 1: Domestic credit to the private sector (DCPS), energy consumption and economic growth**

$$\Delta InDCPS_t = a_0 + \sum_{i=1}^{n} a_{1i}\Delta InDCPS_{t-i} + \sum_{i=0}^{n} a_{2i}\Delta InEC_{t-i} + \sum_{i=0}^{n} a_{3i}\Delta Iny_{t-i} + a_4 InDCPS_{t-1} + a_5 InEC_{t-1} + a_6 Iny_{t-1} + \mu_{1t} \tag{1}$$

$$\Delta InEC_t = \delta_0 + \sum_{i=1}^{n} \beta_{1i}\Delta InEC_{t-i} + \sum_{i=0}^{n} \delta_{2i}\Delta InDCPS_{t-i} + \sum_{i=0}^{n} \delta_{3i}\Delta Iny_{t-i} + \delta_4 InEC_{t-1} + \delta_5 InDCPS_{t-1} + \delta_6 Iny_{t-1} + \mu_{2t} \tag{2}$$

$$\Delta Iny_t = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\Delta Iny_{t-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta InDCPS_{t-i} + \sum_{i=0}^{n} \varphi_{3i}\Delta InEC_{t-i} + \varphi_4 Iny_{t-1} + \varphi_5 InDCPS_{t-1} + \varphi_6 InEC_{t-1} + \mu_{3t} \tag{3}$$

**Model 2: Bank credit (BC), energy consumption and economic growth**

$$\Delta InBC_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i}\Delta InBC_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\Delta InEC_{t-i} + \sum_{i=0}^{n} \alpha_{3i}\Delta Iny_{t-i} + \alpha_4 InBC_{t-1} + \alpha_5 InEC_{t-1} + \alpha_6 Iny_{t-1} + \nu_{1t} \tag{4}$$

$$\Delta InEC_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i}\Delta InEC_{t-i} + \sum_{i=0}^{n} \beta_{2i}\Delta InBC_{t-i} + \sum_{i=0}^{n} \beta_{3i}\Delta Iny_{t-i} + \beta_4 InEC_{t-1} + \beta_5 InBC_{t-1} + \beta_6 Iny_{t-1} + \nu_{2t} \tag{5}$$

$$\Delta Iny_t = \phi_0 + \sum_{i=1}^{n} \phi_{1i} \Delta Iny_{t-i} + \sum_{i=0}^{n} \phi_{2i} \Delta InBC_{t-i} + \sum_{i=0}^{n} \phi_{3i} \Delta InEC_{t-i} + \phi_4 Iny_{t-1} + \phi_5 InBC_{t-1} + \phi_6 InEC_{t-1} + \nu_{3t} \quad (6)$$

**Model 3: Bank lending-deposit spread (BSPREAD), energy consumption and economic growth**

$$\Delta InBSPREAD_t = \pi_0 + \sum_{i=1}^{n} \pi_{1i} \Delta InBSPREAD_{t-i} + \sum_{i=0}^{n} \pi_{2i} \Delta InEC_{t-i} + \sum_{i=0}^{n} \pi_{3i} \Delta Iny_{t-i} + \pi_4 InBSPREAD_{t-1} + \pi_5 InEC_{t-1} + \pi_6 Iny_{t-1} + \varepsilon_{1t} \quad (7)$$

$$\Delta InEC_t = \rho_0 + \sum_{i=1}^{n} \rho_{1i} \Delta InEC_{t-i} + \sum_{i=0}^{n} \rho_{2i} \Delta InBSPREAD_{t-i} + \sum_{i=0}^{n} \rho_{3i} \Delta Iny_{t-i} + \rho_4 InEC_{t-1} + \rho_5 InBSPREAD_{t-1} + \rho_6 Iny_{t-1} + \varepsilon_{2t} \quad (8)$$

$$\Delta Iny_t = \psi_0 + \sum_{i=1}^{n} \psi_{1i} \Delta Iny_{t-i} + \sum_{i=0}^{n} \psi_{2i} \Delta InBSPREAD_{t-i} + \sum_{i=0}^{n} \psi_{3i} \Delta InEC_{t-i} + \psi_4 Iny_{t-1} + \psi_5 InBSPREAD_{t-1} + \psi_6 InEC_{t-1} + \varepsilon_{3t} \quad (9)$$

where:

1) DCPS = domestic credit to private sector as a % of GDP – a proxy for financial institutions' depth;
2) BC = bank credit as a % of bank deposits – a proxy for financial institutions' stability;
3) BSPREAD = bank lending-deposit spread – a proxy for financial institutions' efficiency;
4) y = Real GDP
3) EC = Energy consumption
4) $\mu_{it}$, $\nu_{it}$, $\varepsilon_{it}$ = white-noise error terms; and
5) $\Delta$ = first difference operator.

