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Research article

Determinants of electricity consumption and energy intensity in South Africa

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Abstract: This study investigates the drivers of electricity consumption and energy intensity in South Africa. Relying on annual time series data from 1975–2014, the study examines the effect of income, manufacturing, changing characteristics of manufacturing sector, manufactures trade, domestic credit and urbanization on energy situation in the country. Estimation from the fully modified ordinary least squares method reveals income reduces electricity consumption and energy intensity; urbanization increases electricity consumption; and manufacturing increases electricity consumption and intensity. Domestic credit is found not to exhibit any statistically significant effect on the energy situation in the country. A further analysis to ascertain the effect of these variables on the energy situation in South Africa is done using the variance decomposition analysis. The results among other things imply the need for policymakers to subsidize energy efficient technologies for manufacturing firms and to also improve the rural settlements in South Africa.

Keywords: domestic credit; electricity consumption; energy intensity; income; urbanization; South Africa

JEL Codes: N7, O14, O44, O13, O14, P28, P25, Q01, Q47, Q43

1. Introduction

The importance of energy in the growth and development process of economies is well documented in the literature. Despite its importance, sustainable energy consumption has been a

concern to policymakers in recent times. The reason for such concern includes the fact that sustainable energy consumption promotes energy security and the increasing energy consumption is related to higher greenhouse gas emissions (Adom and Kwakwa, 2014; Kwakwa, 2019; Adom and Kwakwa, 2019). Accordingly, there has been keen interest on the part of policymakers and researchers to identify the drivers of energy consumption especially for electricity consumption and energy intensity. The emphasis on electricity consumption lies in the fact that it is relatively cleaner energy that is needed at household and firm levels for national development and as such inadequate supply to meet growing demand is detrimental. Also, the emphasis on energy intensity is significant because of its close linkage to energy inefficiency and higher carbon dioxide emission.

Empirical papers have revealed that a number of economic and non-economic factors including income (Kwakwa, 2019; Belloumi and Alshehry, 2018; Salim et al., 2017), manufacturing activities (Adom and Kwakwa, 2014), financial development (Rafindadi and Ozturk, 2017; Solarin et al., 2019; Magazzino, 2018) and urbanization (Li and Lin 2015; Chan et al., 2019) influence the level of energy usage. However, researchers are still divided regarding the direction of the effect of these drivers of electricity consumption and energy intensity. To guide policymaking, it is crucial to identify the direction of the drivers of electricity consumption and energy intensity for specific countries. In this study, the effect of financial development specifically domestic credit and manufacturing, alongside income and urbanization, on electricity consumption and energy intensity in South Africa is investigated.

In sub-Saharan Africa, South Africa remains one of the few countries with over 80% of the population having access to electricity (World Development Indicators [WDI], 2018). Until recently, South Africa had a comparatively reliable power supply. However, presently, the country is faced with the problem of inadequate power supply amidst growing electricity demand. The reasons attributed to the crisis which begun somewhere in the middle 2000s are issues of both demand and supply. The increased energy demand started right after the end of the apartheid era leading to a period of rapid industrialization that relies heavily on electricity. Then, it became increasingly more following the implementation of the free basic energy policy in 2001 which saw to the supply of electricity to poor households without any charges (Preturious et al., 2015).

On the supply side, factors including outdated stock of power plants coupled with poor maintenance, delays in the construction of two new power plants, natural disasters which have affected the importation of energy from Mozambique and politicization of the power market (Heineman, 2019) have been cited to be responsible for the crisis. Other factors, according to Joffe (2012), are shortage of capacity, volatile operating performance, low coal stockpiles and wet weather. Trollip et al. (2014) have noted that there has been failure on the part of the country to "create the conditions for adequate investments in major required energy infrastructure developments" leading to a change in the energy situation "from one of general over-capacity and low priced reliable supply to under-capacity and unreliable supply of coal, electricity and liquid fuels…."

The energy crisis has had a big toll on the growth and development process of South Africa. Households and firms have all suffered a great deal because of the crisis which has led to a frequent blackouts and power. Since the situation is expected to get worse as the South African economy grows, the Southern Africa Catholic Bishop Conference (2015) recommended low cost demand management options as a way of tackling the problem. Joffe (2012) has indicated that "lower demand would do much to reduce risk to the system." To this end, the power suppliers and government are calling for efficiency in electricity usage.

In the same vein, the crisis and the country's commitment to achieve low carbon economy has spurred researchers to investigate the forces behind electricity consumption (Ye et al., 2018; Ateba et al., 2018; Louwa et al., 2008; Ziramba, 2008; Molele and Ncanywa, 2018; Inglesi-Lotz and Blignaut, 2011a; Inglesi-Lotz and Blignaut, 2011b; Mtutu and Thondhlana, 2016; Francioli, 2018; Shahbaz et al., 2018) and energy intensity (Adom, 2015; Kohler, 2015; Ruzive et al., 2017; Rafindadi and Ozturk, 2017). Despite the growing empirical studies on energy in South Africa and many countries there appears to be a lacuna that deserves attention. The previous studies have not paid much attention to the possible effect of the manufacturing sector. Thus, previous studies have not focused on the effect of the manufacturing sector on energy consumption in South Africa and elsewhere. As the South African government hopes to increase employment via a vibrant manufacturing sector (National Planning Commission, 2011; Bhorat and Rooney, 2017) which is energy dependent, it is important to ascertain the energy consumption effect of the sector for designing sustainable development policies.

In addition, the possible effect of the expansion of the country's financial sector on energy consumption has been subjected to little empirical investigation (Rafindadi and Ozturk, 2017). Between 2001 and 2014, the size of the financial services in South Africa increased by 29% (Bhorat and Rooney, 2017) which is quite high compared with many developing countries. Since 1992, domestic credit provided by financial sector as a share of GDP in the country has exceeded 100% (WDI, 2018). The financial development of the country may facilitate households' and firms' demand for energy dependent equipment which will increase energy consumption (Chang, 2015). So far, Rafindadi and Ozturk (2017) have examined the effect of financial development on the country's primary energy consumption with little known about the effect on electricity consumption and energy intensity.

Unlike electricity consumption, South Africa's energy intensity has been reducing over the past two decades. This makes the South Africa one of the few countries in Africa to have that experience (WDI 2018). Such a situation is environmentally friendly and must be promoted. It becomes important to therefore unveil the underlying factors of electricity consumption and energy intensity in the country. The paper thus argues that electricity consumption is closely related to energy intensity. If electricity is not consumed in an efficient manner, it leads to inefficiency. Closely related to energy efficiency is energy intensity. Energy intensity has been declining in South Africa over the past decades whereas electricity consumption has been increasing over the same span of years. It would then be prudent to ascertain the factors explaining these opposite trends.

The present study makes four key contributions to the energy literature. First, it offers evidence of the effect of manufacturing sector on the energy consumption in South Africa. The manufacturing sector relies heavily on energy to function well. Therefore, as indicated by Adom and Kwakwa (2014), an expansion of the manufacturing sector increases energy consumption. That notwithstanding evidence based on this argument is scarce. Many studies investigating the effect of trade on energy consumption have also been motivated by the argument that trade openness can positively and negatively affect energy consumption via the increased production for export and the transfer of technology from the developed world to developing economies respectively (Kwakwa et al., 2018; Shahbaz et al., 2016). However, studies that have taken a critical look at the effect of manufactures trade are rare. Thus, the second contribution of the study is that, we explore the effect of manufactures trade on electricity consumption and energy intensity. The third contribution is that the paper examines the effect of domestic credit on electricity consumption and energy intensity which has received little empirical attention from researchers. Fourth, the effect of the changing

characteristics of the manufacturing sector following the country's independence is tested. Generally, such analysis is rare in the literature.

The rest of the paper proceeds as follows: in the second section a review of the literature is done; section three deals with methodological issues; in section four the results are presented and discussed; and in section five the paper is concluded with the recommendation.

2. Literature review

The 1970s energy crisis drew the attention of policymakers to the necessity of energy in the development process of an economy. However, since a greater proportion of energy sources is non-renewable and environmentally unfriendly, arguments have been made and empirical analysis have been embarked upon to ascertain possible drivers of energy consumption. The literature indicates that income, urbanization, financial development and manufacturing activities are among the factors that influence the level of electricity consumption and energy intensity. In the ensuing paragraphs the theories/arguments and empirical evidence on each of the factors mentioned are presented.

Growth in a country's income may exert positive or negative effect on energy consumption. An increase in economy's income increases consumption activities and hence more energy consumption. As income increases, demand for energy consuming gadgets increases energy consumption/intensity (Gertler et al., 2012). However, as individuals become richer, they are able to access energy efficient gadgets which reduce energy consumption/intensity (Kwakwa, 2019). Empirical studies appear to have produced a dominant positive income effect on energy consumption. For instance, Kwakwa (2017) found income to exert a positive effect on electricity consumption in Egypt. Inglesi (2010) reported income has a positive effect on electricity consumption in South Africa. Also, Rafindadi and Ozturk (2017) found income increases energy consumption in South Africa. Similarly, Amusa et al. (2009) study on South Africa revealed income positively contributes to electricity consumption. Adom (2013) and Adom and Bekoe (2012) found a positive coefficient of income on Ghana's electricity consumption. Alberini and Filippini (2011) found income to have a positive effect on electricity consumption in the USA. On the other hand, Kwakwa (2018) reported that rising income levels reduces electricity consumption in Benin. In other areas, Kwakwa et al. (2018a; 2019) obtained a positive effect of income on energy consumption in Ghana. Kwakwa et al. (2018b) recorded a positive effect of income on fossil fuel consumption in Ghana, Kenya and South Africa. Lim et al. (2012) and Dees et al. (2007) confirm a positive relationship between fossil fuel consumption and income. However, Mahalik and Mallick (2014) also found that income growth reduces energy consumption in India. Regarding energy intensity, Kwakwa (2019) and Wang and Han (2017) found that Tunisia's and China's energy intensity is reduced by income respectively. A study by Belloumi and Alshehry (2018), Salim et al. (2017) and Chan et al. (2019) also found income to reduce energy intensity for Saudi Arabia, some selected Asian economies and Southwestern China respectively.