As explained in Pesaran *et al.* (2001), the bounds test for the long-run relationship between the various proxies for financial development, energy consumption, and economic growth can be conducted by using the joint F-statistic (or Wald statistic) for cointegration analysis. This involves testing the null hypothesis of no cointegration against the alternative hypothesis. Two sets of critical values have been recommended by Pesaran and Pesaran (1997) and Pesaran *et al*. (2001) for a given significance level. The first set assumes that all the variables included in the ARDL model are I(0), while the second set assumes that the variables are I(1). If the computed test statistic exceeds the upper critical-bounds value, then the existence of a cointegration relationship among the studied variables is accepted. However, if the F-statistic falls below the lower bounds value, then the null hypothesis of no cointegration cannot be rejected. However, if the computed test statistic falls between the bounds, then the cointegration test is said to be inconclusive (see also Odhiambo, 2009; 2010).

In order to examine the causality between financial development and energy consumption, we employ a dynamic multivariate-causality model. We incorporate economic growth (proxied by real GDP per capita) as an intermittent variable between financial development and energy consumption. We also adopt an error-correction (ECM) based Granger causality model -- in order to capture both the short-run and long-run causal relationships. Our ECM-based multivariate Granger-causality model can, therefore, be expressed as follows:

**Model 1: Domestic credit to the private sector (DCPS), energy consumption and economic growth**

$$InDCPS_t = \lambda_0 + \sum_{i=1}^{m} \lambda_{1i} InDCPS_{t-i} + \sum_{i=1}^{n} \lambda_{2i} InEC_{t-i} + \sum_{i=1}^{n} \lambda_{3i} Iny_{t-i} + \lambda_4 ECM_{t-1} + \eta_{1t} \quad (10)$$

$$InEC_t = \sigma_0 + \sum_{i=1}^{m} \sigma_{1i} InEC_{t-i} + \sum_{i=1}^{n} \sigma_{2i} InDCPS_{t-i} + \sum_{i=1}^{n} \sigma_{3i} Iny_{t-i} + \sigma_4 ECM_{t-1} + \eta_{2t} \quad (11)$$

$$Iny_t = \gamma_0 + \sum_{i=1}^{m} \gamma_{1i} Iny_{t-i} + \sum_{i=1}^{n} \gamma_{2i} DCPS_{t-i} + \sum_{i=1}^{n} \gamma_{3i} InEC_{t-i} + \gamma_4 ECM_{t-1} + \eta_{3t} \quad (12)$$

**Model 2: Bank credit (BC), energy consumption and economic growth**

$$InBC_t = \partial_0 + \sum_{i=1}^{m} \partial_{1i} InBC_{t-i} + \sum_{i=1}^{n} \partial_{2i} InEC_{t-i} + \sum_{i=1}^{n} \partial_{3i} Iny_{t-i} + \partial_4 ECM_{t-1} + \upsilon_{1t} \quad (13)$$

$$InEC_t = \theta_0 + \sum_{i=1}^{m} \theta_{1i} InEC_{t-i} + \sum_{i=1}^{n} \theta_{2i} InBC_{t-i} + \sum_{i=1}^{n} \theta_{3i} Iny_{t-i} + \theta_4 ECM_{t-1} + \upsilon_{2t} \quad (14)$$

$$Iny_t = \omega_0 + \sum_{i=1}^{m} \omega_{1i} Iny_{t-i} + \sum_{i=1}^{n} \omega_{2i} InBC_{t-i} + \sum_{i=1}^{n} \omega_{3i} InEC_{t-i} + \omega_4 ECM_{t-1} + \upsilon_{3t} \quad (15)$$

**Model 3: Bank lending-deposit spread (BSPREAD), energy consumption and economic growth**

$$InBSPREAD_t = \Psi_0 + \sum_{i=1}^{m} \Psi_{1i}\, InBSPREAD_{t-i} + \sum_{i=1}^{n} \Psi_{2i} InEC_{t-i} + \sum_{i=1}^{n} \Psi_{3i} Iny_{t-i} + \Psi_4 ECM_{t-1} + Z_{2t} \quad (16)$$

$$InEC_t = \Phi_0 + \sum_{i=1}^{m} \Phi_{1i}\, InEC_{t-i} + \sum_{i=1}^{n} \Phi_{2i} InBSPREAD_{t-i} + \sum_{i=1}^{n} \Phi_{3i} Iny_{t-i} + \Phi_4 ECM_{t-1} + Z_{2t} \quad (17)$$

$$Iny_t = \Omega_0 + \sum_{i=1}^{m} \Omega_{1i} Iny_{t-i} + \sum_{i=1}^{n} \Omega_{2i} InBSPREAD_{t-i} + \sum_{i=1}^{n} \Omega_{3i}\, InEC_{t-i} + \Omega_4 ECM_{t-1} + Z_{3t} \quad (18)$$

where: ECM $_{t-1}$ is the error correction term lagged one period; and $\eta$, $\upsilon$ and $Z$ are mutually uncorrelated white-noise residuals.

While the F-statistics are expected to determine the short-run causal effects, the coefficients of the error-correction terms are supposed to determine the long-run causal relationships. It is, however, worth noting that even though the error-correction term has been included in all the three equations, only those equations where cointegration is found to exist will be tested with the ECM term. Annual time-series data, which cover the period 1980–2013, are utilised in this study.

### *4.2. Empirical analysis*

#### *4.2.1. Stationarity test*

Although the ARDL-bounds testing approach does not require that variables to be integrated of the same order, it is not applicable if the variables are integrated of order two [I(2)] or higher. For this reason, it is vital to conduct a unit-root test in order to ensure that the variables are not integrated of order two [I(2)] or higher. The results of the stationarity tests (not reported here) show that all variables included in Models 1, 2 and 3 are non-stationary in levels. Since the variables are non-stationary in levels, the next step is to test for the stationarity on differenced variables. The results of the stationarity tests on differenced variables are reported in Tables 3-5.

*Table 3.*

STATIONARITY TESTS OF VARIABLES ON FIRST DIFFERENCE – AUGMENTED DICKEY-FULLER TEST

| **Variable** | **NO TREND** | **TREND** |
|---|---|---|
| In DCPS | -5.313328*** | -5.436516*** |
| In BC | -5.620325*** | -6.021869*** |
| In BSPREAD | -5.904107*** | -4.084970** |
| In EC | -5.698775*** | -5.590099*** |
| In y | -3.497451** | -4.511331 |

Note: ** and *** denote statistical significance at the 5% and 1% levels, respectively.

*Table 4.*

STATIONARITY TESTS OF VARIABLES ON FIRST DIFFERENCE – PHILIPS-PERRON (PP) TEST

| **VARIABLE** | **NO TREND** | **TREND** |
|---|---|---|
| In DCPS | -5.461801*** | -6.209441*** |
| In BC | -5.620325*** | -6.334991*** |
| In BSPREAD | -5.970418*** | -5.847087*** |
| In EC | -5.747604*** | -5.626185*** |
| In y | -3.551227** | -5.425894*** |

Note:

1) The truncation lag is based on Newey and West (1987) bandwidth

2) *** denotes statistical significance at the 1% level.

*Table 5.*

STATIONARITY TESTS OF VARIABLES ON FIRST DIFFERENCE – DICKEY-FULLER - GLS TEST

| **Variable** | **NO TREND** | **TREND** |
|---|---|---|
| In DCPS | -5.267405*** | -5.562608*** |
| In BC | -4.936943*** | --5.898173*** |
| In BSPREAD | -4.799691*** | -3.715230** |
| In EC | -4.652920*** | -5.328523*** |
| In y | -3.212688** | -4.361631*** |

Note: ** and *** denote statistical significance at the 5% and 1% levels, respectively.

The results reported in Tables 3-5 show that all variables included in Models 1, 2 and 3 are integrated of order one [I(1)], and not of order two [I(2)] or higher. The Augmented Dickey-Fuller (ADF), Philips-Perron (PP) test and Dickey-Fuller - GLS tests applied to the first difference of the data series reject the null hypothesis of the non-stationarity for all the variables used in this study. This, therefore, implies that all the variables used in this study are integrated of order one. It also implies that the ARDL-bounds testing approach as proposed by Pesaran and Pesaran (1997) and Pesaran *et al*. (2001) can now be used – because the variables are *not* integrated of order two [I(2)] or higher.

### *4.2.2. Cointegration results*

Having confirmed that all the variables included in the causality test are integrated of order one, the next step is to test for the existence of a cointegration relationship among the proxies of financial development, energy consumption, and economic growth. The results of the bounds test are reported in Table 6.