For a very long time, it has been argued that urbanization exerts pressure on energy resources. The reason being that urban areas are characterized by heavy motor traffic, businesses, demand for housing and other infrastructure all of which require energy (Sadorsky, 2013; Elliot et al., 2014). On the contrary, it is also suggested that urbanization may promote efficiency in the usage of energy resource because of the stress on energy resources (Adams et al., 2016). A study by Kwakwa (2018) and Kwakwa et al. (2019) found urbanization having a positive effect on electricity consumption and energy consumption. Also, Kwakwa and Aboagye (2014) reported a positive effect of urbanization

on energy consumption in Ghana. A later study by Aboagye (2017) reported that urbanization does not exert significant effect on Ghana's energy intensity but when it comes to energy consumption the author found that urbanization has a positive effect. In their study on China, Li and Lin (2014) found a mixture of both positive and negative effect of urbanization on energy consumption depending on the stage of economic development. Similarly, Kwakwa (2019) obtained a positive effect of urbanization on electricity consumption but a negative effect on energy intensity in Tunisia. Further, Shahbaz and Lean (2012) found urbanization increases energy consumption in Tunisia while in Saudi Arabia, Belloumi and Alshehry (2018) found a negative effect of urbanization on the country's energy intensity. Other studies including Liddle (2013) and Ewing and Rong (2008) have also reported urbanization negatively affects energy use. In South Africa, Khobai and Le Roux (2017) have reported in their study that urbanization granger-cause electricity consumption. Chan et al. (2019) found higher urbanization level contributes to higher energy intensity in Southwest China.

Compared to income-energy nexus and urbanization-energy nexus, the discussion on the relationship between financial development and energy consumption is very recent. The effect of financial development on energy consumption is mixed in the literature. Theoretically, it is argued that financial development increases energy consumption by making it easier for individuals and firms to easily access funds for energy consuming equipment (Chang, 2015). In the opinion of Magazzino (2017) financial development facilitates industrial growth and also leads to demand for new infrastructure which put pressure on energy resources. However, financial development is also helpful in the adoption of energy efficient technologies for production which helps reduce energy consumption (Chang, 2015). Empirically, evidences have been found for both arguments. For instance, Rafindadi (2016) found financial development reduces energy consumption in Germany, Rafindadi and Ozturk (2016) also revealed financial development increases electricity consumption in Japan; Shahbaz and Lean (2012) found a positive effect of financial development on energy consumption in Tunisia; Shahbaz et al. (2010) got a positive effect of financial development on energy consumption in Pakistan; and Solarin et al. (2019) recorded a positive effect of financial development on energy consumption in Malaysia. Sadorsky (2010) also noted a positive effect of financial development indicators on energy consumption in Guangdong province, China. On the other hand, investigation by Mahalik and Mallick (2014) on the economy of India revealed that energy consumption is reduced by financial development. Also, Mielnik and Goldemberg (2002) found an inverse relationship between energy intensity and financial development. Chang (2015) had a mixture of positive and negative effects of financial development on energy consumption for a panel of countries and Magazzino (2017) found an insignificant effect of financial development on energy consumption in Italy.

Owing to its important role in the economy, ample studies have analyzed the growth effect of manufacturing sector (Ududechinyere et al., 2016; Addo, 2017). However, the effect of manufacturing on energy usage has not been subjected to much investigation. Manufacturing which is a sub-sector of industrialization involves the transformation or processing of raw materials into finished goods or semi finished goods. Such activities entail the use of energy intensive gadgets. Consequently, an expansion in the manufacturing activities will increase energy usage (Adom and Kwakwa, 2014). Few studies including Jorgenson et al. (2010) and Adom and Kwakwa (2014) have analysed the effect of manufacturing on energy consumption. The empirical studies on energy intensity in Ghana by Adom and Kwakwa (2014) indicated that manufacturing activities increase energy intensity while the changing characteristics of manufacturing sector reduce energy intensity. The changing characteristics tend to assess whether certain policy regime or event has rendered the

manufacturing sector to be efficient or not. In the case of Adom and Kwakwa (2014) the focus was on the effect of the economic reform on the characteristics of manufacturing sector. Jorgenson et al. (2010) found insignificant effect of manufacturing on energy consumption for less developed countries. It is reckoned that ample studies have paid attention to industrialization (Li and Lin, 2015; Sadorsky, 2013; Adom, 2015) of which manufacturing is a sub-sector. That notwithstanding, paying attention to the manufacturing sector will help offer deeper guidelines for policymaking. Many authors have indicated that trade openness increases energy consumption because of the energy required to process raw materials into finished goods, to transport goods for export and also transport imported goods to other parts of the country (Sadorsky, 2011). In this vein it is possible that trading activities involving manufacturing goods may increase energy consumption.

In conclusion, it is realized that energy consumption studies that have focused on South African economy and elsewhere have not produced uniform results suggesting mixed results and giving room for further studies. Again, studies that have analyzed the effect of manufacturing activities as well as its changing technical characteristics are relatively scarce and in the case of South Africa, none exists for it. Moreover, studies that have examined the effect of manufactures trade is not available for the South African economy. The present study seeks to address these identified gaps in the literature.

3. Methodology

3.1. Empirical modeling

From the above review, energy consumption can be expressed as a function of income, urbanization, domestic credit and manufacturing. In a log linear form we have:

$$LE_i = \alpha + \beta LGDP + \varphi LURB + \delta LMAN + \lambda LCRE + \varepsilon \quad (1)$$

where LE_i denotes natural log of energy consumption (specifically, log of electricity consumption [LELEC] and log of energy intensity [LNEIN]), LGDP is natural log of income, LURB is the natural log of urbanization, LMAN is natural log of manufacturing and LCRE natural log of domestic credit. Also $\alpha, \beta, \varphi, \delta$ and λ are all parameters to be estimated and ε is the error term.

As a novelty, the model is augmented with manufactures trade and the changing characteristics of manufacturing sector. Consequently, equation (1) is modified as below:

$$LE_i = \alpha + \beta LGDP + \varphi LURB + \delta_1 LMAN + \delta_2 D^*LMAN + \lambda LCRE + \phi LTO + \varepsilon \quad (2)$$

where *D*LMAN* is the interactive term for manufacturing, which captures the changing technical characteristics of the manufacturing sector and *LTO* is the manufactures trade. Also, δ_2 and ϕ are parameters to be estimated and the rest of the variables remain as defined previously.

3.2. Data and estimation technique

This study uses annual time series data covering the period from 1975 to 2014. Electricity consumption is measured as Electric power consumption (kWh per capita) and, energy intensity is measured as the ratio of total energy consumption to gross domestic product. Also, manufacturing is measured as manufacturing valued-added (constant 2010 US$), urbanization is measured as urban population, income is measured as per capita GDP and domestic credit is measured as domestic credit

provided by financial sector (% of GDP). Manufactures trade is denoted and measured by two separate indicators: manufactures exports *(LMEXP)* and manufactures imports *(LMIMP),* and the sum of manufactures exports and manufactures imports *(LMTO),* which are then, estimated as separate equations. The changing technical characteristic of the manufacturing sector is constructed following Adom and Kwakwa (2014). It begins with the creation of a dummy variable for democracy which is then multiplied by manufacturing sector. A binary dummy for regime change is constructed in which the period before South Africa's democracy in 1994 took 0 and the period after democracy took 1. This dummy is then interacted with the manufacturing value-added variable to generate the changing technical characteristics of the manufacturing sector. Data on electricity consumption, energy intensity, manufacturing value-added, urbanization, domestic credit and income are obtained from the WDI (2018).

The study follows the usual procedure of testing for the stationarity status of the variables and the cointegration among the variables. The former is required to avoid obtaining spurious regression results and the latter is to confirm the presence of long run relationship among the variables. Consequently, the popular Augmented Dickey-Fuller (ADF) is used to examine the stationarity of the series after which the cointegration among the variables is examined using the autoregressive distributed lag (ARDL) cointegration test. After a confirmation of cointegration among the variables, the Fully Modified Ordinary Least Square (FMOLS) technique is used to examine the effect of manufacturing, changing technical characteristics of the manufacturing sector, urbanization, income, domestic credit and manufactures trade on South Africa's electricity consumption and, energy intensity. The choice of the FMOLS technique is justified by its robustness to the problems of serial correlation and endogeniety.