*Table 6.*

BOUNDS F-TEST FOR CO-INTEGRATION

| **Dependent variable** | **Function** | **F-test statistic** |
|---|---|---|
| **Model 1: DCPS, EC and y** | | |
| In EC | In EC (In DCPS, In y) | 4.1403** |
| In DCPS | In DCPS(In EC, In y) | 0.55073 |
| In y | In y (In DCPS, In EC) | 2.1709 |
| **Model 2: BC, EC and y** | | |
| In EC | In EC (In BC, In y) | 3.7148* |
| In BC | In BC(In EC, In y) | 1.3673 |
| In y | In y (In BC, In EC) | 4.8508** |
| **Model 3: BSPREAD, EC and y** | | |
| In EC | In EC (In BSPREAD, In y) | 6.3023*** |
| In BSPREAD | In BSPREAD(In EC, In y) | 7.2448*** |
| In y | In y (In BSPREAD, In EC) | 1.3133 |

| Asymptotic Critical Values | | | | | | |
|---|---|---|---|---|---|---|
| | **1 %** | | **5%** | | **10%** | |
| | **I(0)** | **I(1)** | **I(0)** | **I(1)** | **I(0)** | **I(1)** |
| Pesaran et al. (2001), p. 300, Table CI(ii) Case II | 4.13 | 5.00 | 3.10 | 3.87 | 2.63 | 3.35 |

Note: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively

The results reported in Table 6 show that the calculated F-statistic is higher than the upper-bound critical value in InEC equation in Model 1, InEC and Iny in the case of Model 2 and InEC and In BSPREAD in the case of Model 3. These results, therefore, confirm the existence of a cointegrating relationship among the financial development, energy consumption and economic growth in South Africa, irrespective of the proxy used to measure the level of financial development (i.e., whether the DCPS, the BC, or the BSPREAD is used as a proxy). The results also suggest the existence of causality in at least one direction among the variables employed in this study.

#### *4.2.3. Analysis of causality test based on the error-correction model*

The results of cointegration show that there is a long-run relationship among financial development, energy consumption, and economic growth in South Africa. This means that we can perform the ECM-based causality test – by including ECM in the cointegrating equations. The results of the ECM-based causality are reported in Table 7.

The results of the Granger-causality model reported in Table 7 show that there is a distinct unidirectional causal flow from financial development to energy consumption in South Africa when InDCPS, InBC and InBSPREAD) are used as proxies of financial development. These results apply irrespective of whether the causality is conducted in the short run or in the long run. The short-run causality in this case is supported by the corresponding F-statistics in Models 1, 2 and 3, which have been found to be statistically significant in the InEC equations, but not in the InDCPS, InBC and InBSPREAD equations. The long-run causality, on the other hand, is supported by the coefficients of the ECM in InEC equations in Models 1, 2 and 3, which have been found to be negative (as expected) and statistically significant. This shows that financial development Granger-causes energy consumption in South Africa – both in the short run and in the long run. This finding is robust across all the three proxies used in this study.

Other results show that: i) There is a long-run unidirectional causality from economic growth to energy consumption; and ii) There is a unidirectional causality from economic growth to financial development when bank lending-deposit interest rates spread is used as a proxy for financial development.

*Table 7.*

GRANGER NON- CAUSALITY TEST

| **F-Statistic [P-value]** | | | | **ECM coefficient [t-statistic]** |
|---|---|---|---|---|
| **Model 1: $\Delta InEC_t$, $\Delta InDCPS_t$ and $\Delta Iny_t$** | | | | |
| **Dependent variable** | **$\Delta InEC_t$** | **$\Delta InDCPS_t$** | **$\Delta Iny_t$** | |
| **$\Delta InEC_t$** | - | 3.905302 [0.043]** | 3.562358* [0.079] | -58615 [-3.756]*** |
| **$\Delta InDCPS_t$** | 1.057886 [0.393] | - | 4.764097** (0.043) | - |
| **$\Delta Iny_t$** | 1.525496 [0.2318] | 6.713625 [0.00]*** | - | |
| **Model 2: $\Delta InEC_t$, $\Delta InBC_t$ and $\Delta Iny_t$** | | | | |
| **Dependent variable** | **$\Delta InEC_t$** | **$\Delta InBC_t$** | **$\Delta Iny_t$** | **$ECM_{t-1}$** |
| **$\Delta InEC_t$** | - | 5.392315 [0.00]*** | 7.622815 [0.00]*** | -.42126 [-3.128]*** |
| **$\Delta InBC_t$** | 0.867752 [0.507] | | 1.711718 [0.207] | - |
| **$\Delta Iny_t$** | 4.908657** [0.021] | 4.860529** [0.041] | - | -.084954 [-1.191] |
| **Model 3: $\Delta InEC_t$, $\Delta InBSPREAD_t$ and $\Delta Iny_t$** | | | | |
| **Dependent variable** | **$\Delta InEC_t$** | **$\Delta InBSPREAD_t$** | **$\Delta Iny_t$** | **$ECM_{t-1}$** |
| **$\Delta InEC_t$** | - | 6.396020*** [0.00] | 7.718933*** [0.00] | - .38677 [-2.8581]*** |
| **$\Delta InBSPREAD_t$** | 2.093 [0.218] | - | 7.392*** [0.00] | - .33597 [-2.441]** |
| **$\Delta Iny_t$** | 0.750023 [0.5723] | 5.996616*** [0.00] | - | - |