4. Results and discussion of findings

4.1. Stationary results

The stationary or non-stationary of a time series can strongly influence its behavior. If the time series variables include non-stationary time series, then regression will produce spurious results. To avoid this problem, it is important to undertake stationarity tests to ascertain the unit root properties of these series. In this study, the authors apply the Augmented Dicky-Fuller (ADF) test.

Table 1 shows the results of the ADF unit root tests at levels and at first difference. At levels, all the variables were not stationary with the exception of log of electricity consumption and log of terms of trade. These two variables, log of electricity consumption and log of terms of trade are stationary at levels at 1% and 10% significant levels. This implies that ordinary least squares (OLS) regression involving these non-stationary variables will produce spurious results. We further test for stationarity at first difference for these non-stationary time series variables. The results, in Table 1 shows that the series in their first difference are stationary at 1% and 10% significant levels making it appropriate to use them for regression.

Table 1. ADF Unit Root Test.

Variables	At levels	At first difference
LGDP	0.3519	−4.2435***
LURB	−2.1578	−2.7832*
LMAN	−0.8627	−5.3482***
LCRE	0.0319	−7.9704***
LMIMP	−2.3363	−6.9136***
LMEXP	−1.1335	−5.6993***
LMTO	−2.9308*	
LELEC	−3.7978***	
LNEIN	−1.5489	−5.8967***

Note: ***,** and * denotes 1%, 5%, 10% level of significance respectively.

4.2. Cointegration results

We proceed to investigate the cointegrating relationship between the two dependent variables: energy intensity and electricity consumption; and the explanatory variables. The existence of a cointegrating relationship between these variables implies that a linear combination among these series is stationary. We employ the ARDL Bound approach to cointegration test to identify the existence of long run relationship between energy consumption and the selected explanatory variables. Tables 2 and 3 report the cointegration results for energy intensity and electricity consumption models, respectively. The test results for the energy intensity model with manufactures export and import variables in the system show that there is cointegrating vectors at 1% level of significance implying that linear combinations are stationary. If the sum of manufacture import and export is also used in the energy intensity model, the results also confirm the presence of co integration.

Table 2. ARDL Bound cointegration test for energy intensity model.

	LNEIN| LGDP LURB LMAN LCRE LMTO F-statistic = 3.9735***		LNEIN| LGDP LURB LMAN LCRE LMIMP LMEXP F-statistic = 4.6913***	
Significance	I0 bound	I1 bound	I0 bound	I 1 bound
10%	2.26	3.35	2.12	3.23
5%	2.62	3.79	2.45	3.61
1%	3.41	4.68	3.15	4.43

Note: *** denotes 1% level of significance.

We conduct similar cointegration tests for the electricity consumption model. The ARDL Bound test results from Table 3 show when the sum of manufactures export and import is used to capture trade, cointgreation exists among the variables and same applies when the manufactures import and export are used differently in the model. In summary, the co integration test reveal income, urbanization, domestic credit, manufacturing value added and manufactures trade are the long run drivers of energy intensity and electricity consumption in South Africa.

Table 3. ARDL Bound cointegration test for electricity consumption model.

	LELEC| LGDP LURB LMAN LCRE LMTO		LELEC| LGDP LURB LMAN LCRE LMIMP LMEXP	
	F-statistic = 4.7618***		F-statistic = 5.1597***	
Significance	I0 bound	I1 bound	I0 bound	I 1 bound
10%	2.26	3.35	2.12	3.23
5%	2.62	3.79	2.45	3.61
1%	3.41	4.68	3.15	4.43

Note: *** denotes 1% level of significance.

4.3. Discussion of electricity consumption effect

Table 4 reports the long run regression results using electricity consumption as the main dependent variable. The effect of urbanization on electricity consumption is found to be positive and statistically significant across all four models.

Table 4. Long run estimates for electricity consumption.

Variable	Model 1	Model 2	Model 3	Model 4
LGDP	−1.9526***	−1.9255***	−1.8966***	−1.9060***
	(0.2491)	(0.2468)	(0.2471)	(0.2551)
LURB	0.8306***	0.8333***	0.8358***	0.8422***
	(0.1583)	(0.1598)	(0.1580)	(0.1624)
LMAN	1.8157***	1.7944***	1.6741***	1.5851***
	(0.2588)	(0.2535)	(0.2857)	(0.3000)
LCRE	−0.1020	−0.1723	−0.1043	−0.0961
	(0.1145)	(0.1316	(0.1513)	(0.1553)
D*LMAN		0.00173	0.0023	0.0010
		(0.0021)	(0.0021)	(0.0024)
LMTO			−0.0445	
			(0.0484)	
LMIMP				−0.2819
				(0.2112)
LMEXP				0.0057
				(0.0655)
CONSTANT	1.9015	1.9739	4.1191	7.2331*
	(1.8460)	(1.8224)	(2.9498)	(4.2167)
Adj R sq	0.88	0.86	0.86	0.87

Note: ***, ** and * denotes 1%, 5% and 10% level of significance respectively.

Specifically, a 1 percent increase in urbanization leads to on average a 0.83 percent increase in South Africa's electricity consumption. This result is supported by other studies including Liddle and Lung (2014), Burney (1995) and Adom et al. (2012). South Africa is a typical urbanized country with about 64% of the population living in the country's urban areas. At the same time, the share of urban population increased from 48 percent in 1975 to 64 percent in 2014. The transition of rural residents to urban centers increases urban residential electricity consumption as these rural residents who previously did not have access to electricity (limiting their demand for electrical appliances) are able to purchase

electrical appliances, thereby increasing electricity consumption. The large urban population coupled with the continuous increase in urbanization in South Africa stimulates demand for electrical appliances, thereby increasing electricity consumption.

On the other hand, the effect of income, as measured by the log of GDP on electricity consumption is found to be negative and statistically significant. We find that a 1% increase in income leads to a 1.9 percent decline in electricity consumption in South Africa, on average. This negative relationship between income and electricity consumption is consistent across all models in Table 4. This may be unexpected result as it is hypothesized by many that income positively contributes to increases in electricity consumption. However, this result is in line with the argument that as economies become richer, the citizens are able to access energy efficient gadgets which reduce energy consumption/intensity (Kwakwa, 2019). Further, the finding is very plausible as the South African economy has shifted from the energy intensive sectors such as mining and manufacturing sectors to the less energy intensive sectors such as finance and real estate over the past four decades. The contribution of the industry-value added to GDP has been declining since 1975. For instance, the industry-value added as a percentage of GDP declined from 39 percent in 1975 to 21 percent in 2014 (WDI, 2018). Since the early 1990s, economic growth in South Africa has been mainly driven by the tertiary sector which is less energy-intensive, thereby contributing less to electricity consumption. Another characteristic of the South African economy that explains the negative relationship between income and electricity consumption is the liberalization policies and programs in the 1990s that led to increasing imports in the midst of declining share of exports. The above explanation may justify why the current finding is at variance with that of Inglesi (2010) and Amusa et al. (2009) for South Africa.

Across all the four models, the long run impact of manufacturing output is positive and statistically significant. Across all four models, the coefficient implies that a 1 percent expansion of the manufacturing sector will increase electricity consumption by an average of 1.7 percent. The manufacturing sector is an energy-intensive sector and as a result, consumes a lot of energy and electricity. As a result, as the level of manufacturing base increase, it increases the energy requirements (which includes electricity) causing electricity consumption to increase.

We do not find the interactive term for manufacturing to be a significant factor in increasing or decreasing electricity consumption in South Africa. The insignificance of this interactive term implies that the openness of South Africa's economy since independence has not affected the characteristics of the manufacturing sector. This suggests that the changing technical characteristics of the manufacturing sector have not yielded any significant effect on electricity consumption in South Africa. From the period 2001–2014, the South African economy experienced a structural shift from sectors such as agriculture, mining and manufacturing towards sectors such as the financial service sector. Although the manufacturing sector's contribution to GDP has declined over the years, the sector has not experienced any significant shift towards technical innovation to significantly influence electricity consumption in South Africa. This outcome contradicts the findings reported by Adom and Kwakwa (2014).

The results also reveal that domestic credit does not have a significant effect on electricity consumption. The result suggests that domestic credit provided by the financial sector are channeled to areas that do not significantly contribute to electricity consumption. Although domestic credit has a negative coefficient implying that domestic credit has the potential to reduce electricity consumption in South Africa, much attention should be paid to the recipient and uses of these domestic credits. This finding contradicts that of Rafindadi and Ozturk (2017), Shahbaz and Lean (2012) and Shahbaz et al. (2010) who obtained positive effect of financial development on energy

consumption in their studies and Mielnik and Goldemberg (2002) and Rafindadi (2016) who found a negative relationship between financial development and energy consumption. However, it is in line with Magazzino (2017) who found an insignificant effect of financial development on energy consumption in Italy.

4.4. Discussion of energy intensity effect

This sub-section focuses on the long run impacts of the explanatory variables on energy intensity in South Africa. Table 5 reports the full results of the long run estimates for energy intensity. Our results show a negative relationship between income and energy intensity in South Africa. Specifically, a one percent increase in income leads a 0.03 percent decline in energy intensity. Energy intensity is computed based on economic output and energy consumption.

Table 5. Long run estimates for energy intensity.