## 5. Conclusion

The current study attempts to examine the causal relationship between financial development and energy consumption in South Africa during the period 1980-2013. Currently, there exist four views on the relationship between financial development and energy consumption. The first view argues that there is a unidirectional causal flow from financial development to energy consumption. The second view is in favour of the energy-led financial development hypothesis. This view maintains that it is energy consumption that drives financial development. The third view, however, takes a middle-ground stance, which supports a bidirectional relationship between these two variables. Unlike the first three views, the fourth view supports a neutrality hypothesis, which posits that there is no causal relationship between financial development and energy consumption. Unfortunately, the majority of the empirical studies that have been conducted on the relationship between financial development and energy consumption are mainly concentrated in the Asian and Latin-American countries. Very few empirical studies on this subject exist for the sub-Saharan African countries. Unlike some previous studies, this study uses three proxies for financial development: i) domestic credit to the private sector as a percentage of GDP as a proxy for financial institutions' depth; ii) bank credit to bank deposits as a proxy for financial institutions' stability; and iii) bank lending-deposit spread as a proxy for financial institutions' efficiency. Using the ARDL-bounds testing approach to cointegration and the ECM-based Granger causality test, the study found that there is a distinct long-run unidirectional causal flow from financial development to energy consumption in South Africa. This applied irrespective of which proxy had been used to measure the level of financial development. The study also found that there is a long-run unidirectional causality from economic growth to energy consumption, and a unidirectional causality from economic growth to financial development when bank lending-deposit interest rates spread is used as a proxy for financial development. This, therefore, implies that energy consumption in South Africa is largely driven by the growth-led financial development in the long run. This finding is not surprising given the level of financial development in South Africa. The study, therefore, reiterates the need for South Africa to explore affordable energy-mix in order to cope with the increased finance-led energy demand.

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# POTROŠNJA ENERGIJE I FINANCIJSKI RAZVOJ U JUŽNOJ AFRICI: EMPIRIJSKO ISTRAŽIVANJE


## Sažetak

Ovaj rad istražuje dinamički odnos između potrošnje energije i financijskog razvoja u Južnoj Africi u razdoblju od 1980. do 2013. godine. Kako bi se izbjegla pristranost varijabli, istraživanje uključuje ekonomski rast kao diskontinuiranu varijablu između financijskog razvoja i potrošnje energije. Za razliku od prethodnih istraživanja, ovo istraživanje koristi tri supstituta za financijski razvoj: i) domaći kredit privatnom sektoru kao postotak BDP-a kao supstitut za dubinu financijskih institucija; ii) bankovni krediti bankovnim depozitima kao supstitut za stabilnost financijskih institucija; i iii) širenje kreditnih depozita banaka kao supstitut za učinkovitost financijskih institucija. Koristeći ARDL pristup testiranja granica kointegracije i Grangerov test uzročnosti, rezultati istraživanje pokazuju da postoji izrazito dugoročan jednosmjerni uzročni tok od financijskog razvoja do potrošnje energije u Južnoj Africi. To se potvrđuje bez obzira koji je pokazatelj korišten za mjerenje razine financijskog razvoja. Istraživanje također pokazuje da postoji dugoročna jednosmjerna kauzalnost od ekonomskog rasta do potrošnje energije i jednosmjerna kauzalnost od ekonomskog rasta do financijskog razvoja kada se raspon kamatnih stopa na depozite banaka koristi kao supstitut za financijski razvoj. To, dakle, implicira da je potrošnja energije u Južnoj Africi u velikoj mjeri potaknuta dugoročnim financijskim razvojem uslijed gospodarskog rasta.


Ključne riječi: financijski razvoj, potrošnja energije, Južna Afrika, ARDL pristup