Variable	Model 1	Model 2	Model 3	Model 4
LGDP	−0.0324***	−0.0329***	−0.0308***	−0.0296***
	(0.0100)	(0.0101)	(0.0094)	(0.0094)
LURB	0.0021	0.00199	0.0020	0.0019
	(0.0064)	(0.0065)	(0.0060)	(0.0059)
LMAN	0.0382***	0.0387***	0.0298**	0.0309***
	(0.0104)	(0.0104)	(0.0109)	(0.0110)
LCRE	−0.0047	−0.0032	0.0018	0.0012
	(0.0046)	(0.0054)	(0.0057)	(0.0057)
D*LMAN		−3.49E-05	1.36E-05	5.08E-05
		(8.60E-05)	(8.23E-05)	(8.97E-05)
LMTO			−0.0034*	
			(0.0018)	
LMIMP				0.0026
				(0.0077)
LMEXP				−0.0046*
				(0.0024)
CONSTANT	0.2050***	0.2043	0.3652***	0.2911
	(0.0747)	(0.0748)	(0.1128)	(0.1553)
Adj R sq	0.41	0.40	0.455	0.56

Note: ***, ** and * denotes 1%, 5% and 10% level of significance respectively.

This implies that energy intensity changes when economic output and/or energy consumption changes. Over the past two decades, energy intensity has been decreasing in South Africa. Although both economic output and energy consumption has been increasing during this period, the increase in economic output tends to be higher than the increase in energy consumption explaining the negative relationship between income and energy intensity in South Africa. This also implies economic growth in the country tends to be more efficient with regards to energy usage. In his study on energy intensity in Tunisia, Kwakwa (2019) found that income reduces energy intensity. Moreover, Belloumi and Alshehry (2018) and Salim et al. (2017) obtained similar outcome in their studies.

The effect of manufacturing value-added on energy intensity is positive and statistically significant. Across all the four models, an increase of one percentage in the manufacturing base is expected to increase energy intensity by about 0.03 percent. This result is similar to the earlier results

found when the dependent variable was electricity consumption. Because of the energy-intensive nature of the manufacturing sector in South Africa, the demand for energy increase as the sector expands. Once there are energy demand pressures, energy intensity will increase. Studies on other countries such as Ghana by Adom and Kwakwa (2014) confirm the positive relationship between manufacturing value-added and energy intensity.

The long run effect of manufactures trade openness on energy intensity is found to be negative and statistically significant. Specifically, a one percent increase in manufactures trade openness reduces energy intensity by 0.0034 percent. This result is supported by other studies such as Lai et al. (2006), Adom and Kwakwa (2014) and Hubler (2011) that examined the effect of trade openness on energy intensity. South Africa has undergone significant trade liberalization since the end of apartheid in the 1990s. During this liberalization period, South Africa imposed higher tariffs on consumer products and lower tariffs on imported machinery and capital goods (Thurlow, 2006). This probably has led to competition among local and foreign firms who produce these machinery and capital goods. This could have stimulated the adoption of energy efficient technologies, especially among local firms thereby leading to a reduction in energy consumption, and subsequently reducing energy intensity. This explains the energy-reducing effect of manufactures trade openness in South Africa.

An insignificant relationship between urbanization and energy intensity in South Africa is observed from the results. The effect of urbanization is positive but this is not significant. Although it is not significant, it is expected that urbanization will increase energy consumption and finally increase energy intensity. We also do not find the interactive term for manufacturing to be a significant factor in influencing energy intensity in South Africa. This lends support to our earlier results for electricity consumption that the openness of South Africa's economy since independence has not affected the characteristics of the manufacturing sector enough to affect energy usage. Similar to the results for electricity consumption shown in Table 4, our results reveal an insignificant relationship between domestic credit and energy intensity. The possible explanation could be the channels of domestic credit and the uses of domestic credit. Domestic credit might be channeled to some energy-intensive industries, or energy efficient ventures but not so significant to cause changes in energy intensity.

4.5. Variance decomposition analysis

In the previous analysis, we were interested in analyzing the long run impact of income, urbanization, manufacturing output, changing technical characteristics of the manufacturing sector, domestic credit, manufacturer's imports and exports and terms of trade on South Africa's electricity consumption and energy intensity. In this sub-section, we shift our focus to ascertaining the actual contribution of each of these variables in explaining electricity consumption and energy intensity in South Africa. To achieve this purpose, we apply the Cholesky decomposition method to estimate the share of every one standard deviation shock in either electricity consumption or energy intensity that is accounted for the explanatory variables.

Table 6 shows the variance decomposition results for electricity consumption. The following results are uncovered. First, the results suggest that the share of all the explanatory variables increases with time. For instance, the share of urbanization increases from 0.19 percent in the third period to 0.23 percent in the fourth period, 0.28 percent in the fifth period and so on. This increase in the shares is consistent for all the explanatory variables. From the second period to the sixth period, log of domestic credit provided by the financial sector has the largest share with urbanization having

the smallest share. However, from the seventh period to the tenth period, there is a change of pattern as the manufacturing sector now has the largest share with urbanization still having the smallest share. The result for energy intensity is a little different compared to the result for electricity consumption. The result for the variance decomposition analysis for energy intensity is shown in Table 7. Similar to the result for electricity consumption, the contribution of all the factors increases with time. However, from the second to fourth periods and fifth to tenth periods, the manufacturing sector and income contributed the most to energy intensity, respectively. Similar to the result in Table 6, urbanization contributes the least to energy intensity, on average.

Table 6. Variance decomposition analysis for electricity consumption.

Period	S.E.	LELEC	LGDP	LURB	LMAN	LCRE	D*LMAN	LMTO
1	0.028652	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.043997	77.95499	1.351239	0.121217	1.080872	18.10615	0.067958	1.317575
3	0.051273	75.34909	1.557520	0.188335	2.310695	17.89345	1.708747	0.992167
4	0.056456	72.98763	1.736162	0.226528	5.858982	16.90315	1.410355	0.877188
5	0.060248	69.52079	2.113503	0.278235	9.422474	14.95494	1.653167	2.056893
6	0.063897	65.15484	2.673815	0.454952	11.59013	13.33260	2.516265	4.277396
7	0.067314	61.27744	3.383003	0.718305	12.44763	12.09772	3.342563	6.733347
8	0.070259	58.69209	4.068593	1.066310	12.60122	11.10864	3.889849	8.573300
9	0.072788	57.20410	4.546221	1.478208	12.52204	10.38675	4.229125	9.633555
10	0.075011	56.41759	4.747199	1.924187	12.42324	9.905916	4.486243	10.09562

Table 7. Variance decomposition analysis for energy intensity.

Period	S.E.	LIEN	LGDP	LURB	LMAN	LCRE	D*LMAN	LMTO
1	0.001236	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.001687	96.78881	0.149244	0.636401	1.006949	0.406982	0.964043	0.047573
3	0.001974	90.70660	1.043152	0.561789	4.148407	2.446741	0.765704	0.327607
4	0.002210	81.08154	5.538709	0.448589	6.839227	4.853365	0.975552	0.263015
5	0.002390	75.03379	9.067873	0.609212	8.037173	4.665160	2.304303	0.282490
6	0.002551	72.72296	9.171411	1.285298	7.940273	4.097821	3.727361	1.054873
7	0.002738	72.18880	8.002768	2.067878	7.172450	3.581353	3.937195	3.049560
8	0.002952	72.22023	6.911858	2.517867	6.318978	3.140663	3.527088	5.363318
9	0.003158	71.94157	6.045758	2.717204	5.676686	3.193319	3.125833	7.299632
10	0.003340	71.04830	5.416759	2.883718	5.250213	3.587921	2.917574	8.895512

5. Concluding remarks

This paper has examined the determinants of electricity consumption and energy intensity in South Africa. Specifically, we were interested in analyzing the long run impact of income, urbanization, manufacturing output, changing technical characteristics of the manufacturing sector, domestic credit, manufacturer's imports and exports on South Africa's electricity consumption and energy intensity. The estimation results showed that urbanization is positively related to electricity consumption in South Africa. Urbanization is taking place everywhere in the world, but proactive steps need to be taken to address its rapid growth. With the current rate of

urbanization in South Africa, there is the need to begin focusing on improving the rural settlements in South Africa.

Our results also revealed the significant role that manufactures trade can play in reducing energy intensity. One of the factors contributing to the declining energy intensity in South Africa is the liberalization policies that have favored increasing imports. Going forward, focus should be channeled to strengthening the institutional framework in response to the higher degree of trade openness especially for manufactures trade in South Africa. Again, manufacturing was found to increase electricity consumption and energy intensity. The implication is that, it is imperative for policymakers to pay attention to the manufacturing sector. Efforts should be made by policymakers to subsidize energy efficient machines to enable the manufacturing sector to consume less energy. Also, efforts should be made by the authorities to make it easier for manufacturing firms to acquire energy efficient machines for their operations. There should be stricter enforcement on the ban of the importation of outdated and energy inefficient machines.

The negative effect of income on electricity consumption and energy intensity in South Africa, implies that policies geared towards the attainment of higher per capita income will improve energy efficiency in the country. Lastly, it is imperative for policy makers to thoroughly investigate the uses of domestic credit in South Africa since our results revealed its impact on both electricity consumption and energy intensity to be statistically insignificant. Domestic credits could provide a means to reducing both energy intensity and electricity consumption in South Africa, if they are properly channeled and used in a productive and sustainable way.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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